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# Remote Accreditation: What Have We Learned and How are We Positioned?

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## Abstract

Accreditation, along with the States and the U.S. Department of Education, serves as an essential tool to promote quality and to facilitate continuous improvement U.S. Higher Education system. Furthermore, some accrediting agencies conducted accreditation reviews during the spring of 2020 were required to hold traditional onsite visits remotely. Not only was this an ad hoc transition, but it was also made without full knowledge of the impact the shift in evaluation mode would have on the effectiveness and quality of accreditation reviews against accreditation standards and criteria. Therefore, a critical need existed to evaluate the efficacy of the remote mode of accreditation review. The study analyzed the impacts of remote site visits on accreditation efforts. Using qualitative and quantitative survey data collected from ATMAE Board of Accreditation, visiting team members, and institutional contacts involved in 2020 accreditation visits, an assessment of effectiveness and quality of accreditation review was performed. Qualitatively, strong themes were found in the dataset revealing the impacts of the remote modality on accreditation review effectiveness and quality; also, highlights of advantages, disadvantages, and opportunities to leverage this modality were discovered. Quantitatively, the remote modality was overwhelmingly reported to be effective for most accreditation standards, while impacts on quality were more negligible. Furthermore, specific accreditation standards that received a high number of negative impacts to effectiveness were also the same standards that received a high number of negative impacts on quality. Results of this study help characterize the impacts to accreditation amid the COVID-19 pandemic and help lay the foundation for best practices for future remote accreditation site visits.

*Keywords: accreditation, remote, virtual, Covid-19*

## Introduction

Survival in the modern era of higher education is a practice in the survival of the fittest. Colleges and Universities use third-party agencies such as the Accrediting Board of Engineering and Technology (ABET), the Association of Technology, Management and Applied Engineering (ATMAE), the Higher Learning Commission (HLC), or the Southern Association of Colleges and Schools (SACS) as mechanisms to assess the validity of an institution's program(s). Unfortunately, the 2019 coronavirus pandemic (COVID-19) compounded the significance and challenges of institutional and programmatic accreditation. COVID-19 hamstrung the primary instrument – the onsite visit – used by accreditors to assess institutions and programs.

ATMAE required ad-hoc transitions to conducting accreditation reviews remotely during the spring of 2020 without full knowledge of the impact that remote site visits would have on the effectiveness and quality of accreditation reviews against accreditation standards. It is reasonable to expect similar modes of evaluation to continue into the near future, even though the unprecedented events of the spring of 2020 were unique. Therefore, a critical need existed to evaluate the efficacy of this mode of accreditation review. ATMAE and other higher education institutions, accrediting agencies, and governing bodies (e.g., Council for Higher Education Accreditation) will be able to make data-informed decisions regarding remote site visits or proactively prepare for similar global scenarios with this evaluation. Therefore, to begin to understand the impacts of remote site visits on the accreditation review process, this study pursued two research objectives, 1) to assess the effectiveness and quality of remote accreditation site visits, and 2) to develop lessons learned and best practices for future remote accreditation site visits.

## Background

The COVID-19 pandemic of 2020 and 2021 put significant pressure on higher education institutions in several ways (Priddy & Pelletier, 2020). One such pressure point was accreditation site visits. Accreditation bodies such as ATMAE include criteria that evaluate "curriculum," "facilities," and "institutional support," suggesting the importance of the onsite visit. To date, limited research has been published evaluating remote approaches to accreditation visits. Kinzie (2020) suggested that disruptions resulting from COVID-19 are an opportunity for improvement. However, much of the initial discussion has focused on learning outcomes and equity challenges in student resiliency and effective learning. While policies and logistical guidance for accreditation visits during the COVID-19 pandemic were published, most address medical disciplines,

including nursing and medical transport. Cobourne and Shellenbarger (2021) discussed adaptations in preparation and planning for a remote accreditation visit in nursing but did not address the quality of the visits related to accreditation. Frazer (2021), speaking on behalf of the Commission on Accreditation of Medical Transport Systems (CAMTS), advised programs to do the best they could to meet standards related to quality and safety and serve the patient. Potts, Lipsett, and Matthew (2021), speaking for the Accreditation Council for Graduate Medical Education and its Review Committee, characterized the remote accreditation visit as "forced" on them due to the COVID-19 pandemic. They described the tools used in accreditation, disruptions in the accreditation system, and the impact on resulting accreditation decisions. However, surgical, nursing, and medical transport education have a different educational context than the conventional classroom and laboratory learning typical of STEM disciplines.

Eaton (2020), President Emeritus of the Council for Higher Education Accreditation (CHEA), noted that as higher education institutions change and innovate, so must accreditation. Eaton asserted that the most significant shift in accreditation has been how institutions and programs are reviewed and examined. The move from in-person visits to remote visits through Zoom™ or other video conferencing platforms changed engagement. What is less clear is the impact this change has imposed. The pandemic has been a force for change in many parts of society – it was not expected to change the higher education environment. Remote accreditation site visits potentially address many social and parity concerns and broaden the scope of reviews to include alternative providers and alternative credentials. However, limited research has examined how STEM-focused accreditation bodies can leverage this review modality.

## Materials and Methods

### Research Design

In order to understand the impacts and lessons learned from ATMAE remote site visits completed during the spring of 2020, this study used a mixed-method approach. Specifically, qualitative and quantitative survey data provided perceptions of effectiveness, quality, advantages/disadvantages, and opportunities to leverage the remote modality for future ATMAE accreditation site visits. This study drew a representative survey sample from a population of ATMAE Board of Accreditation (BoA) members, ATMAE visiting team members, and institutional contacts during the spring of 2020. The authors gave study participants four weeks to complete the survey, with weekly reminders to participate, as recommended by the Tailored Design Method

(Dillman et al., 2014). Select questions from these surveys are included in Appendix A (BoA survey) and Appendix B (visiting team and institutional contact survey).

**Experimental Setting**

Traditionally, ATMAE visits take place on the college campus, submitting for accreditation over two days. The accreditation team interviews faculty, staff, administration, students, and the advisory board to verify the college's submitted self-study report and tour laboratories and classrooms, and inspect the equipment utilized to deliver the program to ensure that proper facilities are used and maintained. The team addresses any shortcomings or concerns and positive feedback to the faculty, staff, and administrators on the end of the second day.

Due to the COVID-19 pandemic, ATMAE moved its spring 2020 site visits to a remote modality. These remote site visits largely followed the same structure as the in-person visits, minus in-person observations and conversations (i.e., lab tours, discussions with students, etc.). The institution under review utilized a video conferencing platform, providing the visiting teams with meeting links to complete the required interviews.

**Measures**

The study characterized effectiveness, quality, advantage/disadvantage, and leverage measures using the survey questions and data types indicated in Table 1. The survey presented specific definitions for *effective* and *quality* to survey participants as follows: "*Effectiveness* is the extent to which planned activities (e.g., accreditation self-study reports and accompanying site visits) are realized and planned results (e.g., program accreditation decisions) are achieved"; *"Quality* is the inherent perception of the user (e.g., customer's perspective), which in this case is the accreditation team and/or institution being reviewed." Measures of *advantage*/*disadvantage* were defined during the analysis based on positive (advantage) or negative (disadvantage) themes in the dataset. In contrast, measures of *leverage* were defined based on "Yes/Maybe/No" responses coupled with themes found in the dataset.

**Table 1**. Alignment between the study's research objectives, questions, measures, survey questions, data types, and subpopulations.

| | | Survey | | Research | |
|---|---|---|---|---|---|
| Measure | Characterization | Question | Data Type | Question | Objective |
| Effectiveness | Effectiveness of remote site visit modality at upholding accreditation rigor | 2, 3[a]<br>2[b] | Qual.<br>Quant. | 1 | 1. Assess the effectiveness and quality of remote accreditation site visits |
| Quality | Impact and rating of accreditation quality given remote site visit modality | 4, 5[a]<br>6[b] | Qual.<br>Quant. | 2 | |
| Advantage/ Disadvantage | Perceived advantages/disadvantages of remote site visit modality | 6, 7[a]<br>10, 11[b] | Qual. | 3 | 2. Develop lessons learned and best practices for future remote accreditation site visits |
| Leverage | Perceived opportunities to leverage remote site visit modality in future | 8[a]<br>12[b] | Qual. | 4 | |

[a]BoA survey see Appendix A; [b]Team and Institution survey see Appendix B

## Results and Discussion

### Descriptive Results

This study collected self-reported survey responses of perceptions for three subpopulations: ATMAE BoA members, ATMAE visiting team members, and institutional contacts. As indicated by Table 2, the overall response rate of the study was 41% ($n$ = 35 responses from a survey population of N = 86).

**Table 2**. Survey population, sample, and response rates per group.

| Group | Population (N = 86) | Sample ($n$ = 35) | Response Rate |
|---|---|---|---|
| BoA Members | 17 | 11 | 65% |
| Visiting Team Members | 21 | 12 | 57% |
| Institutional Contacts | 48 | 12 | 25% |
| Total | 86 | 35 | 41% |

### Effectiveness and Quality

The first objective of the research was to assess the effectiveness and quality of remote accreditation site visits. To build this assessment, the authors asked the BoA members whether remote visits were effective at upholing the rigor of accreditation reviews. Categorizing BoA members' sentiment, it was found that n = 3 (27%) felt remote site visits were not effective ("no"), n = 1 (9%) were undecided ("unknown"), and n = 7 (64%) felt positive ("yes"), as indicated in Table 3. Furthermore, when performing a thematic analysis of rationales provided for their sentiment, a strong theme of efficacy became evident in BoA members' open-

ended responses, as illustrated in Table 4. This theme of efficacy, defined as the intended accreditation results were met, but there was a lack of in-person interaction that posed challenges to the review process. While the observed theme of efficacy came from the entire pool of responses, regardless of sentiment, a statistically higher proportion of responses (p-value = 0.0488) felt positive towards the effectiveness of remote site visits to uphold the rigor of accreditation review. These results illustrate the confidence that BoA members appeared to have in the remote modality, albeit tempered by the practical void of physical interaction that was reported to detract from the review process.

**Table 3.** Categorization of BoA members' sentiment to whether remote site visits effectively upheld the rigor of accreditation reviews?

| Sentiment | Counts | % |
|---|---|---|
| No | 3 | 27 |
| Unknown | 1 | 9 |
| Yes[a] | 7 | 64 |
| Total | 11 | 100 |

[a]$H_0$: Proportions of Yes = others (*p-value* =0.0488)

**Table 4**. Codes, counts, and theme observed from BoA members' rationale regarding sentiments of the effectiveness of remote site visits.

| | | | Frequency | | | | |
|---|---|---|---|---|---|---|---|
| Theme | Definition | Codes | Per Code | Yes | No | Unknown | Theme Total |
| Efficacy | Intended results met, but lack of in-person had its challenges. | #effective | 5 | 5 | | | 9 |
| | | #physical | 4 | 1 | 3 | | |

Team members and institutional contacts were asked to rate the remote modality for each standard to further develop the assessment of effectiveness. All standards except two were rated as "effective" to "very effective" (*p-values* < 0.05; *n* = 24) on a five-point Likert scale, as indicated by Table 5. These results did not change between team member and institutional contact responses (per Standard comparison: all *p-values* < 0.05). Not surprisingly, Standard 11 Facilities, Equipment & Technical Support was not found to be more "effective" to "very effective" vs. "very ineffective" to "neutral" (*p-value* = 0.0535). The second standard to receive a higher proportion of "very ineffective" to "neutral" ratings was Standard 17 Advisory Committee Approval of Overall Program (*p-value* = 0.1143). This result is more surprising, as the ability to meet with an institutions' advisory committee was still technically available to visiting teams, albeit logistically more challenging due to the newness of virtual video conference format during the spring of 2020.

**Table 5**. Per standard hypothesis test results comparing the effectiveness of remote site visits at upholding the rigor of accreditation reviews, as rated by team and institutional groups on a 5-point Likert scale of "very ineffective," "ineffective," "neutral," "effective," "very effective."

| Standard | Description | *p-value*[a] |
|---|---|---|
| 1 | Preparation of Self-Study | 0.0000 |
| 2 | Program Definition | 0.0000 |
| 3 | Program Title & Mission | 0.0000 |
| 4 | Program Goals | 0.0000 |
| 5 | Program Learning Outcomes | 0.0000 |
| 6 | Program Structure & Course Sequence | 0.0000 |
| 7 | Student Admission & Retention | 0.0002 |
| 8 | Transfer Course Work | 0.0000 |
| 9 | Student Enrollment | 0.0000 |
| 10 | Administrative Support & Technical Support | 0.0075 |
| 11 | Facilities, Equipment & Technical Support | **0.0535** |
| 12 | Program/Option Operation | 0.0075 |
| 13 | Graduate Satisfaction with Program/Option | 0.0075 |
| 14 | Employment of Graduates | 0.0075 |
| 15 | Job Advancement of Graduates | 0.0022 |
| 16 | Employer Satisfaction with Job Performance | 0.0217 |
| 17 | Advisory Committee Approval of Overall Program | **0.1143** |
| 18 | Outcome Measures Used to Improve Program | 0.0075 |
| 19 | Program Responsibility to Provide Info to Public | 0.0000 |

[a]H0: Proportion of Effective & Very Effective responses ≤ all other responses

Based on the data collected from BoA members, team members, and institutional contacts, it was apparent that spring 2020 remote site visits were perceived to be effective at upholding the rigor of accreditation review. To assess the impact on quality, survey data from BoA members, team members, and institutional contacts were evaluated and presented in Table 6. It was found that $n = 3$ (27%) felt the impact on quality was negative, $n = 6$ (55%) felt it was neutral, and $n = 2$ (18%) felt the impact was positive. Statistically, there was no difference in the proportion of negative vs. not negative sentiment (*p-value* = 0.2727) towards an impact to quality. These results lack a distinctive sentiment, or more importantly, do not illustrate a distinctive negative sentiment.

**Table 6**. Categorization of BoA members' sentiment of the impact remote site visits had on the quality of accreditation reviews?

| Sentiment | Counts | % |
|---|---|---|
| Negative | 3 | 27 |
| Neutral[a] | 6 | 55 |
| Positive | 2 | 18 |
| Total | 11 | 100 |

[a]$H_0$: Proportions of Negative = Not Negative (*p-value* 0.2727)

To further unpack BoA members' rationale for sentiments of quality, the study used thematic analysis to identify a theme of *outcomes* across all negative, neutral, and positive results. As illustrated in Table 7, this theme was defined as *some standards were challenging, some were easy, and some were the same to assess using a remote modality*. Even though BoA members did not agree in their sentiment regarding the impact that the remote modality had on quality, there was a strong sense of outcomes focus of responses that point to a *status quo* impact on the quality of the review process. This inference is supported by the statistically insignificant proportion of results between sentiment categories (*p-value* = 0.2727) of Table 6.

**Table 7**. Codes, counts, and theme observed from BoA members' rationale for their sentiments regarding the impact on quality from remote site visits.

| | | | Frequency | | | | |
|---|---|---|---|---|---|---|---|
| Theme | Definition | Codes | Per Code | Positive | Negative | Neutral | Per Theme |
| Outcome | Some standards were challenging, some easy, and some same to assess using remote modality. | #standards | 4 | | 2 | 2 | 9 |
| | | #methods | 2 | 1 | | 1 | |
| | | #status_quo | 2 | | | 2 | |
| | | #limitations | 1 | | | 1 | |

To offer a fuller perspective, the evaluation asked team members and institutional contacts to rate the perceived impact on quality for each standard. As Table 8 indicates, no statistical difference was found between the proportion of "high quality" to "very high quality" and "neutral" to "very low quality" ratings for all standards, except three. The three standards that did exhibit statistically different ratings (i.e., "high quality" to "very high quality" vs. "neutral" to "very low quality") were Standard 1 Preparation of Self-Study (*p-values* = 0.0215), Standard 2 Program Definition (*p-values* = 0.0215), and Standard 4 Program Goals (*p-values* = 0.0215). Statistical differences in ratings are not surprising, as these standards inherently lend themselves to a remote review modality. Moreover, no statistical differences were found between team members and institutional contacts per standard ratings (all *p-values* < 0.05, *n* = 24).

By triangulating results from BoA, team member, and institutional contact surveys, there appeared to be no marked impact on quality. Taken with effectiveness results, respondents indicated that the remote site visits of spring 2020 were effective at upholding the rigor while also not negatively impacting the quality of the accreditation review process.

**Table 8**. Per standard hypothesis test results comparing the impact on quality of remote site visits, as rated by team and institutional groups on a 5-point Likert scale of "very low quality," "low quality," "neutral," "high quality," "very high quality."

| Standard | Description | *p-value*[a] |
|---|---|---|
| 1 | Preparation of Self-Study | **0.0215** |
| 2 | Program Definition | **0.0215** |
| 3 | Program Title & Mission | 0.0551 |
| 4 | Program Goals | **0.0215** |
| 5 | Program Learning Outcomes | 0.1207 |
| 6 | Program Structure & Course Sequence | 0.0551 |
| 7 | Student Admission & Retention | 0.2280 |
| 8 | Transfer Course Work | 0.1207 |
| 9 | Student Enrollment | 0.2280 |
| 10 | Administrative Support & Technical Support | 0.7102 |
| 11 | Facilities, Equipment & Technical Support | 0.9278 |
| 12 | Program/Option Operation | 0.5460 |
| 13 | Graduate Satisfaction with Program/Option | 0.8416 |
| 14 | Employment of Graduates | 0.3756 |
| 15 | Job Advancement of Graduates | 0.5460 |
| 16 | Employer Satisfaction with Job Performance | 0.5460 |
| 17 | Advisory Committee Approval of Overall Program | 0.5460 |
| 18 | Outcome Measures Used to Improve Program | 0.3756 |
| 19 | Program Responsibility to Provide Info to Public | 0.2280 |

[a]$H_0$: Proportion of High Quality & Very High Quality responses ≤ all other responses

## Lessons Learned and Best Practices

Qualitative data were evaluated to realize the second research objective: to develop lessons learned and best practices for future remote accreditation site visits. The first phase of this analysis was to evaluate perceived advantages of the remote modality. A strong theme of *expenditure* was observed from BoA, team member, and institutional contact responses. As illustrated in Table 9, this theme of *expenditure* was defined as *the financial costs were less, travel logistics were less, technical logistics were more, and convenience/time commitment was reduced*. All codes that comprised this them, except #technical_logistics, spoke to a sense of reduced resource expenditure required.

**Table 9**. Codes, counts, and theme observed from all survey groups regarding advantages of remote site visits.

| Theme | Definition | Codes | Frequency | |
|---|---|---|---|---|
| | | | Per Code | Per Theme |
| Expenditure | Financial cost less, travel logistics less, technical logistics more, convenience/time commitment reduced. | #cost | 13 | 29 |
| | | #convenience | 8 | |
| | | #time_commitment | 5 | |
| | | #logistics | 2 | |
| | | #technical_logistics | 1 | |

Two themes emerged when analyzing disadvantages of remote site visits reported by BoA members, team members, and institutional contacts. As illustrated in Table 10, the first and strongest theme was *interaction*, defined as *limited first-hand observation, limited in-person interaction, or limited ability to connect with students, faculty, and advisory board members.* The second theme observed in the dataset was *protocol* and was defined as *some standards were harder to evaluate; the process was more difficult from a technical perspective; the method of remote visits can be refined,* as illustrated in Table 10.

**Table 10**. Codes, counts, and themes observed from all survey groups regarding disadvantages of remote site visits.

| Theme | Definition | Codes | Frequency | |
|---|---|---|---|---|
| | | | Per Code | Per Theme |
| Interaction | Limited first-hand observation, in-personal interaction, or ability to connect with students, faculty, and advisory board members. | #physical | 14 | 22 |
| | | #engagement | 5 | |
| | | #networking | 3 | |
| Protocol | Some standards harder to evaluate, process more difficult technically, methods can be refined. | #standards | 5 | 10 |
| | | #technical_logistics | 3 | |
| | | #methods | 2 | |

All three survey groups were asked to provide perceptions of whether a remote modality should be leveraged in the future to understand best practices for future usage of remote site visits for accreditation reviews. Categorizing sentiments of the $n = 31$ responses, it was found that $n = 12$ (39%) felt "yes" this modality should be leveraged in the future, $n = 9$ (29%) felt "maybe," while $n = 10$ (32%) felt "no," as illustrated by Table 11. From a statistical test of proportions, there was no difference in yes vs. not yes sentiments (*p-value* = 0.5770). In non-statistical terms, this indicated no consensus among respondents of whether to leverage remote site visits in the future. However, statistically, there are grounds to argue that there was no overwhelming negative

**Table 11**. Categorization of all survey groups' sentiment of whether remote site visits should be leverage in the future.

| Sentiment | Counts | % |
|---|---|---|
| Yes[a] | 12 | 39 |
| Maybe | 9 | 29 |
| No | 10 | 32 |
| Total | 31 | 100 |

[a]$H_0$: Proportions of Yes = Not Yes *(p-value* = 0.5770)

(i.e., "no") sentiment in the data for leveraging this modality in the future. Therefore, to understand further whether remote site visits should become a best practice review modality, the study evaluated open-ended rationales underpinning respondents' sentiments. The following paragraph presents this further analysis.

Analyzing participants' open-ended responses explaining why they felt remote site visits should or should not be leveraged in the future, three distinct themes emerged. As indicated in Table 12, the strongest theme across all sentiment categories was *impact*, as indicated by $n$ = 14 total instances of related codes. From the data, *impact* was defined as *how reviews are conducted affects outcomes: remote visits can be effective and accomplish the goals of a review, but remote visits can also be non-effective.* Not surprisingly, this definition echoes the non-definitive sentiment observed in Table 11. The second theme observed was *expenditure*, defined as *remote site visits requiring less time and cost but increased technical difficulties.* The last theme was *interaction* and was defined as *less first-hand observation, and in-person interaction was a negative; however, the remote modality has the potential to increase capacity and engagement opportunities*.

**Table 12**. Themes and codes observed from all survey groups regarding leveraging remote site visits in the future.

| | | | Frequency | | | | |
|---|---|---|---|---|---|---|---|
| Theme | Definition | Codes | Per Code | Yes | No | Maybe | Per Theme |
| Impact | Way reviews are conducted impacts outcome: remote visit can be effective and accomplish goals but can also not be effective. | #methods | 7 | 2 | 2 | 3 | 14 |
| | | #effectiveness | 5 | 1 | 3 | 1 | |
| | | #accomplish | 2 | 2 | | | |
| Expenditure | Less time and cost but at increased technical difficulties. | #cost | 4 | 3 | | 1 | 9 |
| | | #time_commitment | 3 | 1 | 2 | | |
| | | #technical_logistics | 2 | 1 | | 1 | |
| Interaction | Less first-hand observation and in-person interaction negative, remote modality has potential to increase capacity and engagement opportunities. | #physical | 4 | 1 | 2 | 1 | 8 |
| | | #engagement | 2 | 1 | | 1 | |
| | | #capacity | 2 | | | 2 | |

This study revealed answers to what advantages and disadvantages were observed from the remote site visits of 2020. While these answers offer lessons learned, it was unclear how these advantages and disadvantages should be leveraged for future accreditation reviews or what best practices should be offered for future remote site visits. Therefore, further research is needed to understand definitively how to leverage remote site visits for future accreditation reviews.

**Implications**

The study revealed several results that hint at how future remote accreditation visits may be improved. Among the inferences noted is that remote accreditation worked better than expected, regardless of a strong preference of about one-third of respondents for face-to-face visits. Remote accreditation was overwhelmingly perceived as effective in assessing program rigor across all standards except two. Considering the effectiveness of remote site visits, Standard 11 Facilities, Equipment & Technical Support, and Standard 17, Advisory Committee Approval of Overall Program, were the only standards perceived to have negative impacts. Non-negative impacts for all other standards indicated they are candidates for future remote assessment. The quality of the accreditation process was not perceived to be affected by the remote process. The assumption being that the ATMAE standards addressed by self-studies provide a better indicator of program excellence than personal contact by the visiting team.

**Limitations**

The factors limiting the validity and generalizability of this study follow. First, the sample size was too small to conclude with certainty that remote accreditation can completely replace the traditional site visit. However, aspects of the remote accreditation process are already in place and will continue to operate in this fashion. Second, the themes of effectiveness and quality are highly subjective, even with definitions provided. Respondent bias was likely present as each individual's perspective varies greatly on the level to which the planned activities and results were achieved, with their concurrent perception of inherent quality. Each accreditation team and institution were unique. The study considered the results for a limited period for the small sample of people involved.

## Conclusion

This study collected data from the spring of 2020 to assess the effectiveness and quality of remote accreditation site visits and develop lessons learned and best practices for future remote accreditation reviews. Results indicated that it is possible to accredit an institution without the need for an onsite visit. Furthermore, the findings provided an initial roadmap for further refinement and improvement of the ATMAE accreditation process. The primary takeaway from this research is that remote site visits are a viable means of achieving accreditation, provided the self-study contains the information needed to assess program quality and rigor.

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## Appendix A

Select questions from the Board of Accreditation survey,

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**Question 2**

***Effectiveness* can be defined** as the extent to which planned activities (e.g., accreditation evaluations, including site visits) are realized and planned results (e.g., informed Board of Accreditation decisions) are achieved.

Considering this definition of *effectiveness*, **were the remote site visits of 2020 effective in upholding the rigor of ATMAE Accreditation reviews?**

[] Yes
[] No
[] Unknown

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**Question 3**

Please provide a brief rationale for your answer above.

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**Question 4**

*Quality* **can be defined** as the degree to which a set of inherent characteristics fulfills standards (i.e., fitness-of- purpose) or the inherent perception of the user (e.g., customer's perspective).

Considering a "fitness-of-purpose" definition
for *quality*, **what impact did the remote site visits of 2020 have on the quality of ATMAE Accreditation reviews?**

[] Negative (did not meet standards)
[] Neutral (met standards)
[] Positive (exceeded standards)

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**Question 5**

Considering a "customer perspective" definition
for *quality*, **describe your perception of why the remote site visits had a positive, negative, or neutral impact on the quality of the Board's final decision to accredit a program?** (*Please explain*.)

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**Question 6**

What advantage(s) to ATMAE Accreditation were observed from the remote site visits of 2020? (If none, respond with "none".)

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**Question 7**

What **disadvantage(s)** to ATMAE Accreditation were observed from the remote site visits of 2020? (If none, respond with "none".)

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**Question 8**

Should remote site visits be leveraged for future ATMAE Accreditation reviews? (Please explain.)

## Appendix B

Select questions from the Team and Institution survey,

**Question 2**

*Effectiveness* **can be defined** as the extent to which planned activities (e.g., accreditation self-study reports and accompanying site visits) are realized and planned results (e.g., program accreditation decisions) are achieved.

Considering this definition of effectiveness, **please rate (per ATMAE Accreditation Standard) how effective remote site visits of 2020 were at upholding the rigor of the accreditation reviews?**

For reference, the ATMAE 2019 Accreditation Standards can be found here.

| Standard | Description | *Very Ineffective* | *Ineffective* | *Neutral* | *Effective* | *Very Effective* |
|---|---|---|---|---|---|---|
| 1 | Preparation of Self-Study | [] | [] | [] | [] | [] |
| 2 | Program Definition | [] | [] | [] | [] | [] |
| 3 | Program Title & Mission | [] | [] | [] | [] | [] |
| 4 | Program Goals | [] | [] | [] | [] | [] |
| 5 | Program Learning Outcomes | [] | [] | [] | [] | [] |
| 6 | Program Structure & Course Sequence | [] | [] | [] | [] | [] |
| 7 | Student Admission & Retention | [] | [] | [] | [] | [] |
| 8 | Transfer Course Work | [] | [] | [] | [] | [] |
| 9 | Student Enrollment | [] | [] | [] | [] | [] |
| 10 | Administrative Support & Technical Support | [] | [] | [] | [] | [] |
| 11 | Facilities, Equipment & Technical Support | [] | [] | [] | [] | [] |
| 12 | Program/Option Operation | [] | [] | [] | [] | [] |
| 13 | Graduate Satisfaction with Program/Option | [] | [] | [] | [] | [] |
| 14 | Employment of Graduates | [] | [] | [] | [] | [] |
| 15 | Job Advancement of Graduates | [] | [] | [] | [] | [] |
| 16 | Employer Satisfaction with Job Performance | [] | [] | [] | [] | [] |
| 17 | Advisory Committee Approval of Overall Program | [] | [] | [] | [] | [] |
| 18 | Outcome Measures Used to Improve Program | [] | [] | [] | [] | [] |
| 19 | Program Responsibility to Provide Info to Public | [] | [] | [] | [] | [] |

*(survey questions continue on next page)*

### Question 6

***Quality* can be defined** as the inherent perception of the user (e.g., customer's perspective).

With this definition in mind, **please rate (per ATMAE Accreditation Standard) the quality of accreditation review experienced from the remote site visits of 2020?**

For reference, the ATMAE 2019 Accreditation Standards can be found here.

| Standard | Description | *Very Low Quality* | *Low Quality* | *Neutral* | *High Quality* | *Very High Quality* |
|---|---|---|---|---|---|---|
| 1 | Preparation of Self-Study | [] | [] | [] | [] | [] |
| 2 | Program Definition | [] | [] | [] | [] | [] |
| 3 | Program Title & Mission | [] | [] | [] | [] | [] |
| 4 | Program Goals | [] | [] | [] | [] | [] |
| 5 | Program Learning Outcomes | [] | [] | [] | [] | [] |
| 6 | Program Structure & Course Sequence | [] | [] | [] | [] | [] |
| 7 | Student Admission & Retention | [] | [] | [] | [] | [] |
| 8 | Transfer Course Work | [] | [] | [] | [] | [] |
| 9 | Student Enrollment | [] | [] | [] | [] | [] |
| 10 | Administrative Support & Technical Support | [] | [] | [] | [] | [] |
| 11 | Facilities, Equipment & Technical Support | [] | [] | [] | [] | [] |
| 12 | Program/Option Operation | [] | [] | [] | [] | [] |
| 13 | Graduate Satisfaction with Program/Option | [] | [] | [] | [] | [] |
| 14 | Employment of Graduates | [] | [] | [] | [] | [] |
| 15 | Job Advancement of Graduates | [] | [] | [] | [] | [] |
| 16 | Employer Satisfaction with Job Performance | [] | [] | [] | [] | [] |
| 17 | Advisory Committee Approval of Overall Program | [] | [] | [] | [] | [] |
| 18 | Outcome Measures Used to Improve Program | [] | [] | [] | [] | [] |
| 19 | Program Responsibility to Provide Info to Public | [] | [] | [] | [] | [] |

### Question 10

What **advantage(s)** to ATMAE Accreditation were observed from the remote site visits of 2020? (If none, respond with "none".)

### Question 11

What **disadvantage(s)** to ATMAE Accreditation were observed from the remote site visits of 2020? (If none, respond with "none

### Question 12

Should remote site visits be **leveraged** for future ATMAE Accreditation reviews? (Please explain.)

# Information Technology Entrepreneurship Projects – Business and Industry Partnership with Academics for Assessments

Author:

**Savitha Pinnepalli**

## Abstract

Most students graduating from a community college lack work experience and soft skills. The IT Entrepreneurship project addresses these shortcomings by providing students opportunities to brainstorm ideas to create an IT Company which may sell products or develop services from scratch. Students create a business plan, a logo and mission statement for the company. A group of three to four students form the team to run the company for a semester by creating an organization chart using Microsoft Visio software. They create a testimonial video with an elevator pitch  summarizing their skills. An ePortfolio with resume, cover letter, references, LinkedIn profile, and a business card serves as a personal branding activity. A SWOT (Strength, Weakness, Opportunity, Threat) analysis of their company helps students identify a problem/opportunity in their community and provide solutions using their IT skills. Students work on a business process data flow diagram and set goals for their company. Students conduct present value and ROI (Return on investment) analysis, and financial analysis on an excel spread sheet to determine the cost of running the IT company. They use Microsoft Project Management software to analyze personnel, resource, and cost. They look for funding opportunities, grants, and write an RFP (request for proposal) to find future investors, stake holders and business partners. Finally, they create marketing materials and pitch their idea through a 15-minute presentation to the business and industry personnel who may hire the students for internships or full-time jobs.

Employability skills are the soft skills of the 21st century for career readiness and success in the work-place. There is a gap in formulating the skills for employability needed by entry-level IT workforce between Employers and Educators. Since IT is pervasive in most sectors, the skills needed by IT workers differ in each sector. There is a lag in delivery of skills needed by the industry and academics.

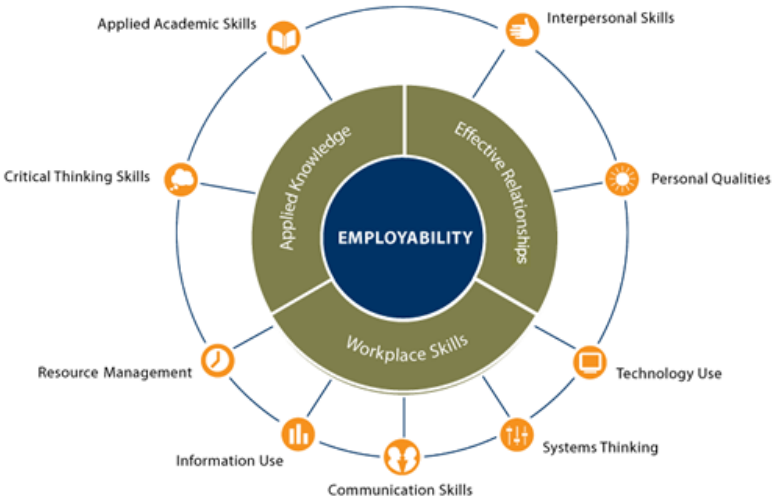
**Challenges educators face include:**

- Preparing current students to be able to analyze and implement new technologies which may not be part of their current academic environment is the greatest challenge facing technology instructors.
- There is limited dialog between IT Employers and Educators to tailor IT skills desired by Industry with the curriculum adopted by academia.
- The speed of adoption and innovation of IT technologies is aided by availability of private sector funding, in contrast to lack of funding in education. Time needed to implement programs by accreditation and committee approvals hampers delivery of state-of-the-art technologies to our students in a timely manner.

Adoption of technology in commercial settings progresses at a faster pace due to innovation, necessity, and availability of funds. To bring a new IT program for adoption in academia may take years of peer review and approvals by accrediting agencies and college committees. Peer review and approvals are needed to vet proposals and resources in the best interest of students and institutions. As per Necessary Skills Now Network, (https://www.necessaryskillsnow.org/) employability skills feature prominently in top 10 attributes employers are seeking in new graduates. Job Outlook 2021 – National Association of Colleges and Employers (NACE).

| ATTRIBUTE | % OF RESPONDENTS |
|---|---|
| Problem-solving skills | 91.2% |
| Ability to work in a team | 86.3% |
| Strong work ethic | 80.4% |
| Analytical/quantitative skills | 79.4% |
| Communication skills (written) | 77.5% |
| Leadership | 72.5% |
| Communication skills (verbal) | 69.6% |
| Initiative | 69.6% |
| Detail-oriented | 67.6% |
| Technical skills | 65.7% |

This project aids collaboration of employers and educators to foster better communication, resource sharing, professional developm 0ent, and keep the community informed of resources, research, and employer perspectives as well as professional development opportunities to students. Students learn work ethic, team-work, and gain leadership skills. As per US Department of Education Employability skills framework LINCS | Adult Education and Literacy | U.S. Department of Education, PCRN: Employability Skills (ed.gov), http://cte.ed.gov/employabilityskills




Students require many skills to be career ready, including academic knowledge, technical expertise, and a set of general, cross-cutting abilities called “employability skills.”

**The IT Entrepreneurship project follows the eight-employability skills framework:**

1. Interpersonal Skills and Teamwork:  teamwork, leadership, conflict resolution and responds to customer needs.
2. Communication Skills: written and verbal communication, active listening, observes carefully
3. Integrity and Professionalism: Personal Qualities like adaptability, flexibility, responsibility, self-discipline, works independently, willingness to learn, integrity, professionalism, enthusiasm, motivation, takes initiative, positive attitude and sense of self-worth, responsibility for professional growth.
4. Problem Solving and Decision Making: Critical Thinking Skills, Creative problem solving, decision making, planning, and reasoning, attention to detail and organizing skills.
5. Applied Academic Skills: Reading, Writing, mathematical strategies and procedures, and Scientific principles/ procedures.

6. Information Processing: Information use: locates, organizes, uses, analyzes, and communicates information effectively. Understands and uses technology.
7. Resource Management and Workplace skills: soft skills, time, money, materials and management of budget and personnel.
8. Entrepreneurship: Systems Thinking, understands, monitors, and improves systems.

Students are challenged to research and brainstorm an idea to start an IT business that will be instrumental in selling a product or service. Students then work in teams to create various artifacts listed in grading rubric below. The project timeline is set to run for a semester of 7 weeks. Students gain soft skills and employability skills by creating an ePortfolio. Students receive critical feedback from Business and Industry. Student's projects that show potential for success in the industry result in internships and potential job offers. Hence the IT Entrepreneurship project has been a vehicle to connect employers and potential employees. Students get valuable advice from BILT (Business and Industry Leadership Team) on IT trends and certifications they should pursue. Students also receive interview tips and career counselling through the colleges career services.

Soft skills trainings are imparted to students by Business and Industry Leadership team members (BILT). Industry Advisory Board members (IAB) present on current IT trends. Students have opportunities to visit local IT companies like DC Blox and Field trips to ORNL Oak Ridge National Labs and UTC Sim center. Students receive peer mentoring through tutoring, volunteering opportunities as lab monitors, teaching assistants through Hour of code, Cyber Seniors and Girl Scouts STEM Day projects. IT HUB Club activities provide student engagement and networking opportunities. Student competitions like Skills USA programming, PC technician competitions and Capture the Flag demonstrate Team building activities. The college has the following resources for our students: AWS (Amazon Web Services), Oracle Academy, Google IT specialist and CISCO Networking Academy.

## CITC – 2335 12/2/2021 11:00 – 12:15 p.m. Project Evaluation Form

| **Name:** | **Presentation Date:** | | | |
|---|---|---|---|---|
| **Topic:** | **Team Number:** | | | |
| **Each Step is worth 50 points** | **Excellent 90 -100 %** | **Good 70-89 %** | **Fair 60-69 %** | **Points Earned** |
| **Step1:** You can create a fake company or collaborate with a real company. If you are planning on working on a fake company you created, you will have to create the Business process, analyze problems, and provide solutions. Working with a real company will help you receive data and content they currently have, and your task will be to improve the Business Process Model.<br>• Title: Your company Name<br>• Team Members: Form a team and nominate team leader.<br>• Mission of your company, Vision of your company<br>• Conduct market research to perform SWOT analysis.<br>• Project charter plan and executive summary<br>• ePortfolio – cover letter, resume, references, business card, LinkedIn profile, thank you letter.<br>• Estimate total budget needed to run your company for one semester (Excel Spreadsheet). Include budget for personnel, items needed, hours of work needed etc. on an **excel spreadsheet**.<br>• Create **organizational chart** using Visio 2019 software to include your team members names, titles and picture from creative common license that can be found online.<br>• Create a Project Timeline with tasks and deadlines using **Microsoft Project** 2019 Software. | | | | |
| **Step2:**<br>• Data Flow diagram for your project using Visio 2019 software.<br>• Create a database to implement your project. (Access or PHP My SQL Database)<br>• Launch your website.<br>• How will you market your company? (News Paper Ads, TV ads, Flyers, social media, brochures, website (Wix.com), presentation, Fairs, Public Domain, Business cards) Display at least three items in binder.<br>• Project presentation- Power Point<br>• Video of your company<br>• A video of your testimonial. | | | | |
| **Comments:** | **Total:** | | | |

## Conclusions

The IT Entrepreneurship project has proved that students are engaged and empowered with skills needed to be career ready including soft skills and employability skills as described in the employability skills framework. Educational institutions may also work with certification groups to match curriculum with skills desired by industry.

Some in the industry distinguish soft-skills and employability skills. Employability skills are primarily skills desired in prospective employees augmenting technical skills. Soft skills are not limited to the industry and often are desired in social settings as well. Though there is no consensus about what constitute soft skill, here are some desirable traits/abilities: work ethic, communication, self-confidence, positive attitude, flexibility, organization, emotional awareness, initiative, time management, negotiation, leadership, teamwork, accountability, self-motivation, stress management, networking, and decision making.

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Crawford, Pat et al, Comparative Analysis of Soft Skills: What is Important for New Graduates?, Washington DC: Association of Public and Land–grant universities, August 2011.

Other resources found online:

"Employability Skills Feature Prominently in Top 10 Attributes Employers Are Seeking in New Graduates"

https://www.necessaryskillsnow.org/

https://lincs.ed.gov/

https://www.seattlejobsinitiative.com/wpcontent/uploads/SJI_SoftSkillsReport_vFINAL_1.17.13.pdf

"Why Employability Skills?" http://cte.ed.gov/employabilityskills

"Life Skills vs. Soft Skills vs. Career Skills vs. Employability Skills — What Are the Differences?" https://www.aeseducation.com/blog/life-skills-soft-skills-career-skills-employability-skills-what-are-the-differences

"Employability and Entrepreneurship E-guide" https://www.edusampo.fi/files/2629/EEE-guide.pdf

# Innovations in Remote Academic Internships During the COVID-19 Pandemic

Author:
**Lori Sussman**

## Abstract

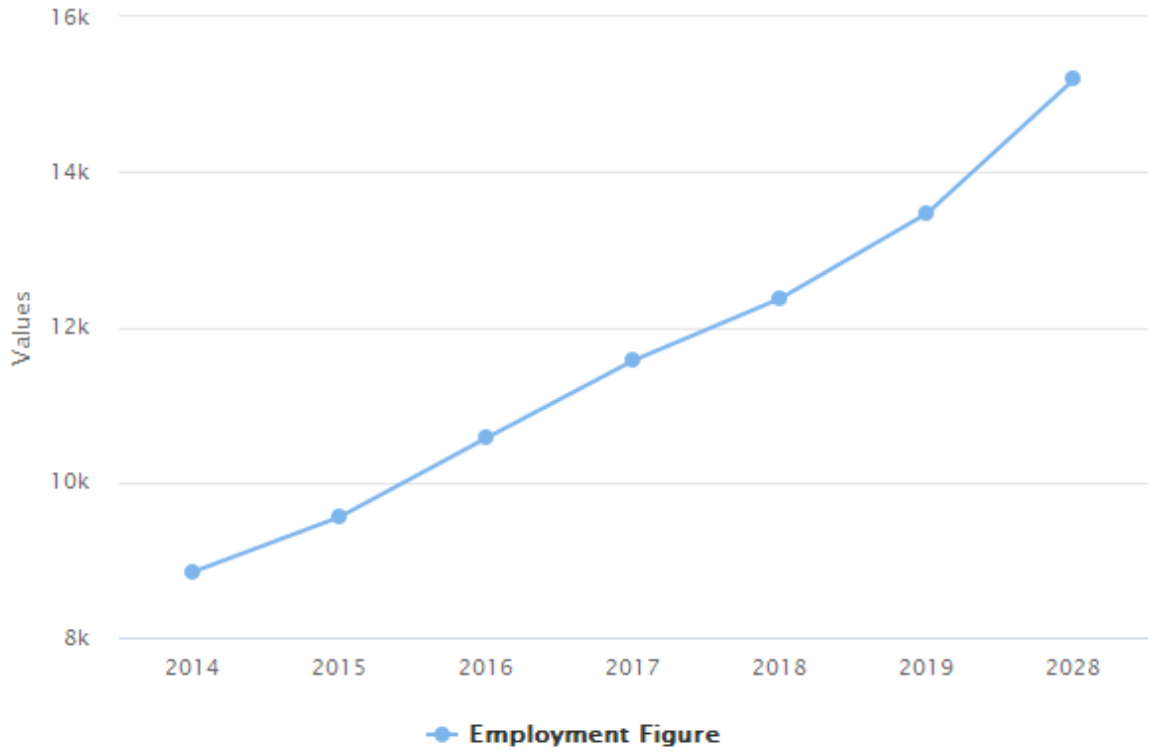
The Cybersecurity Ambassador Program provides professional skills training for emerging cybersecurity professionals remotely. The goal is to reach out to underrepresented populations who may use Federal Work-Study (FWS) or grant sponsored internships to participate. Cybersecurity Ambassadors (CAs) develop skills that will serve them well as cybersecurity workers prepared to do research, lead multidisciplinary, technical teams, and educate stakeholders and community members. CAP also reinforces leadership skills so that the next generation of cybersecurity professionals becomes a sustainable source of management talent for the program and profession. The remote curriculum innovatively builds non-technical professional skills (communications, teamwork, leadership) for cybersecurity research through student-led applied research and creating community-focused workshops. These student-produced workshops are in phishing, identity and privacy cyber safety, social media safety, and everyday home cyber safety. The CAs tailor the program to a particularly vulnerable population such as older adults, students, veterans, or similar people that make up most workshop participants. The pedagogical approach for curriculum development is grounded in the Ground Truth Expertise Development Model (GTEDM) for exploring suitable non-technical, exceptionally soft KSAs for cybersecurity professional development.

*Keywords*: cybersecurity skills; cybersecurity education; cybersecurity curriculum; KSA; non-technical skills; cybersecurity training; cybersecurity roles; cybersecurity workforce, cybersecurity professional development, remote internship; educational innovation

Cybersecurity workers feel the pressure of being understaffed despite aggressive actions to hire people with the right expertise (Crumpler & Lewis, 2019). Even before the COVID-19 pandemic, reports of cyber-attacks, social engineering scams, identify theft, and cyber-based financial fraud frequently made news headlines (FBI, 2020, June 9; USSS, 2020, March 9). However, the COVID-19 pandemic further exacerbated the shortage of required cybersecurity professionals (BLS, 2020, July 2) (Figure 1).

**Figure 1**

*Burning Glass Demand for Cybersecurity Workers Growth Data*




*Note:* Burning glass Information Security Analyst Expected Job Growth over next 10 Years

With the increased home, learning, and business activity online came a corresponding surge in cybercrime (USSS, 2020, March 9). The Federal Bureau of Investigation (FBI) COVID-19 Working Group, in conjunction with the Secret Service's Global Investigative Operations Center (GIOC), reported that COVID-19 related cybercrime accounted for a 300 percent jump in complaints in the first four months of the COVID-19 pandemic (FBI, 2020, June 9). The pandemic heightened the need for corporate, academic, and government institutions to work together to figure out better ways to attract and retain cybersecurity professionals despite

being forced to keep socially distant. Students were aware of the tremendous opportunities in cybersecurity and looked for enhanced entry skills.

The University of Southern Maine (USM) Department of Technology developed the Cybersecurity Ambassador Program (CAP) with the workforce and students' demands in mind. Both the graduate and undergraduate programs were growing because students saw the opportunity for work at high salaries. At the time, there were thousands of unfilled jobs in New England, where the median New England Salary was $101K (BLS, n.d.). The faculty used KSAs from the National Security Agency (NSA) guidelines for Centers for Cybersecurity Academic Excellence – Cyber Defense (CAE-CD) to increase student cyberinfrastructure (CI) literacy, increase workforce readiness, and create mechanisms to help the community. The program started with in-person sessions but pivoted to online early in 2020 due to pandemic restrictions,

The faculty's primary goal was to incorporate scholarly cybersecurity research with workshop preparation to increase student writing, presentation, and investigative skills. Its secondary objective was to support Maine's vulnerable populations by creating and executing targets workshops for vulnerable people to increase community cybersecurity awareness. CAP started student training with four introductory seminars and continues to use that format. Graduate Assistants (GAs) and senior Cybersecurity Ambassadors (CAs) mentor and coach the incoming cohort to ground them in the basics in these critical areas of cybersecurity awareness training.

## CAP Evolution

There was not a great deal of budget to launch the CAP program. The faculty started with student volunteers. Unfortunately, that number dwindled over time due to competing work and study requirements. The faculty realized that CAP needed to provide students with work income to grow. The USM faculty advisor solicited public and private partners to fund internships. As such, the faulty sought to fund CAP's first Cybersecurity Ambassadors (CAs) through the Federal Work-Study (FWS) Program, grant-funded internships, and using an allocated partial graduate assistantship.

The Maine Office of Securities provided a generous grant to jumpstart the program. Their only request was for USM to discuss financial risks as part of the outreach workshops. These initial funds allowed the faculty to create a marketing brand, use that branding for student incentives such as caps and shirts, purchase presentation equipment, and fund four one-semester internships.

The faculty advisor, supported by a part-time graduate assistant, hired CAs using the federal work-study program and grant-funded internships. They hired students interested or showed an aptitude for cyber-security technology and wanted to work twenty hours each week during the semester. The faculty advisor created a three-tier program to allow those students who participated for more than one term to have scaffolded goals and objectives (Figure 2).

**Figure 2**

*Cybersecurity Ambassador Program (CAP) Tiered Approach for Student Development*


Cohorts of CAs achieved the first or bronze tier through oral and written assessments based on technical training and career planning modules developed and taught by working Cybersecurity researchers and Cybersecurity professionals. They must also successfully present at least two of the four workshops. The second (silver) phase emphasized leadership and mentorship and required students to deliver on the four core areas. The advisor and graduate assistant assessed CA presentation skills, leadership, collaboration, and research efforts. CAs achieved the top (gold) level when they could help coordinate outreach and certify other students.

It cannot be overstated that the vision was to promote sought-after cybersecurity workplace skills for students while simultaneously giving back to the community. At the same time, this program provided access and support to students from historically underrepresented populations in the Information Security and Cybersecurity disciplines. We found that international and minority cybersecurity students applied for the CAP internship citing difficulty getting hired by outside entities. One area for future study is to determine if bias forms barriers for students from underrepresented populations in cybersecurity to get outside internship opportunities. Regardless, CAP provided a means for these minority students to earn internships needed to graduate from the USM cybersecurity undergraduate program.

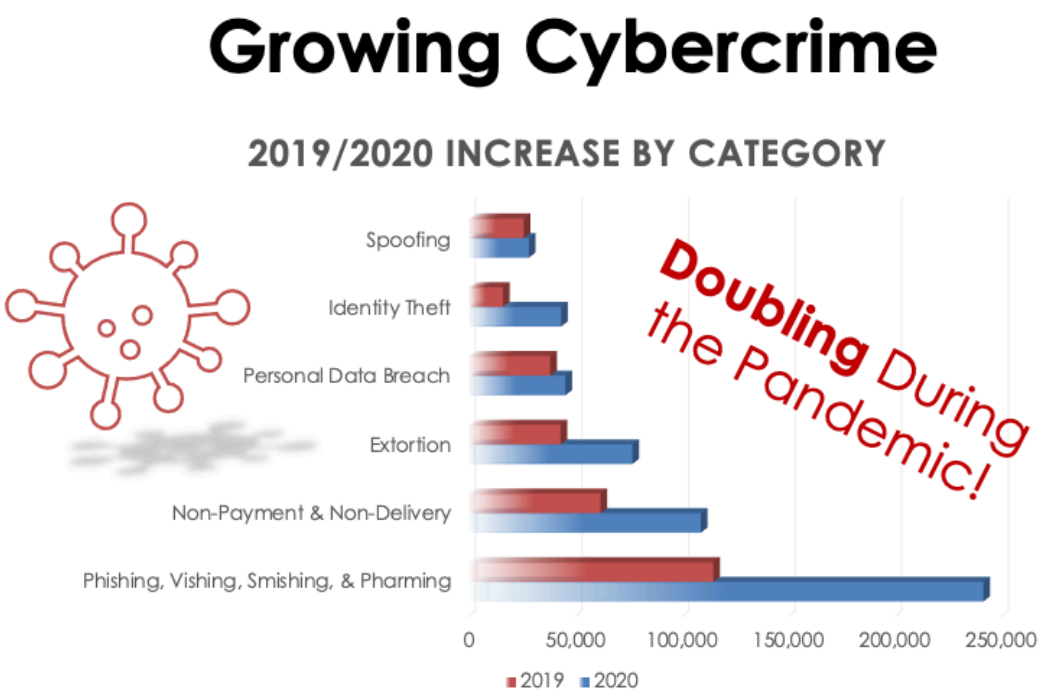
The first CA cohorts spent most of their time understanding the current cybersecurity-related trends and how to promote awareness of those trends to at-risk communities in Maine. We fostered an open work environment where asking questions became core to helping the overall team understand what they could do to help each other. The students quickly created a social platform on Discord to facilitate chats between members. We used a shared Google drive to create, collaborate, and archive scholarly and presentation artifacts.

The initial program intended to use students who started with a keen technical understanding of cybersecurity built from their undergraduate cybersecurity curriculum. The faculty used the premise that these STEM students entered with foundational cyber knowledge, skills, and abilities (KSAs). The program focused on enhancing complimentary non-technical skills to increase student workforce readiness. The objective was, and remains, to provide students with immersive experiences and exposures to cybersecurity awareness and to train research that complimented their cybersecurity KSAs as they produced community awareness training for vulnerable populations. This enrichment accelerates students' transition to practice by creating applied projects that use CAE-CD sanctioned technical and non-technical KSAs to achieve objectives. Students apply what they know about social engineering, privacy, and interventions to thwart cybercrime.

The CAP team looked at the FBI (2020, 2019) Internet Crime Reports and continued using such government data to keep the four key cybersecurity workshop areas up to date. As the data revealed, these topics creating awareness about phishing, identity/privacy, cyber safety, social media safety, and cyber home safety were and remain relevant (Figure 3).

**Figure 3**

*Top Cybercrime Reported to the FBI in 2019 and 2020*




*Note*: Figure derived from the FBI 2019 and 2020 Internet Crime Reports.

We realized that we could not wait for the pandemic to recede when we first started. Cybercrime incidents doubled from 2019, and this data increased the faculty's urgency to get a remote model operational.

Maine is a very rural state but still experienced a significant rise in cybercrime (Figure 4).

**Figure 4**

Maine *Cybercrime Reported to the FBI in 2019 and 2020*

**Maine vs. National Losses**

| | MAINE | | NATIONAL | |
|---|---|---|---|---|
| Age Range | Count | Losses | Count | Losses |
| Under 20 | 47 | $298,227 | 23,186 | $70,980,763 |
| 20 - 29 | 163 | $78,519 | 70,791 | $197,402,240 |
| 30 - 39 | 248 | $694,123 | 88,364 | $492,176,845 |
| 40 - 49 | 211 | $706,649 | 91,568 | $717,161,726 |
| 50 - 59 | 263 | $1,792,048 | 85,967 | $847,948,101 |
| Over 60 | 368 | $2,471,681 | 105,301 | $966,062,236 |

*Note*: Figure derived from the FBI 2019 and 2020 Internet Crime Reports.

The CAP CAs mined Maine crime data to provide facts and data in their presentations. The intention was to tailor general workshops to increase significance to the organization receiving the training event.

CAP also provided opportunities for students to apply their knowledge as leaders. Although CAP is faculty-led, it is a student-driven organization dedicated to raising cybersecurity awareness in high-risk groups throughout Maine. It continues to provide interested students opportunities to participate in cybersecurity awareness and education research, organize that research into presentations, and deliver this content to those at-risk individuals and organizations who request support. Students who participated in the program got a unique opportunity to give back to their communities, develop highly sought-after workplace skills in the field of cybersecurity, and build their confidence in conveying complex concepts to non-technical participants.

Students continue to run CAP workshops that focus on phishing, social media safety, online identity protection, and cyber home safety. The students share tips, tricks, and information to help participants evade disruptions due to cybercriminal activity. In addition, the CAP students help Maine residents with practical advice on protecting their privacy, identity, and financial information. Many Maine residents face the challenges of not knowing what steps they can take to avoid cyberattacks, and CAP students help them feel more empowered based on shared information. The feedback is that the student workshops are highly effective in helping these vulnerable groups avoid being victimized.

## Continuing CAP in the New Normal

This year Governor Janet Mills signed an executive order establishing a cybersecurity advisory panel "to strengthen the security and resiliency of the State's information technology infrastructure to protect against cyber risks and ensure effective cybersecurity communications" (Maine Exec. Order No. 2021-25, 2021, January 13, p. 1). This executive order codifies the urgency surrounding synchronizing cybersecurity efforts to identify, mitigate, and detect Maine citizens' cybersecurity risk. However, many Mainers do not know where to start to identify, mitigate, and report cybercrime. CAP provides education and information to protect Maine's vulnerable populations. We intend to keep the virtual team format going forward but include more in-person opportunities as the pandemic subsides. Thus, eventually, CAP will have a blended versus entirely virtual modality.

CAP is also a relationship-based program despite the remote modality. The CAP team meets weekly at the beginning of the week to gauge progress, discuss tasks, and prepare for upcoming workshops. The GA charged with student coordination meets with each participant one-on-one weekly to provide encouragement and review deliverables. CAP was awarded a second part-time GA position in AY2021-2022. The new GA was charged with content coordination and oversight for more complex collaboration, ensuring product outcome quality. The program continues to have students collaborate using online conferencing and collaboration tools such as Zoom, Trello, CANVA, Zotero, Discord, and shared drives. Their experience as remote workers using various tools strengthens independence and interdependence.

Students are central to this program and work with cybersecurity experts as coaches and advisors. This cybersecurity education, training, and awareness research enhances the students' technical and non-technical education through career mentoring. USM CAP provides direct mentoring of undergraduate and graduate students with active Cybersecurity researchers and professionals. A diverse group of researchers/community professionals provides training in Cybersecurity domains that include:

1) Securing personally identifiable information,
2) Securing the internet of things,
3) Social media safety,
4) Internet risks,
5) Cybersecurity incident response,
6) Cybersecurity governance, policy, and legislation.
7) Cybersecurity ethical considerations.

Students perform research and produce artifacts used and shared throughout various communities in Maine that include organizations for older adults, K-12 and higher education students, and veterans as just a few examples.

Said another way, the pandemic forced a virtual team model. However, this is a model readily used in the technology field. As such, CAP supports the integration of virtual learning and work.

This Cybersecurity Ambassador Program addressed the challenge of creating a trained and ready future cybersecurity workforce in general and in Maine in particular. This program promotes students' technical and professional skills to progress in the growing science, technology, engineering, and math (STEM)

field while helping the community. Students learn that knowledge of cybersecurity issues alone is not enough to be work-ready. Effective communication is essential for dealing with non-technical clients. Our next steps will be to work with interdisciplinary faculty for increased student proficiencies skills that build interpersonal connections and productive relationships. At the same time, we have added the production of short videos and podcasts to expand CAPs outreach using new modalities. Finally, we continue to scout technology that can be used to enhance presentational speaking and communication facilitation skills for small groups and workshops.

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# Multidisciplinary Student Collaboration in the Three-Class Integrated Curriculum

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## Abstract

This paper discusses the results of the first stage in the three-year project that addresses critical higher education goals to enhance the instructional quality and improve student multidisciplinary collaboration capabilities. The project proposes an innovative Multidisciplinary Curricula Integration (MCI) framework and instructional methods to enhance student career readiness.

The empirical results on student learning outcomes, students' learning progress and overall satisfaction with their in-class experiences are offered to highlight the benefits and challenges of the MCI framework's implementation. The results of the first year serve as a baseline for future steps in research and practice for improvement, implementation, and sustaining the approach.

*Keywords:* multidisciplinary student collaboration, curriculum integration

## Background

The current market is global and complex with intensive competition for businesses. Competition requires complex problems to be addressed on a global scale, which has caused companies to look at developing new, more effective solutions in product development, production, and marketing. Industry has increased their expectations of college graduates' skills to address the most challenging economic, health, environmental, and societal issues (Andersen, 2004; Robles, 2012; Yusof, Anuar, & Latif, 2019). Agriculture increasingly faces complex problems outside the knowledge of any one discipline, and industry has moved toward interdisciplinary teamwork as evinced by academic literature (Schimmelpfennig, 2016; Halachmi, Guarino, Bewley, & Pastell, 2019; Clark, n. d.; Schmitt, 2017).

The Agricultural and Biosystems Engineering Advisory Council highlighted the need for college graduates to be trained in a way that would allow them to work on interdisciplinary teams. The prevailing point of view is that college graduates in the engineering disciplines have very good technical skills but lacking an understanding of how to work with groups outside of their discipline (Robles, 2012; Hora, 2017). The lack of ability coupled with college students not seeing their shortcomings in this area has emphasized the need for development of the multidisciplinary education project (Hendrix & Morison, 2018; NACE, 2019). Advisory Board members indicated that higher education institutions are the best place to integrate this training/development activity so they could hire multidisciplinary trained graduates and place them directly into the work environment. To address the need, higher education must attend to the calls of industry stakeholders and revise and improve their curriculum in preparing students (Heldrich, 2005; Lai, DiCerbo, & Foltz, 2017).

Prior research has demonstrated the effectiveness of teaching methodologies grounded in practical simulations, to enable productive learning environments and stimulate students' acquisition of critical professional skills (Kragt et al., 2016; Eriksson, Manfredsson, & Hilletofth, 2016; Crawford & Dalton, 2016). This research project is grounded in practical simulations and student role-playing to offer an insight into the practical implementation of the developed Multidisciplinary Curricula Integration (MCI) framework in the context of three disciplines. The overall objective of the project was to propose novel pedagogical approaches and curricular modifications at the college level to address the industry needs for student professional competencies. The paper discusses the designed and piloted instructional framework to promote development of the multidisciplinary collaboration skills in college students and highlights students' experiences participating in the multidisciplinary integrated project.

## Methodology

### An Overview of the Designed and Piloted Teaching Framework

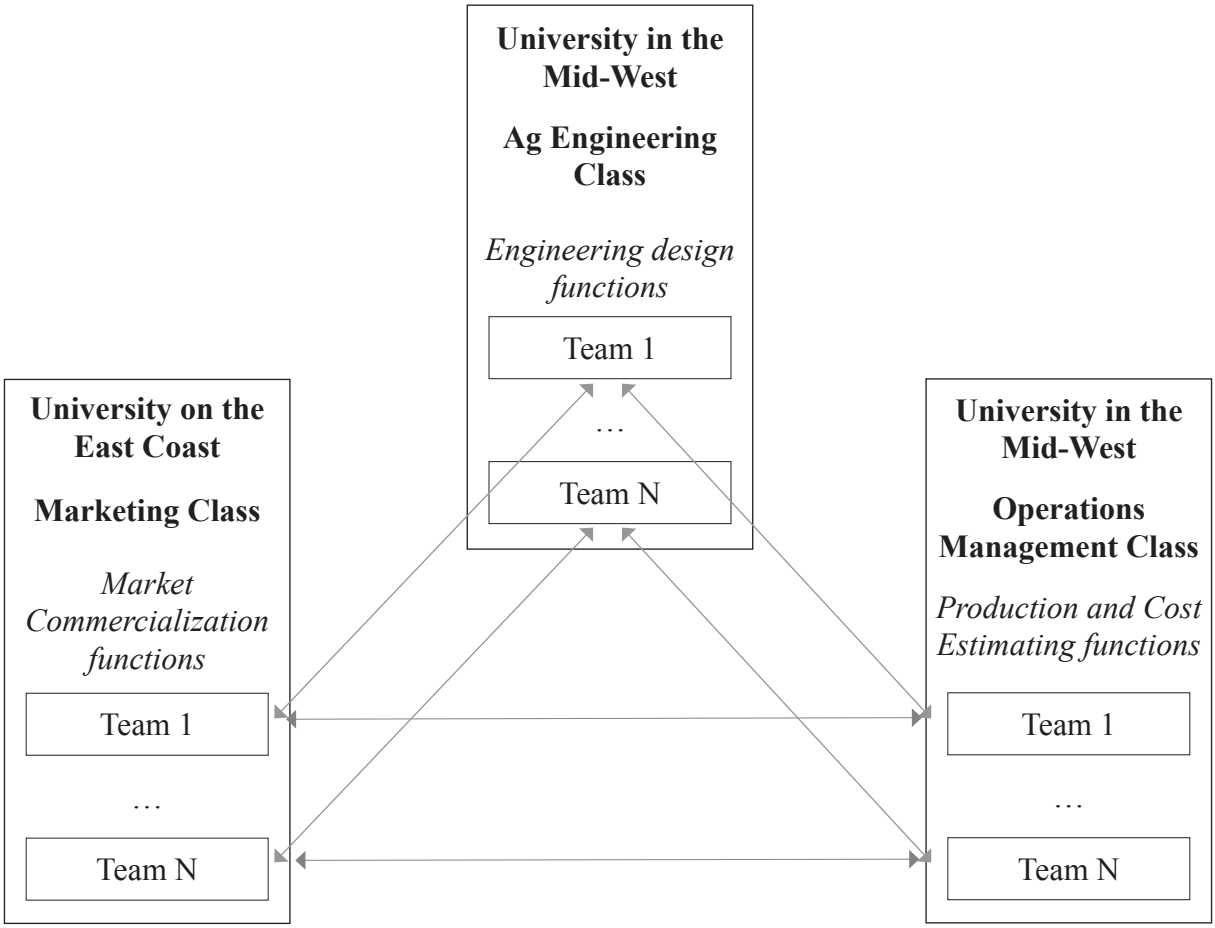
The project was initiated by integrating three courses from two colleges in the Midwest and a business school on the East Coast. In the first year of the project, students from the Agriculture and Biosystems Engi-

neering, Marketing, and Operations Management disciplines worked collaboratively, using teleconferencing technology, on a shared project to design a temperature measurement and control system for barns in the hog industry. The specific objectives in the project included technical design and development of the product, an estimation of production costs, and product commercialization in the Midwest region. The diversity and complexity of the project objectives effectively simulated real-world industry environment.

Figure 1 represents the functional organization of the project and flows of information within the proposed and developed Multidisciplinary Curricula Integration (MCI) framework. Each participating class was meeting for lectures and discussions relevant to their discipline-specific coursework. Early in the semester, the students were introduced to the collaborative project by their instructors and invited industry experts. Student teams participated in a tour of an existing hog facility. Presentations by the industry experts and the manager of the facility helped review the problems with existing temperature control systems available in the market and outlined industry expectations regarding the functionality, operator skill level, maintenance costs, and reliability of the product. To fulfill the project objectives, teams had to collect data required for their parts of the project from external resources and from the other classes' teams.

**Figure 1**

*Multidisciplinary Curricula Integration (MCI) Framework*



Student learning outcomes (SLOs) specific for each participating major were aligned with the core subject requirements. In addition to the discipline-specific SLOs, an ability to demonstrate effective multidisciplinary collaboration skills was included as an additional student learning outcome in every participating course. In order to achieve the overall objective of the collaborative project, students from all the participating classes had to coordinate their decisions and work closely together to ensure all the parts of the project are aligned and fit nicely.

**Participants**

Fifty-eight students participated in the project, putting together two classes from the University in the Midwest, the Agricultural and Biosystems Engineering class and the Operations Management class, and one class from the business school in the University on the East Coast, the Principles of Marketing. The demographic data for each class are provided in Table 1.

**Table 1**
*Student Demographic Data*

| | | Agricultural Engineering Class | Principles of Marketing Class | Operations Management Class |
|---|---|---|---|---|
| Year in the Program | First Year Student | 0.0% | 13.3% | 0.0% |
| | Sophomore | 0.0% | 53.3% | 0.0% |
| | Junior | 0.0% | 33.3% | 45.0% |
| | Senior | 100.0% | 0.0% | 55.0% |
| Gender | Female | 0.0% | 46.0% | 8.0% |
| | Male | 100.0% | 54.0% | 92.0% |
| Class Size | | 11 | 23 | 24 |

**Data Collection and Analyses**

Data collection was executed via self-administered online survey and qualitative reflection journals that allow student assessment of their current skill level and progress on Student Learning Outcomes (SLOs) and evaluate their experiences in the multidisciplinary collaborative project. The survey was administered in each class at the end of the semester, using the scales developed and validated previously (Laird, Prince, & Spence, 2003; Bhavnani & Aldridge, 2000). In addition, throughout the semester every student was asked to complete an individual self-reflection journal, to track their learning and professional development in the course.

To quantitatively analyze data collected via the survey, nonparametric statistical analyses were conducted, specifically the series of Wilcoxon Signed-Rank tests and Kruskal Wallis tests, to assess students' progress on learning outcomes. The Wilcoxon Signed-Rank test is an appropriate test for the same sample with repeated measures and thus was used to test the hypothesis that student collaborative skills would improve as a result of participation in the multidisciplinary collaborative project. Upon the project completion at the end of the semester, students were requested to evaluate their collaborative skills retrospectively, at the beginning of the semester, and also provide assessment of their collaborative skills currently, at the end of the semester, using Likert scales. Paired scores were tested for each class with *H1*: (End of Semester Perceived Competency minus Initial Perceived Competency assessed retrospectively) > 0. Kruskal Wallis tests were conducted to analyze differences in students' satisfaction and experiences between the classes.

Student responses to the survey open-ended questions and reflection journals were used to complement the quantitative data findings, as well as for triangulation purposes, and to ensure reliability and trustworthiness of the results.

## Results

The empirical results of the research project shed light on the impact of the proposed MCI framework on student learning outcomes and their progress in developing the multidisciplinary collaboration skills. They also alerted the research team on the necessary improvements to boost student satisfaction and learning experiences.

Among the 58 participating students from the Agriculture and Biosystems Engineering, Principles of Marketing, and Operations Management classes, 93% of students received 70% or higher for the project grade, and 91.5% of students received 70% or higher for the overall course grade. The results suggest that in the case of the Operations Management class (n=20), there was a statistically significant difference (*p-value = 0.002)* between student evaluations of their multidisciplinary collaborative skills at the project start and at the end of the semester. The results further show that in the Agricultural Engineering Class (n=10), there was no significant difference (*p-value = 0.25)* between student evaluations of their collaborative skills at the project start and at the end of the semester. Finally, in the Principles of Marketing class (n=10), there was no statistically significant difference *(p-value = 0.688)* between student self-evaluations of collaboration skills at the project start and at the end of the semester. Thus, it can be concluded that students' assessment of their

progress on multidisciplinary collaborative skills differ across the three classes, and more work has to be done on the instructional framework to achieve statistically significant improvements in students' multidisciplinary collaboration skills in all the classes.

To get deeper insight into differences in student progress with respect to their collaborative skills, the series of Kruskal Wallis tests were used to analyze differences (or lack thereof) in student evaluations of their experiences in the collaborative project among the three independent samples. The results are summarized in Table 2 reporting means for each class on the 7-point Likert scale. The results suggest that the students in the Principles of Marketing class report overall the highest satisfaction levels with the collaborative project experience. However, all classes report similar attitudes in regards to amount of communication with other teams, cordial conflict resolutions, and appreciation of perspectives of other discipline teams along with needs for their input. The greatest differences in perceptions relate to quality of communications, relevancy of supplied information, and students' multidisciplinary teamwork experience.

**Table 2**
*Student Evaluations of Their Experiences in the Multidisciplinary Collaborative Project*

| | Response Mean | | | |
|---|---|---|---|---|
| Question | Agricultural Engineering Class | Principles of Marketing Class | Operations Management Class | Kruskal - Wallis test results |
| The quality of communication we have with the other groups is very good. | 4.2 | 4.9 | 3.7 | *p=0.04* |
| There have not been any major misunderstandings when talking with the other groups. | 3.7 | 5.4 | 3.6 | *p=.002* |
| The other groups provide relevant and helpful information. | 3.4 | 5.1 | 4.1 | *p=0.03* |
| Our group and the other groups always "pulled together." | 4.5 | 5.5 | 3.9 | *p=.002* |
| I liked working with the other groups. | 4.9 | 5.3 | 4.0 | *p=0.04* |
| Working with the other classes has been a great experience. | 4.8 | 5.6 | 3.5 | *p=.002* |
| I appreciate the perspective of the other groups and see the need for their input. | 4.8 | 5.7 | 5.1 | n.s. |
| The amount of communication we have with the other groups is very good. | 4.3 | 5.0 | 4.2 | n.s. |
| We resolve conflicts with the other groups cordially. | 5.0 | 5.8 | 5.2 | n.s. |

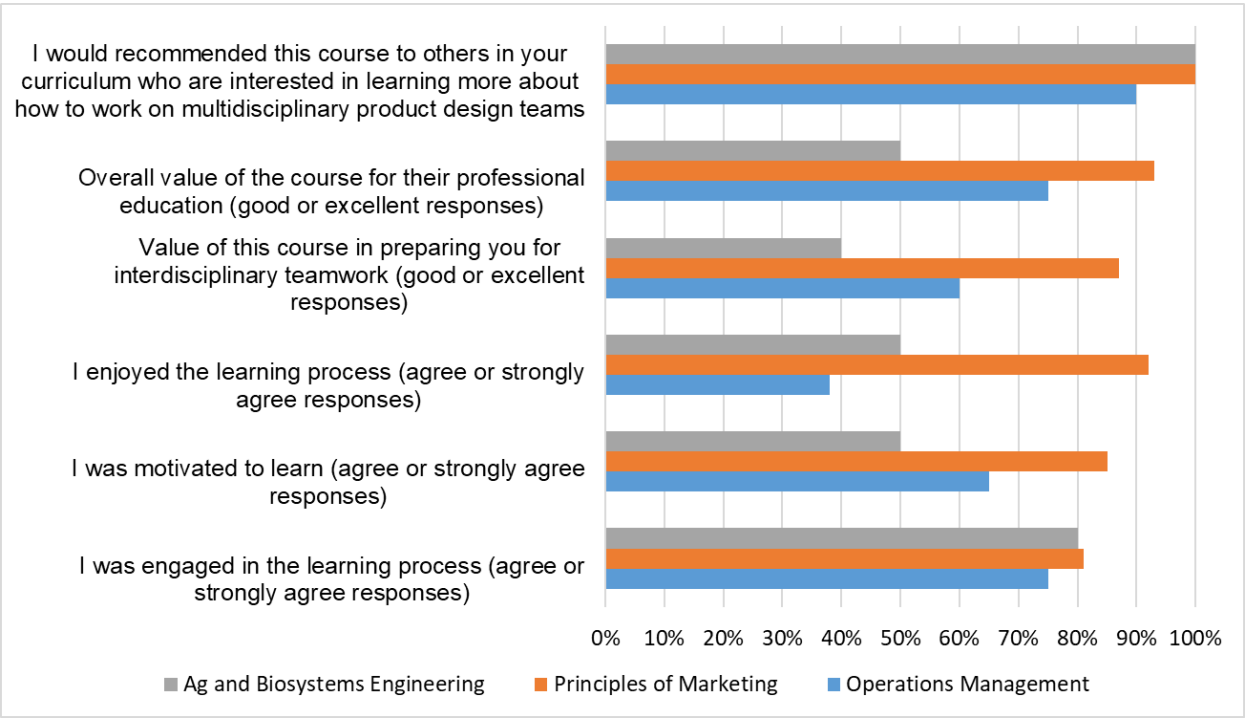
*Note*: Based on the 7-poin Likert Scale

These differences could be attributed to the demographic makeup of the sample. Thus, Agriculture and Biosystems Engineering (ABE) students were 100% seniors, Operations Management (OM) students were 55% seniors and 45% juniors, while Principles of Marketing class (POM) were mostly younger students with no seniors and only 33.3% juniors. Another possible factor could be the amount of collaboration, communication, and interdependence classes have had with each other. For example, ABE and OM classes had more interdependence in their respective tasks, and therefore, needed to manage the multidisciplinary collaboration constraints and trade-offs on the larger scale in comparison with the POM class, which could contribute to their perceptions as challenges. Finally, the differences in class sizes might have skewed the results, i.e., one ABE student response has twice the impact of an OM or a POM student.

Figure 2 shows comparison of student satisfaction and perceived course value among the three classes.

**Figure 2**

*Student Satisfaction and Perceived Course Value*




The similar trend of overall better satisfaction was reported by the Principles of Marketing students. Notably, over 70% of participants in all three classes reported they were engaged in the learning process, and more than 90% indicated they would recommend this course to learn multidisciplinary collaboration skills (yes or maybe responses). Based on these preliminary results, the researchers concluded that modifications to the instructional framework and organization of the collaboration processes are necessary to further improve student motivation, enjoyment, and to achieve better perceived value of the course.

Student feedback in the survey open-ended questions and their reflection journals support quantitative findings and shed light on the major causes of student stress and dissatisfaction at times. Examples of student responses to the survey open-ended question from all the classes are provided in Table 3.

**Table 3**
*Student Responses to the Survey Open-Ended Questions*

| | |
|---|---|
| Agriculture and Biosystems Engineering | • "It was confusing as to what team was in charge of what, it was hard communicating on zoom with the other groups"<br>• "The Start of the project was very rough there was limited communication with other groups. The ABE class did not receive a list of who was in the other class group until halfway through project. After communication between other classes started it made the project much more beneficial and our group started to learn a lot about working with other groups from different educational areas"<br>• "Needs more structure on how the groups are related and what scope of projects are for each group with meetings early to layout a lot of the goals and project responsibilities. It went better once those were laid out" |
| Principles of Marketing | • "I think the idea was great, I really enjoyed working as a team to complete a marketing plan report and presentation. To hear from the students at […] University was interesting and I loved the zoom meeting we had, where they presented their information and excel sheets and also provided us with their input. All around, great idea and should definitely be continued for other courses/semesters"<br>• "Loved every second of this class/project"<br>• "Personally, I found the multidisciplinary project with the […] University students very intriguing and helpful. Obtaining a different perspective, specifically from an engineering perspective, truly helped myself and my team conduct our marketing reports for our new innovative product. I found this project very beneficial and feel as if other courses should consider a similar type of project with another university with their students as well" |
| Operations Management | • "It was overall a good experience. Sometimes hard, but that will happen in the real world as well"<br>• "I found that it was slightly hard to communicate with the classes of other university as we were unable to share too much or gather all the information we needed as there was confidentiality issues. I understand that it is like this in the work force but found it difficult to get all the information they had gathered to help us with our parts"<br>• "It was an interesting experience, I will say that. I think if we were able to come together with the other classes more in the beginning of the semester that would have been a lot of help. To be honest I don't really know what the Ag engineering class is really doing other then got a list of what they needed. For the marketing class they got some basic numbers for us but that was about it, or maybe I am just not reading between the lines or we just aren't supposed to fully know what they are doing."<br>• "I had fun, most problems came from my own classmates, rather than the other classes" |

Students acknowledged complexity of the collaborative project and in general had positive attitude about the project. Most of student concerns are attributed to ambiguity of each class's responsibilities, responsiveness, and timely communication from partnering teams, and delays in launching the project. Other notable factors were difficulties in remote communications and scheduling, related to the impact of the Covid-19 pandemic.

## Discussion

Based on the experience of practical implementation of the multidisciplinary curricula integration the research team concluded the framework and its potential to effectively promote students multidisciplinary skills and prepare students for their career in industry is viable. However, there are several challenges that need to be addressed to sustain the approach and provide better experiences for students and instructors, while achieving the ultimate goal of the project.

First, communications in the multidisciplinary context pose a very unique and critical problem. The different disciplines often use the same or similar words to mean different things. Education and training have not included other disciplines leaving students with little real knowledge of what other disciplines do and how they add to product development. The lack of knowledge and understanding may lead to microaggression (Metinyurt, Haynes-Baratz, & Bond, 2021) which can harden the silo walls making interdisciplinary work more difficult. Instructors have to be more proactive in helping teams to develop an attitude of 'how can I work with other discipline groups' rather than 'you are with me or against me (with my group or against my group).'

Another challenge would be for instructors is how to find the right balance between the amount of instruction to direct to students' work in multidisciplinary teams versus providing more opportunities for discussions and freedom to make decisions on their own. Students may feel insecure with higher level of ambiguity, which complex problems pose for the interdisciplinary teams. This is necessary for development of the multidisciplinary teamwork skills but can contribute to students' higher level of stress resulting in dissatisfaction.

There are also several organizational challenges such as scheduling and coordination of work of different classes, especially in the multi-university format. External factors cannot be discounted as well. Thus, the Covid-19 pandemic impacted students' attitudes and it was a major challenge to engage and motivate students for active participation in the project. Students felt overwhelmed in general and were not able to meet in person to collaborate on the project.

Despite the challenges, the first-year results are promising and inspiring to continue work in this direction, to improve instructional and organizational approaches, and to sustain the initiative.

## Summary

The three-class integrated curriculum was designed and implemented in Fall 2020. The curriculum included course activities and student learning outcomes for each individual class (core subject), along with the integrated multidisciplinary course project to achieve the student learning outcome for their multidisciplinary collaboration skills. Data were collected and analyzed to evaluate student performance and progress, their attitudes and satisfaction.

To work effectively in an interdisciplinary environment, students must improve soft skills, which include communications, management, leadership, and collaboration. These areas currently are addressed by university core curriculums, but often lack context to a work environment. Collaboration and teamwork are emphasized in the Capstone courses and various lab courses, however they often involve students from the same discipline and fail to address multidisciplinary collaborative context.

The developed and implemented teaching framework to promote multidisciplinary student collaboration has demonstrated promising results with required improvements identified for further implementation. The first year results will serve as a baseline to assess improvements in the following offering of the courses and the multidisciplinary project.

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# Building an On-Campus Food Bank as a Service-Learning Teaching Lab

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## Abstract

To assist with reducing food insecurity across a college campus, a student-run food bank was created to efficiently collect, manage, and distribute donated food and hygiene items. This operation serves as an experiential and service-learning lab to support undergraduate coursework while supporting student-facing food pantries across campus. The lab is designed to simulate a fully functioning distribution center to provide experiential learning for students to master real-world warehouse and distribution center operations and technology. Students are exposed to the full range of warehouse processes, including receiving (of donated food and hygiene items), barcode labeling, putaway into addressed storage locations, storage technologies, scanner-assisted order picking, unitizing, RFID tagged shipping containers, and inventory control techniques. To further enhance experiential and service-learning, the incorporation of warehouse management system software was added along with the application of total quality management concepts and techniques. The results of having students work in a hands-on, real-world service-learning lab includes increased student knowledge, awareness of warehouse and distribution center practices, and mastering technologies that will allow for smoother transition into the ever-growing commercial e-commerce world.

*Keywords*: Experiential learning, Learning labs, Service-learning, Technology, Warehouse

## Building a Service-Learning Technology Teaching Lab

Active and experiential learning are important pedagogical factors in preparing undergraduate students to enter the fast-paced, knowledge-worker workforce which awaits them upon graduation. Textbooks and case studies with lecture-based pedagogy provide conceptual knowledge transfer but are not always able to engage students or facilitate diverse learning styles. Graduates will be better positioned to enter industry through a pedagogy which provides foundational principles enhanced by active/experiential learning to apply those principles (Untener, Mott, & Jones, 2015).

This paper discusses taking technology-related active/experiential learning into a STEM-related application through the creation of a service-learning lab, via establishment of a student-run food bank to store, manage and distribute food donations to help reduce food insecurity on a college campus. Food insecurity is an issue affecting anywhere from 14% to 59% of college students nationwide (Daugherty, Birnbaum, & Clark, 2019). The Food Bank of Central and Eastern North Carolina (Food Bank CENC) identified 145,000 people in their service region as food insecure, and a 2018 East Carolina University (ECU) survey revealed 39% of students expressed food insecurity (Norwood, 2018).

In response, the ECU Purple Pantry was established in 2018 through a partnership with the Food Bank CENC to serve the campus population. However, lacking the storage space, infrastructure, and expertise to manage food inventory, the university's Collegiate Recovery Community Coordinator reached out to the Industrial Distribution and Logistics (IDIS) degree program within the Department of Technology Systems. IDIS then conceptualized a food bank as a technology lab for an existing Warehousing and Materials Handling course. This collaboration between social science and technology motivated university administration to support the establishment of a student-run, service-learning, technology-rich distribution center (DC) which allows a steady supply of food donations to reach students while simultaneously supporting curriculum.

## Learning Theories

Geringer et al. (2009) summarized key benefits of service-learning: academic outcomes, career development, personal growth, and civic responsibility. The key is to relate service work to course content, then intertwine the activity with reflection-type assignments to discover the meanings of the service experience. It offers students the opportunity to apply and integrate classroom theories in real-life settings as they work on community projects (Geringer, Stratemeyer, Canton & Rice, 2009).

Experiential Learning

The Kolb cycle develops experiential learning theory by establishing four stages needed for effective experiential learning: 1) concrete experiences, 2) reflective observation, 3) abstract conceptualization, and 4) active experimentation (Akella, 2010). The experiential learning described herein is attained through active management of a functioning DC using warehouse management system (WMS) software and automatic identification and data capture (AIDC) technology. The use of commercial (technology) applications provides a "more realistic and relevant context for the presentation of critical management concepts" (Sweeney, Campbell, & Mundy, 2010). Additionally, after students are trained on the warehouse processes, they are challenged to use quality assurance tools to develop new methods and improve efficiency.

Service-learning

The American Association of Community Colleges (AACC) defines service-learning as the combination of community service and classroom instruction, with a focus on critical, reflective thinking as well as personal and civic responsibility (Gottlieb and Gibson, 2006). The National Commission on Service-learning defines service-learning as a "teaching and learning approach that integrates community service with academic study to enrich learning, teach civic responsibility, and strengthen communities" (Fiske, 2002). Fiske (2002) noted service-learning assists in fostering academic success, increasing student involvement within the community, enhancing the student's motivation to learn, and decreasing dropout rates. This type of pedagogy usually engages students in community-based projects or volunteer work (Wang and Fuller, 2020).

Wang and Calvano (2018) found student learning outcomes are highly and significantly associated with the student's perception of the four learning stages within service-learning courses: 1) preparation, 2) action, 3) reflection, and 4) demonstration. When students perceived higher levels of the four stages of the cycle, they tend to have more positive outcomes, such as academic learning, career development, personal growth, and civic responsibility (Wang and Calvano, 2018). Service-learning also enhances student personal growth and behavioral learning, along with increased course valuation and an increased understanding of course content (Macias et. al., 2019).

## Designing the Service-Learning Lab "Food Bank"

Conceptualized in the summer of 2018, the fall 2018 semester began with a white paper summarizing the goals and benefits of creating a service-learning lab for the IDIS degree program. The goal was to simulate

a fully functioning distribution center, practicing all fundamental warehouse operations and inventory control techniques, aided by real-world technology applications. The 2019 spring semester completed negotiations with administration and acquisition of lab space and then funding through university fees. Appendix A shows the final hardware and software budget, including specifications, source, and cost.

The 2019 fall semester began with conceptualization of the storage spaces and facility layout (see Figure 1) development of a warehouse address system, and the learning curve for the WMS and AIDC equipment and software. Except for the pallet racks, the physical labor to set up the facility was faculty managed but student performed. Student participation in the manual aspects of forming the lab space created an awareness of food insecurity for students and administrators while starting student ownership of the DC. Concurrently, labs were developed for the Warehousing and Material Handling course which were implemented in the spring of 2020. Food donations began with the fall 2019 homecoming football game and by Thanksgiving, a functioning operation was in place, albeit with processes still in the "beta-test" phase.

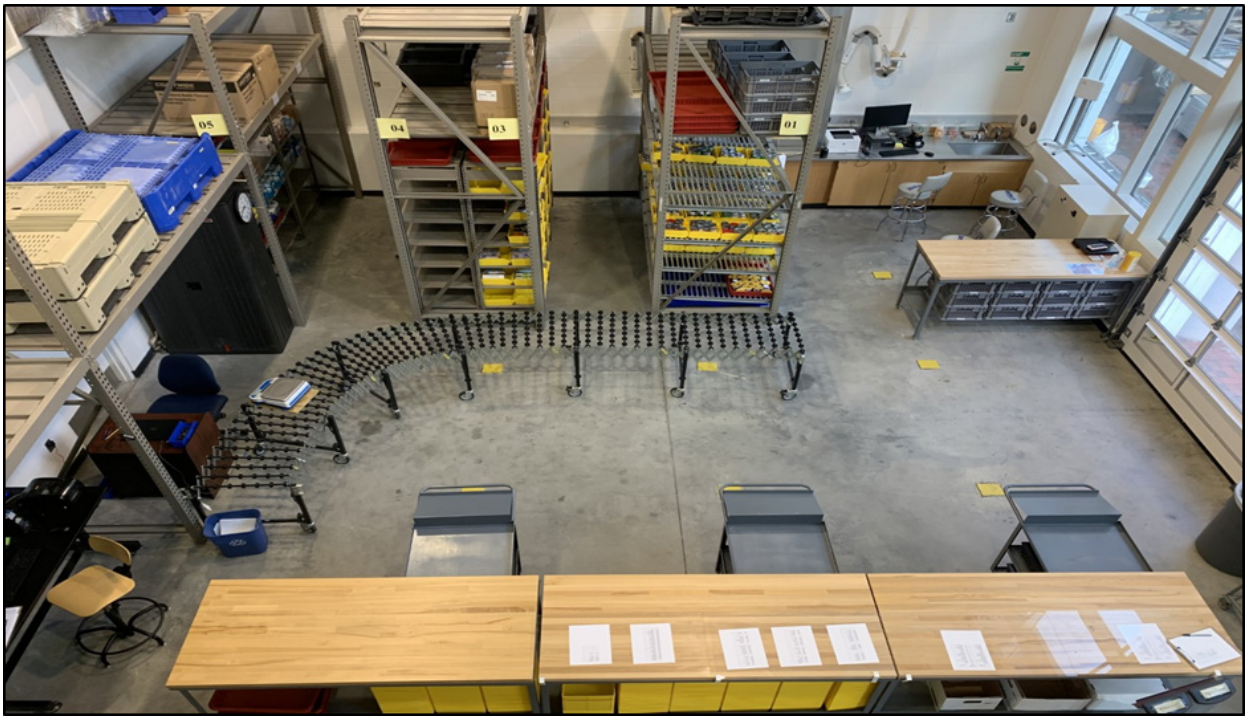


**Figure 1**. Overhead view of the service-learning lab

Physical structure

The physical infrastructure uses approximately 1,200 $ft^2$ of floor space, 100 addressable storage slots capable of storing approximately 4,000 pounds of food in fast-pick areas and 2,000 pounds in reserve storage

locations. Lab clear height is over 20' to allow use of pallet racks and demonstrate forklift applications. The single overhead dock door serves as the shipping and receiving bay, with a clockwise product flow starting from the lower-right corner.

Technology and Software

WMS are information technology software the rely on identification of warehouse storage locations and individual inventory items/containers. The system tracks quantity and location of inventory, facilitating fundamental warehouse operations. Transactional data subsequently allows the user to perform higher level analysis to improve storage and order picking efficiency. The challenge in operating a food bank with a WMS is that commercial/standard WMS software is designed to process inbound material which comes with some type of standardized identification, labeling and packaging. Typical food donations are the opposite, arriving in un-sorted bulk, with a wide variety of type, manufacturer, and sizes.

The technology infrastructure used employs an off-the-shelf WMS software from WASP Barcode Technologies along with Zebra Radio Frequency Identification (RFID) enabled barcode printers and scanners. Manual data entries are minimized via use of bar code technology, with scanning of part numbers and storage locations during putaway and order picking. As processes are executed, the WMS creates required documentation to support a full learning experience for distribution center operations.

TracerPlus mobile software allows applications to be created for the Zebra MC3390R and the Wasp HC1 handheld AIDC devices. The application aids in data collection by simplifying and validating scanned information. TracerPlus was selected as it has many sample applications which are easily modified for specific functions and easily allows captured data to be transferred into Excel for analysis and reports.

During warehouse operations, data is transmitted to and from the mobile devices via Bluetooth. The Windows Mobile Device Center is required on the desktop computer for interfacing with Windows OS mobile devices. Android mobile devices can be connected to the desktop via Bluetooth without the use of additional software or add-ons. An RFID application is used to assign a serial number, printed, and encoded onto an RFID barcode label, to each returnable shipping container. Label design, encoding, and printing utilizes Bartender software from Seagull Scientific. RFID data capture uses an application built with TracerPlus.

Warehouse Operations

*Receiving* operations are supported by transfer carts, plastic totes, sorting tables, a barcode printer and weigh-count scale. Incoming food donations are reviewed for expiration date and pre-sorted into large plastic

totes by one of fifteen unique commodity codes. Donations are then separated into one of two different sizes of plastic totes by the 180 different product codes. A barcode printer creates a label to identify the product tote, which is then weighed to determine the amount of the donation. A barcode scanner completes the receiving operation by confirming receipt to the WMS.

*Putaway* processes utilize a flexible skate-wheel conveyor to transfer labeled totes to the storage racks. A random storage methodology is used to maximize space utilization and demonstrate utility of a WMS.

*Storage* hardware includes pallet racks, static shelves, and gravity flow racks. There are 92 uniquely identifiable fast-pick storage locations, with capacity for 450 plastic totes containing food donations. Storage is zoned for fast-pick and reserve. A rolling ladder is required for access to reserve storage. Not included in the material handling list is also collapsible dunnage and a man-aboard reach-type forklift.

*Order picking* utilizes barcode scanners to record selected food totes and their location. Product is transferred via the skate-wheel conveyor or order-picking carts depending on the lab learning objectives.

*Sortation and unitizing* of picked product sortation are simulated by manually transferring food from the storage totes to customer-facing returnable containers. Returnable containers have RFID-enable barcodes to assist in tracking and management.

*Shipping* utilizes food-grade pallets to stage orders for shipping, which is accomplished with the aid of university transit vehicles/students.

**Integrating Experiential and Service-Learning into Curriculum**

Curriculum was developed to touch on multiple courses within the Department of Technology Systems. While the primary IDIS course is Warehousing and Material Handling, the lab also contributes learning outcomes for modules in Enterprise Resource Planning (SAP based), Transportation Logistics, and Distributor Sales and Branch Management. Further, industrial technology degree programs will utilize the lab and data for courses in Quality Assurance concepts, and Engineering for Food Safety and Sanitation. The lab is also working with an Advanced Manufacturing Systems course to integrate robotic material handling.

Students are introduced to the hands-on coursework in-person and participate weekly in the service-learning lab to master all warehouse processes of receiving through shipping. Students master concepts within separate learning modules for material handling, technology, and warehouse operations. Material handling includes conveyor systems, gravity flow racks, static shelving, bin and cart picking, cycle counting,

warehouse layout, and pickup and delivery scheduling. Understanding and mastering warehouse technologies are vital to putaway and order picking, inventory management and cycle counting. Technology utilizes bar-code scanners, barcode systems, labeling, WMS systems, Bluetooth, and RFID. Warehouse operations utilize full case picking, broken case picking, zone picking, free-form picking, batch picking, single-order picking, packing, and shipping. Supplementary process concepts include electronic creation of pick sheets, packing slips and invoice, plus manual entry for bill of ladings.

**Integrating Continuous Improvement and Quality Assurance**

The application of total quality management concepts and techniques are integrated as complementary academic goals. As this is service learning, the primary principles of total quality management are customer-focus, process-centered improvements, integrated systems and systematic approach, and fact-based decision making. Quality practices are experienced with respect to receiving inspection, inventory control, 5S methods and process improvement activities utilizing data analysis. Throughout their time in the lab, students are challenged to develop critical thinking to improve processes.

The first group of students assisting in the creation of the lab and processes had the most in-depth experience, but faculty acknowledge that future students should be able to gain that experience. To that end, IDIS students will complete projects in a senior-level research course to propose process improvement using lean techniques. The course will also allow students to propose technology and/or material handling advancements for infrastructure upgrades. Data analysis and total quality management techniques using lean and DMAIC will include such things as dock-to-stock and order-picking cycle time. The breadth of the senior level distribution research class will allow this service-learning lab to become self-sustaining with students managing all aspects with faculty support.

<u>Accomplishments and Future Plans</u>

Progress was halted in the 2020 spring semester when the university sent most students home due to the Covid-19 pandemic. Students were asked for feedback at the end of the spring 2020 warehousing course and responded with positively stating *"The lab being a part of the class helped me learn the materials better because you are seeing things hands-on while learning terminology. I feel the instructor provided the materials in a way that allowed students to get hands-on learning to help strengthen knowledge of concepts taught."*

Although plans were developed for a return to campus for the 2020-21 academic year, the campus

again mostly shut down after only two weeks. Lab operations and process improvements continued with graduate student volunteers and faculty, but the undergraduate course aspects were put on hold. That said, since inception, the food bank has managed over 7,800 pounds of donations and the ECU has opened two additional food pantries across campus to serve students.

Once students return to campus without Covid protocols, the next goals are to create videos for online courses to demonstrate the real-world technologies and activities. Future plans include developing tablet-based inventory control and warehouse process applications, plus point-of-sale smartphone apps for real-time communication with students.

## Conclusion

The integration of experiential and service-learning provides students with hands-on learning in a fully functioning distribution center, allowing students to master real-world technology and processes of warehouse and distribution centers. The lab incorporates technology including WMS software and AIDC, along with STEAM-related total quality management concepts and techniques. The WMS used is a low-cost, commercially available, application supported with a Microsoft Excel off-line program. AIDC includes barcode and RFID applications. Barcode design and printing software is used, along with the automated scanner applications. RFID utilizes Gen 2 read-write tags. Both are supported with RFID enabled barcode printers and scanners. A template and budget have been created to allow replication at other college campuses. Ideally, the systems employed will support a service-learning structure that may be modeled and replicated by other universities.

The service-learning lab has increased student knowledge of warehouse and distribution center practices along with an increased awareness and understanding of food insecurity among their peers. This concept can be replicated by other universities looking to support technology-related degree programs while providing a valuable service for the student population.

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Appendix A

| Category | Process | Item | Qty | Cost (Each) | Total Cost | Source | Item Number | Item Description | Web Link |
|---|---|---|---|---|---|---|---|---|---|
| Material Handling | Receiving | Sorting Table | 4 | 400 | 1,600 | Global Industrial | WGB298746 | Little Giant Welded Workbench; 72x30x37.75" | www.globalindustrial.com |
| Material Handling | Receiving | Tote | 314 | 3 | 1,021 | Uline | S-19944Y | Plastic Shelf Bins 11x12x4", Yellow | www.uline.com |
| Material Handling | Receiving | Tote | 36 | 14 | 504 | Global Industrial | WG334105RD | Plastic Dividable Container 22.5x17.5x3" | www.globalindustrial.com |
| Material Handling | Receiving | Tote | 26 | 26 | 676 | Global Industrial | WGB649664 | LEWIS Bins Divider Box DC3050xl; 22.5x17.5x5" | www.globalindustrial.com |
| AIDC | Receiving | Barcode Printer | 1 | 499 | 499 | Wasp Barcode | WPL305 | Barcode Label Printer | www.waspbarcode.com |
| AIDC | Receiving | Barcode Scanner | 1 | 3,079 | 3,079 | Covington Barcoding | MC3390R | Zebra EVM, UHF RFID, Linear Antenna, WLAN 802.11 A/B/G/N/AC, Extended Range 1D/2D Imager (SE4850), 47 Key, Android GMS, 4GB Ram / 32gb ROM | www.covingtonbarcoding.com |
| Material Handling | Putaway | Scale | 1 | 462 | 462 | Global Industrial | WGB2292177 | Adam Equipment CKT 16 Scale | www.globalindustrial.com |
| Material Handling | Putaway | Conveyor | 1 | 1,752 | 1,752 | Global Industrial | 22624024-P | NestaFlex 226 Gravity Conveyor; 24' wide; 24' long | www.globalindustrial.com |
| Material Handling | Storage | Pallet Rack | 3 | 489 | 1,467 | Uline | H-6200 | Two Shelf Pallet Starter Unit 120x48x144" | www.uline.com |
| Material Handling | Storage | Pallet Rack Beams | 8 | 123 | 984 | Uline | H-6236 | Pallet Rack Beam; 120" | www.uline.com |
| Material Handling | Storage | Pallet Rack Decking | 12 | 40 | 480 | Uline | H-6234 | Pallet Rack Wire Decking w/supports 58x48" | www.uline.com |
| Material Handling | Storage | Shelving | 9 | 196 | 1,764 | Uline | H-2884 | Industrial Shelving Unit 36x24x87" | www.uline.com |
| Material Handling | Storage | Shelf | 6 | 27 | 162 | Uline | H3354-ADD | Additional Industrial Shelves 36x24" | www.uline.com |
| Material Handling | Storage | Gravity Flow | 36 | 43 | 1,548 | Lift One | Selectrak | Gravity Flow Rack 12x48" | www.liftone.com |
| Material Handling | Storage | Hangers | 72 | 5 | 353 | Lift One | | Hanger for gravity flow racks | www.liftone.com |
| AIDC | Order Picking | Scanner | 1 | 1,495 | 1,495 | Wasp Barcode | HC1 | Handheld computer with barcode scanner | www.waspbarcode.com |
| Material Handling | Order Picking | Cart | 3 | 396 | 1,188 | Zoro | G4147880 | Order Picking Cart | www.zoro.com |
| Material Handling | Sortation | Tote | 24 | 17 | 398 | Uline | S-20633GR | Mesh-Straight Wall Container 24x16x8.5 Gray | www.uline.com |
| Material Handling | Shipping | Scale | 1 | 129 | 129 | Uline | H-480 | Rubbermaid Digital Utility Scale; 150lb | www.uline.com |
| Material Handling | Shipping | Pallets | 3 | 45 | 135 | Uline | H-7426 | USDA/FDA compliant 4 0x 48" pallet | www.uline.com |
| AIDC | Shipping | Scanner | 1 | 169 | 169 | Uline | H-1670W | USB Barcode Reader; Zebra LS2208 1D Barcode Scanner | www.uline.com |
| | | | | | | | | | |
| Software | Inventory Control | WMS | 1 | 6,995 | 6,995 | Wasp Barcode | InventoryCloud OP | Inventory Cloud On-Premises warehousing software (5 Users) | www.waspbarcode.com |
| Software | Barcode | Programming | 1 | 1,903 | 1,903 | Bartender | Cbbt16-EA3 | Bartender Enterprise License (plus CBBTM-EA3 | www.covingtonbarcoding.c |
| Software | Barcode | API | 5 | 261 | 1,305 | TracerPlus | PTS-2200 | Software to build barcode App | www.tracerplus.com |
| Office | Barcode | Labels | 1 | 149 | 149 | Wasp Barcode | 6.33808E+11 | Label; 2x1" DT, 12 rolls, 2300 per roll; 5" OD; 1' | www.waspbarcode.com |
| Office | Equipment | Workstation | 2 | 533 | 1,066 | Global Industrial | T9F237371A | Mobile Workbench; 60x30" | www.globalindustrial.com |
| Office | Equipment | Computer | 2 | 1,479 | 2,958 | Dell | OptiPlex 5080 Small Form Factor | Intel Core i7-10700 (256G SSD) (16G RAM)(WIN 10 Pro 64bit) | www.dell.com |
| Office | Equipment | Printer | 1 | 299 | 299 | CDW | 5583101 | LaserJet Pro M404dn | www.cdw.com |
| Office | Consumables | Various | | | 1,000 | | | office supplies as needed | |
| | | | Total Investment | | 35,539 | | | | |

# Collaborating with Professional Trade Associations for Student Growth

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## Abstract

It is essential for technology-based degree programs to ensure that graduates are equipped with current industry-focused knowledge. One method to assist faculty is to capitalize on industry trade association data, research, and training aids. An established partnership between the Industrial Distribution and Logistics program at East Carolina University and the Material Handling Equipment Distributors Association (MHEDA) recognized the need for industry-related training for students. A multi-year Plan-Do-Check-Act cycle was implemented to use MHEDA's resources, website, and learning management system. Select modules were chosen for undergraduate students to evaluate for effort level, learning outcomes, and comparison to textbook material. Faculty, in cooperation with MHEDA, narrowed down the offerings to create a cost-effective, higher education degree-specific career track titled the "MHEDA Industrial Distribution Academy of Sales" or simply "MIDAS". The MIDAS track may be integrated into a semester-based curriculum and upon successful completion, MHEDA awards students a formal "certificate of completion" to recognize their accomplishment. The multi-year college-industry initiative is being prepared for roll-out to peer industrial distribution higher education degree programs.

*Keywords:* College-Industry Partnerships, Distributor Sales, LMS, Pedagogy

## Introduction

Technology curriculums must constantly evolve to prepare students to enter the workforce with a solid academic foundation and up-to-date industry-demanded skills and knowledge. Technology-laden industries are constantly changing and advancing, and it is crucial that academic programs stay up to date on industry happenings. Partnerships with industry and professional organizations allow a higher education academic program direct access to the most relevant information and advances so that students are gaining the knowledge and skills required to meet industry needs after graduation. Embedding industry resources and training into academia assists with not only maintaining educational content currency, but it also helps provide career guidance and pathways after graduation.

With a dropout rate of more than 40% of all first-time college students in the United States, offering students a credential, or in this case a certificate of completion (i.e. industry recognition) before graduation assists with addressing dropout and retention rate (Gilbert and Horn, 2020). The Brookings Institution found that 86% of STEM jobs require some type of post-secondary education and with those extra credentials, pay more than other jobs with similar academic requirements (Keniry, 2020). According to a study conducted by Goetz, et. al., there are four main benefits to students enrolled in higher education degree programs that offer "professional designations": "(1) availability of career choice information; (2) improved academic performance; (3) increased marketability and value to prospective employers; and (4) greater preparedness for the workforce" (Goetz, et. al., 2011).

## Professional Organization and University Partnership

The Material Handling Equipment Distributor's Association (MHEDA) was established in 1954 and is a "non-profit trade association dedicated to serving all segments of the material handling business community" (MHEDA, n.d.). The Industrial Distribution and Logistics (IDIS) program at East Carolina University (ECU) and MHEDA work closely together to provide students with the opportunity to attend industry conferences, meet business leaders, and network with students and faculty at peer higher education institutions.

Both IDIS and MHEDA realized the need for industry training directly related to distributor sales positions. To that end, IDIS has a junior-level course titled Distributor Sales and Branch Management. MHEDA has an online learning management system (LMS) for current association members that offers individual courses in what are termed "career tracks", focusing on specific topic modules that include videos, webinars,

and test questions. In 2015, MHEDA approached the IDIS program, seeking to enroll students in a new learning management system (LMS) they were implementing. MHEDA saw this as an opportunity to kick-start their LMS utilization while further developing skills for undergraduates they hoped to hire into entry-level positions upon graduating. The complementary benefit for the IDIS program was to increase student's industry real-world knowledge, assist with career preparedness, and meet university assessment goals that included calls for external certifications/recognition.

A multi-year effort using the Deming Plan-Do-Check-Act cycle was implemented with ECU faculty, students, and the MHEDA team to use their website and courses offered within their LMS. Professors in the IDIS degree program examined the LMS and chose fifteen courses, four webinars, and four career tracks to test. The selection was made based on the overall description and outcome of each topic to ensure they aligned with the Distributor Sales and Branch Management course objectives and outcomes. The ECU-IDIS course has a two-hour per week lab component for "hands-on" experiences, including sales presentation development and role plays. Thus, the goal was to choose LMS courses that supplemented that week's lessons and fit into the lab activities.

Seniors that had previously completed the junior-level class were selected to review several MHEDA courses to provide feedback on effort level, alignment to learning outcomes, and comparison to textbook material. Students were given MHEDA LMS accounts and completed a set of courses assigned by faculty. At the conclusion of each, students provided faculty a report of time to completion, notation on a checklist of IDIS program learning objectives comparing LMS content, and free-form text on value-add. The free form was critical since the selected trial-students had already taken the intended IDIS degree course and were considered the program's top-tier students. The underlying input provided key insights on the complementary nature of the material, the amount of repetition and its value added, and an opinion if the LMS video presentations could hold the attention of an undergraduate.

This year-long initiative yielded a preliminary series of MHEDA LMS courses. The process was repeated in 2017 due to an LMS revision, which allowed a second group of select students to repeat the PDCA process. In 2019, work completed and the MHEDA Industrial Distribution Academy of Sales (MIDAS) "career track" was narrowed down to twelve courses that could be aligned with each week's lesson and lab. The final LMS courses chosen include customer service, leadership, negotiating, selling skills, supervision,

finance for non-financial employees, how to sell with questions, managing an enterprise account, the customer care experience, voicemail techniques to get calls returned, inside sales 101, and how to crush price objections. It was determined that the overall cost was over $1,000 per student, but with the help of MHEDA, the fee was discounted to $49 per student. MHEDA then built the MIDAS career track directly into their LMS. Finally, a MHEDA Industrial Distribution Academy of Sales (MIDAS) Certificate of Completion was created. Students that score a 70% or better on each MIDAS course as well as a cumulative final exam earn the "Certificate of Completion" from MHEDA, shown in Figure 1. In addition to providing current industry training, the program offers students a credential they could earn before graduation to add to their resume. Students that earned a 70% or better on each were awarded a digital MHEDA Industrial Distribution Academy of Sales Certificate of Completion sent directly from MHEDA to print and add the credential to their resumes.


**Figure 1**. MHEDA Recognition Certificate Template

## Pilot Program

The MHEDA Industrial Distribution Academy of Sales Certificate of Completion was offered for the first time in the fall semester of 2020 to all students in Distributor Sales and Branch Management. The pilot group was comprised of thirty-nine undergraduate students that were primarily IDIS juniors. This was essentially a self-selection process as the students had simply signed up for the IDIS distributor sales class as part of the regular curriculum requirements. The MIDAS content was added to the course, and they were notified it was a first-time roll out. In the beginning of the semester, students were able to create a free MHEDA mem-

bership account, purchase the MIDAS Career Track, and access all materials within the MHEDA website. Each course provided students with relevant content to match the week's Distributor Sales and Branch Management topic, offering visual/audio media and embedded quiz questions to test each student's knowledge at various points during delivery. MIDAS courses were assigned a weekly due date, and students had unlimited attempts on each as comprehension rather than a first-time pass rate was the goal. The LMS allowed the professor the ability to view scores for each student, allowing manual transfer into the ECU gradebook for record-keeping.

Due to time limitations and scheduling conflicts in the pandemic shortened semester, only eight of 12 courses plus the comprehensive final exam were completed by the pilot group. Table 1 summarizes the results, showing that 94% of students completed all eight LMS courses with a 70% or better and 95% of students completed the comprehensive final exam with a 70% or better.

**Table 1**: LMS Course Results

| Rating | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Superior (≥ 90%) | 32 | 18 | 22 | 20 | 38 | 13 | 20 | 23 |
| Satisfactory (70%-89%) | 2 | 17 | 12 | 15 | 0 | 21 | 12 | 13 |
| Below Expectations (60% – 69%) | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 1 |
| No Significant Achievement (< 60%) | 4 | 3 | 4 | 3 | 0 | 2 | 5 | 1 |
| % of Samples Rated Satisfactory or Above | 89% | 92% | 89% | 92% | 100% | 89% | 84% | 95% |

At the end of the semester, students were asked to provide feedback on their experiences with the LMS and MIDAS via an anonymous, free-form questionnaire. The overall opinion of students was positive and reinforced the knowledge gained in the classroom through real-world industry training. The following is a sample of responses:

> *"I did like them! I thought they did a great job, especially with touching on every little detail of areas we as students might not think of, such as dealing with customers and employees on an emotional level. We hit quite literally every topic as it pertains to business and what to expect and I thought the labs did a good job of showing us what to honestly prepare for."*

> *"I thought the labs were very informative and I feel like I learned a lot. Especially when I would retake the quizzes if I did not understand the content, it helped instill the concepts in my head. I thought this information was very applicable and easy to understand. I liked that each lab had something different rather than the same thing every time."*

*"Overall, I enjoyed the labs. Once you really sit down and actually do them, they provide a lot of good information for all things sales. Great content, the videos aren't too long, and the quizzes help to reenforce the information."*

*"I liked the topics the most. I truly felt like I gained more knowledge about the real world of the industry in those labs than I did in any other course. The other courses we take are important to develop different skills, but these labs made it much more understandable."*

*"I do not know if it is something that you could change but maybe just give a reminder to not wait until the last minute to start doing the labs. When I first logged on, I did not know what to expect and did not realize that some of the lab assignments required a bit of time to complete. That's more so on us as students but a little reminder would not hurt."*

Post Pilot Program Adjustments

Based on what the professor experienced throughout the semester and the student feedback, a few adjustments were planned for the fall 2021 delivery. While it was felt the LMS system was easy to work with, a more detailed explanation document and instruction tutorial was provided to assist students with getting started. The semester's plan was adjusted so that all twelve courses could be administered, and they were reordered so that they were better coordinated with each week's academic lesson. To assist with grading and record-keeping, students were required to submit to the ECU LMS a screen-capture of their course test scores, making sure to capture the date and time on their computer screen to verify it against the MHEDA LMS gradebook.

## Distance Education Course Design and Conclusion

Technology-based academic programs must continually evolve to meet the needs of industry so that students are prepared to enter the workforce with the knowledge and skills required by employers. Collaboration with industry trade associations is an excellent method to maintain curriculum currency in ever-evolving technology degree programs. Providing undergraduate students with real-world industry expertise can be supported by partnering with an industry or professional organization, utilizing their resources to stay current on industry trends, innovations, and happenings.

In Felder and Silverman's learning style model, a student can be an active learner or a reflective learner, a sensing learner or intuitive learner, a visual learner or verbal learner, and/or a sequential learner or global learner (Cheng & Chau, 2016). According to the study conducted by Cheng & Chau, student learning and stu-

dent participation are linked through information access, interactive learning, networked learning, and materials development (Cheng & Chau, 2016). In the study it is important to note that the authors found a correlation between each type of learning style and online learning. The Distributor Sales and Branch Management course along with MIDAS were designed so that most learning styles were accommodated through various forms and medias including lectures and lecture notes, real-time immediate feedback, videos, reflection exercises, various forms of assessments, collaboration, discussion boards, and written and oral presentations.

The industry-partnership model presented can by utilized by any degree-program to establish an industry-based collaborative learning system for students. Detailed instructions and tutorials on getting started are being developed to create a replication model by other industrial degree programs. This work-in-progress summary paper will be updated based on the fall 2021 student data.

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# Developing a Digital Twin for Highly Flexible Learning Modalities

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## Abstract

From the outset of the Covid-19 pandemic, course modalities across most campuses were thrown into a state of chaos and constant flux. For many institutions, the only modality option that could be offered to students was fully online, remote learning – an option perhaps never before attempted, especially with lab-oriented courses that traditionally rely on Face-to-Face (F2F) due to the need for highly specialized equipment and resources. For courses that focus on topics such as automation and robotics, the need for a highly flexible set of tools that could be used to support any teaching modality became critically evident. This paper describes how ABB's RobotStudio software was deployed in two undergraduate robotics integration-related courses, an introductory course and capstone course, to generate a digital twin, a nearly identical virtual replica of the physical workstation. This enabled authentic learning experiences such as handling physics-enabled objects, working with kinematically constrained mechanisms, "virtual wiring" of I/O signals, and more in a purely virtual environment. Initial observations of this experience suggest the digital twin model is beneficial in supporting teaching and learning, especially in times of rapidly shifting or uncertain course modalities.

**Keywords:** *digital twin, robot simulation, engineering technology, remote learning*

## Introduction

Due to the global COVID-19 pandemic, university course modalities were often shifted online without warning or preparation in 2020. Adjusting face-to-face, lab-oriented courses to 100% online courses often created many challenges for students and faculty, thus an immediate need arose for deploying course content that is highly flexible regardless of mode of instruction (modality). Keeping in line with the authors' philosophy of providing students with authentic learning experiences, the need arose for developing course materials that engaged students in real-world, applied activities that served to facilitate learning geared towards future career skills, even if those skills were to be taught via simulation tools (Lombardi & Oblinger, 2007). The purpose of this paper is to provide an overview of how the digital twin concept was utilized in two such cases to achieve flexibility in the rapid shift between course learning modalities. The authors will present a sample workflow, discuss observations, and provide suggestions for future study and development.

## Background

Courses taught in the field of integrated manufacturing and robotics and automation often involve the use of specialized tools, equipment, and resources required within a physical space. Recent advances in technology, coupled with the larger scope of "industry 4.0", a strategic shift towards digitalization practices in manufacturing, for example (Tao, et al., 2019), has brought the concept of the digital twin to the forefront. Kritzinger et al. (2018) contend that a key enabler of the digital twin is the ability to provide simulation by virtually mirroring a product or system to gain as close to the same result as the physical counterpart as possible. In addition to visual and aesthetic features, a fully integrated robotics system digital twin may include features such as signals integration, physics-enabled objects, and algorithm-based events that allow the user to interact with the station in both the virtual and physical setting simultaneously in some circumstances (Schluse & Rossman, 2016). The overarching goal of the authors, who acted as co-teaching faculty, was to replicate learning activities and projects that normally occurred face-to-face (F2F) in a remote learning environment as closely as possible.

The digital twin concept was implemented in two core (required) undergraduate Engineering Technology program courses: 1) an introductory robotics systems integration course and 2) a senior-level capstone course, with the intent of providing students with a means to work on learning activities and laboratory projects remotely and without the need to connect to a physical robot workstation, yet still be able to develop

programs and solutions that could be transferred between an online physical robot-based workstation (station) and an offline digital design environment with minimal effort in the transfer process. To achieve this goal, students used ABB's RobotStudio software with the purpose of creating programs and solutions suitable for the types of robots that are present in the physical space of the University laboratory: an ABB model IRB 140 or model IRB 2600 industrial robot.

*The Digital Twin as a Laboratory Station Replica*

The use of a digital twin in the following cases served mainly as a virtual replica to the physical laboratory station. Course faculty sought to provide students with as similar of an authentic learning experience as possible despite the lack of physical station components and systems. The initial work to create the digital twin was carefully done by faculty members so that the most important elements of the station would be included and would mirror both the look and functionality of the real-world counterparts. The first element added to the virtual station was the  virtual controller replica (provided within software), which provided students with the same controller functionality, signals, drive systems, and other options as a real robot and allowed for future transfer of programs and routines between offline and online stations. Next, the manipulator (robot) was added. ABB provides digital replicas of each robot within their RobotStudio software CAD library, which contain kinematically-constrained assembly linkages, providing accurate virtual representations of range of motion and degrees of freedom. To further customize the station, RobotStudio software allows users to import user-generated CAD geometry. This is a critical aspect of developing the digital twin, as it allows users to include necessary objects in their precise locations within the station.

The digital twin does not need to include minor details of a station if they are not essential to the execution of the robot task. For example, models of common wiring and tubing were omitted, while virtual sensors and signals remained active in the digital station, as they were important to the solution of the station. Recent advances in RobotStudio have allowed for the implementation of physics-based properties with geometry. This means that "dynamic physics" can be enabled to modify the behavior of geometry so that it behaves like it would in the real-world. For example, if a physics-enabled part (geometry) is dropped on a surface that is similarly physics-enabled, it may bounce, roll, or slide against that object.  Users may attach geometric objects to the robot wrist to define custom end-of-arm-tooling (EOAT). Depending on the functionality of the EOAT, mechanisms may be created by defining kinematically-constrained joints, mimicking the

motion and control capability of real tooling. Beyond replicating the look and feel of the workstation, faculty implemented "virtual wiring" into the design, which allowed students the ability to experience working with simulated inputs and outputs, which may typically be provided by an external device such as a programmable logic controller (PLC). This was possible through RobotStudio's *I/O simulator* and *Station Logic* tools, which act as a virtual wiring between the robot control system and external signals, even if those external signals are purely representational. All programming written to control the robot was identical in the virtual and physical controllers. While the preferred method of programming may be text-based, the robot can be jogged and programmed via teach mode using a virtual pendant that mirrors the physically attached teach-in pendant as well, giving students a hands-on feel.

In some cases, faculty wanted to limit what students had control over in the design process so that they could focus on a specific task. For example, in the case of the introductory level course project, students were to only focus on the material handling work of the robot. In the physical version of the workstation, a separate system delivered parts to the incoming part queue in which the robot picked from. This was demonstrated in the digital twin by randomly "spawning" parts directly at the queue. Since the programming of this logic was beyond the scope of the course but was essential to the functionality of the simulated system, the faculty designers applied password protection to the *Smart Component* where it was created.

## Discussion

*Applications*

In the introductory course, students utilized the digital twin as a virtual replica throughout their laboratory exercises, culminating with a course project. The course project was a "block sorter station", which was based closely off a real project that students would have completed if they were working at the robot station face-to-face (see Figure 1). The project workflow required students to develop a program to retrieve a sliding block from a queue of blocks that ranged between three lengths, determine the length of the block using sensor signals, then place the block on the worktable based on a preselected stacking routine by the station operator. Students did not create any of the virtual replica objects or actions (e.g., spawning of or physics of the blocks, kinematics within the EOAT gripper mechanism, signal I/O, etc.), rather, they were tasked with using these elements in a manner that reflected real robot movements and operations. Once the program was

ready to run, a virtual operator window that allowed for human interaction and a simulated I/O panel could be deployed which allowed for automatic simulation and monitoring of the robot task (see Figure 2).

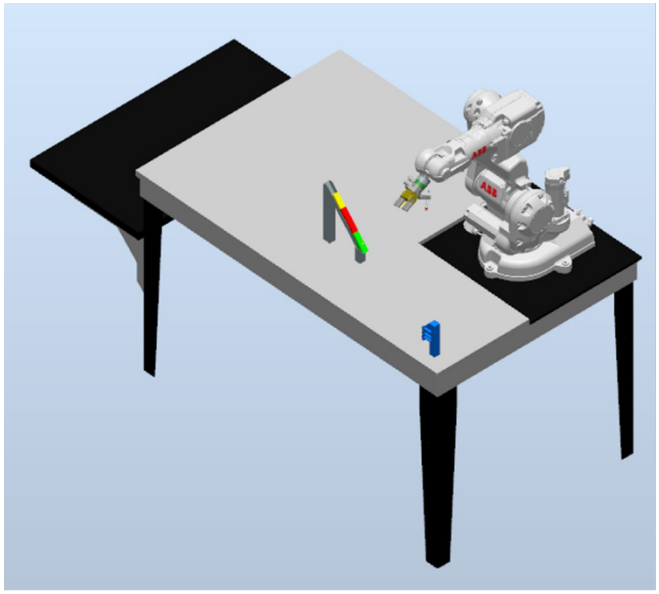

Figure 1. Virtual Replica Station of "Block Sorter"

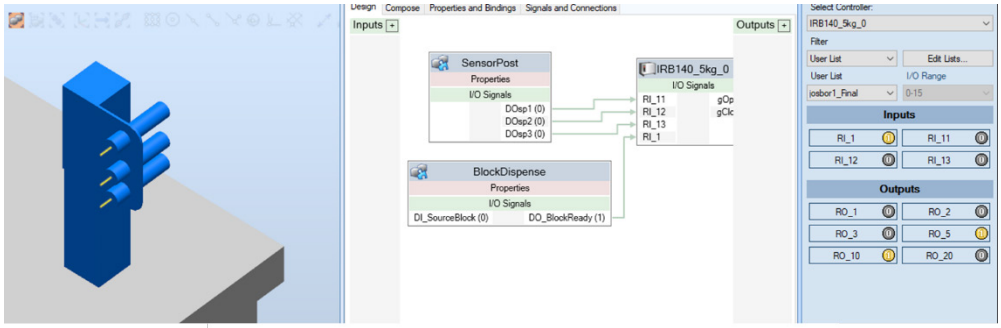


Figure 2. Simulated I/O and Virtual Station Wiring

Students in the capstone course created their own virtual replica systems, using many of the techniques previously mentioned to create a bin-picking and assembly solution. This included full station development by importing and arranging CAD geometry of all workcell entities and creating an EOAT gripper mechanism that mimicked the motion and physical properties of the real tooling and parts (See Figure 3). The robotics workcell in the physical lab space is pre-arranged and does not typically require students to build the station from individual elements, other than the occasional rearranging or repositioning of entities such as a convey-or. Students were required to design and digitally-assemble the "fingers" of the gripper tool, which would be attached to a commercially available base (See Figure 4). Additionally, while working in the digital twin station, students designed equivalent station logic in their virtual replica to detect when parts were present to be picked and to determine whether a part was in the EOAT grip using virtual sensor and wiring techniques.

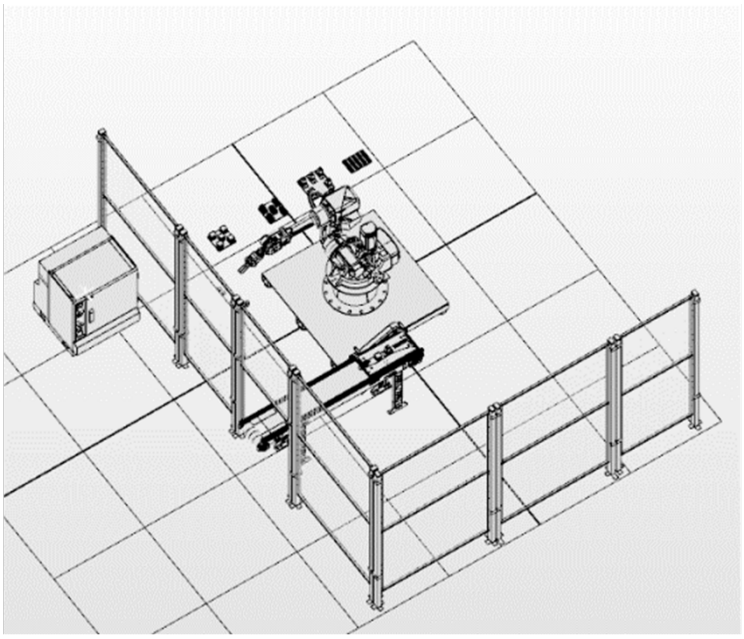

Figure 3. Student-created Virtual Replica of capstone Course Robotics Workcell

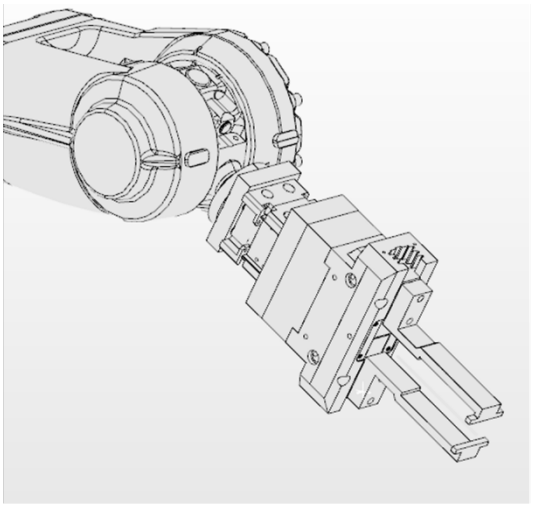

Figure 4. Student-created Digital Model of "Fingers" Designed to Work with Commercially Available Base for Gripper EOAT

*Observations*

As students worked within the virtual environment, several informal observations were made by the co-faculty teaching the course and were discussed in comparison to what has been previously observed while running the physical robot. A recurring topic of discussion was the methods in which students approached programming and testing of their solutions. In the virtual space, there is added flexibility in how programs are tested, because a simulation can simply be reset to the original state with the click of a button. This may

include resetting I/O signals to default states simultaneously as well. In the physical station, operators would often need to reset and/or adjust a variety of individual, yet interdependent entities to return to a default starting condition. Use of the virtual station as a primary teaching tool revealed a deeper perspective of how students understand coordinate systems, especially in work object creation and manipulation, an essential concept that is often difficult for novice robot programmers at physical robot stations. A possible advantage to completing design work in the virtual station was that it provided students with specific visual indicators (e.g. directional arrows and axis lines) that allow students to see how those systems are constructed and may relate to one another (See Figure 5). In addition to supporting coordinate system understanding, locating targets and moving the robot to precise locations to avoid collisions or to ensure that parts are handled in an optimal manner (e.g. considerations of center of gravity when lifting, verifying the tool is properly oriented, verifying the opening/closing of the gripper, etc.) can be done in the virtual environment with little to no risk to the physical equipment, saving time and protecting both the equipment and operator once the program has been transferred to the physical control. In the completely remote learning modality scenario, students and faculty used online meeting tools (i.e. Zoom) to share screens and collaborate in real-time in order to facilitate teaching and learning.

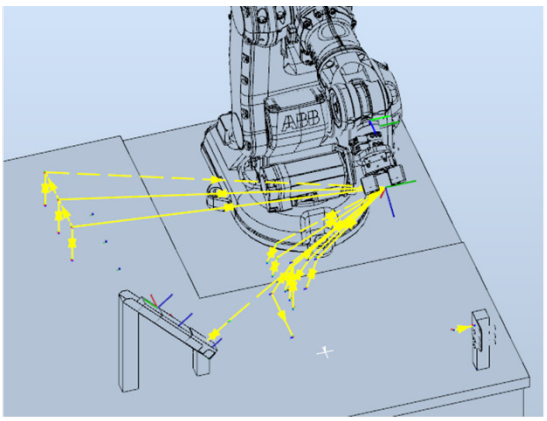

Figure 5. Virtual Representation of Coordinate Systems and Path Moves

Observations from the capstone course initially revealed that some students appeared to struggle with the virtual build and configuration of the complete robotics workcell. This is likely not a unique problem to the digital twin, rather, reveals a potential issue in either environment since the commissioning (building and configuration) of a workcell is not something typically done in the course while F2F. If any problems arose, students were provided online support in the form of collaborative online meetings and just-in-time, on-de-

mand written and video tutorials, which included additional training on how to implement various simulation-specific events in the virtual space. This support was a direct result of the learning modality, but could be archived for potential later use to supplement any other modalities, such as traditional face-to-face instruction. While simulated environments such as RobotStudio endeavor to serve as "What-You-See-Is-What-You-Get" (WYSIWYG), no simulated environment is perfectly identical to its physical counterpart, therefore some level of verification and rectification is often needed. Common areas of correction include adjustment of Tool Center Point (TCP) and locating and/or calibrating work object markers once in the physical station.

## Conclusions and Further Research

Ultimately, the use of a virtual replica as a digital twin appeared to serve as a highly useful and potentially flexible model for working within the constraints of rapidly shifting modality requirements of the COVID-era classroom, especially during times of remote-only options. As COVID restrictions have changed, resulting largely in a return to the physical lab for all, current and future curriculum is undergoing revision to include the digital twin as a virtual replica and beyond model. To explore this concept beyond robotics systems, one of the authors of this paper is examining how an introductory electronics course, for example, might benefit from a virtual replica station along with using traditional, physical tools and resources. The authors of this paper plan to continue to explore teaching and learning using this model in the future, regardless of the course modality, noting that the overall experience has appeared initially beneficial to their teaching and learning practices and may provide a viable gateway to authentic learning experiences via simulation.

There were many digital twin design concepts and capabilities within RobotStudio that were not fully integrated into the virtual replica due to lack of time and scope of the coursework that may provide additional opportunities in development, understanding, and collaboration. For example, the software has eXtended Reality (XR) capabilities, specifically in Augmented Reality (AR) and Virtual Reality (VR). Students could potentially visualize a working robot in a real space via AR or use the same gestures required to move, jog, and program the robot tasks in-person through VR manipulation instead (see Chang, et al., 2020). The authors of this paper are also interested in further studying the use of collaborative robotics (cobots) in this format.

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# Teaching Sensor Application in Robotic Education

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## Abstract

This paper investigates introducing students in robotics class to a newly created custom-built Arduino lab with two different formats on separate weeks to develop the delivery format of understanding sensors. The frame wasn't exclusive to displaying sensors, but it also engaged students in the custom-built experiments and spiked their interest. Lab sheets exercises were created with questionnaires and performance requirements assigned on each lab aimed to raise students' curiosity and tackle their critical and creative thinking. The labs weren't exclusive to displaying sensor applications, but they also covered the coding behind developing these experiments to electronic parts and the logic involved in building the designs. Labs were divided into two formats. The first format was focused on the students observing already-made experiments on different stations that display sensor functionality along with the design code and additional questions regarding each station. The second format was to engage the students in building one of the stations given instructions, assistance when needed, and bonus questions. Due to Arduino's popularity, more research is needed regarding its teaching benefits and effectiveness in various fields.

*Keywords:* hands-on learning, developing delivery formats.

## Introduction and background

Robotics System has been a core course within the engineering technology program for many years. Students in the robotics course obtain hands-on learning on the programming and operation of robotics arms. These arms also include embedding sensors, whose functions have historically been addressed via lectures, pictures, and videos. These methods were not always effective. Izabela, Tomasz, & Piotr (2019) note the challenges in teaching programming by making it more engaging and less theoretical. They also call out a need for new, unique, and creative methods of teaching programming as the current traditional methods of code writing are no longer attractive to students.

In our pursuit to create a unique and attractive learning experience for students, we chose Arduino. Arduino was selected because it is open-source, relatively cheap, reliable, easy to learn, and has plenty of valuable resources. Ong Sing Ling and Jill Ling Pei Wah (2019) state that "Arduino allows the students to experiment with new educational processes, experiences and ways of learning." Izabela et al. (2019) stated that due to Arduino's popularity, there are plenty of guides and resources on the internet that students can research to help them with their assignments. Not only does this relieves the instructor, but it also teaches the student important technological literacy and critical skills such as researching, formulating questions, processing and analyzing data and ideas.

Izabela et al. (2019) used Arduino to build a custom application programming interface that contains an LED, graphic display, ultrasonic sensor, and more. Students did not have any background in electronics. The basic functionality of the board was explained so that students could work on their projects. The authors emphasize the importance of introducing interactive media into teaching and the importance of visualization. They also improve students' motivation and creativity. They also showed that this method was well received by nearly 80% of the students. The results were very effective as almost 75% of the participants wished to continue their Computer Science education using Arduino.

Pech & Novák (2018) discuss using the Arduino platform in teaching programming. The project aimed to be a teaching and methodological material that will serve as a pedagogical guide. Their reason for selecting the Arduino platform is that it provided real-life interactions which motivated the students. In addition, it was a crucial tool to learning and experimenting with electronic connections. They offered a sketched teaching

plan of the basics and had a final project for each step as an application to the taught basics for learning retention and student assessment.

Arduino is not just exclusive to programming learning. It can have a wide variety of uses and applications, as Oprea (2018) adopted the Arduino into Physics education. The author illustrated how two Arduino-based projects were conceived and implemented in the Physics class. The first project was for the stable levitation of a ferromagnetic object actively controlled through an infrared barrier. The second project was for the building of a light-based musical instrument. The author pointed these Arduino-based projects triggered a very high degree of interest among the students and improved their scientific research skills.

Arduino can be a critical tool in STEM fields. Ling, O. S., & Wah, J.L. (2019) conducted a study to examine whether Arduino, as a teaching and learning tool, can increase students' interest in STEM programs to counter the disinterest and low STEM student enrollment numbers in Malaysia. Students were introduced to Arduino, and tutorials were provided. They supplied several reference web pages, introductory videos, and sample projects for the students. The students were introduced to the basic programming concepts and syntaxes, such as sequence, selection, looping, function, and variables. The Authors also provided multiple survey questionnaires to get informative feedback, showing that Arduino made STEM learning more enjoyable and increased students' motivation to enroll in STEM programs.

Udvaros & Végh (2020) illustrate how programming microcontrollers (such as Arduino) can make the teaching of programming more enjoyable. They noted that visual (lights) and sound effects help capture students' attention. Their main focus was on making programming learning attractive. The authors recommended Arduino's starter kit for beginner students. Although they used a different microcontroller (ATMega 32u4 ), after learning the basics, they claimed it was easy to switch to other controllers like the Arduino. They used the Arduino IDE program for writing the codes, which displays Arduino's versatility.

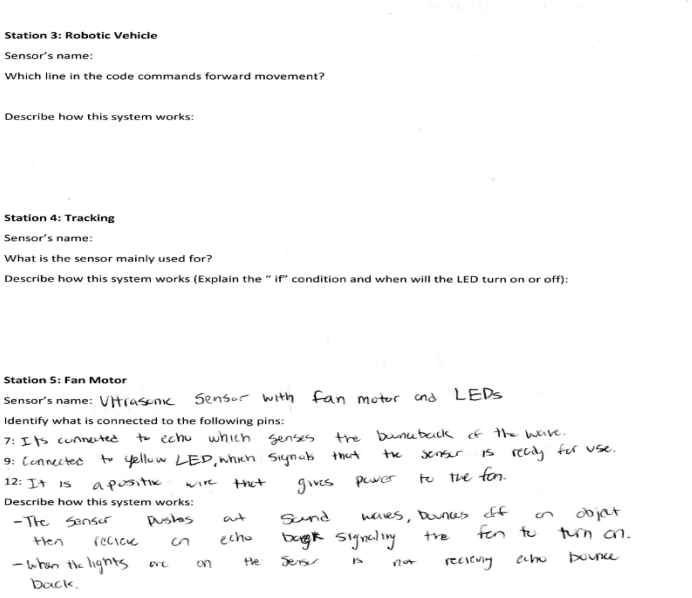
Mellodge & Russell (2013) experimented with introducing students to fundamental computing and engineering concepts in a highly visual and easy-to-use environment. Students used the Arduino platform to design interactive systems. They also noted that participatory or project-based learning methods could equalize the difficulty level for different types of students. They mention these projects that value interactivity, cooperation, and collaboration can result in more students feeling more comfortable and engaged, which involves female and minority students who have been less accessible to computer science and engineering.

Hoffer (2012) discusses how Arduino educational trainers were created along with assignments to introduce fundamental concepts in math and science to the students. While at the same time allowing them to mimic real-world applications of using the C programming language (which is Arduino's programming language as well). This technology is not available in many of their STEM high school classrooms, which shows that Arduino can fill the gaps to improve educational needs, such as in our case.

## Methodology

In the Robotics and Automated Systems class, a 2-week hands-on learning Arduino lab experience was added, providing for multiple hands-on sensor application experiments so that students could observe and interact with the sensors via specifically defined experiments.

For the first week Lab, six different Arduino experiments were created and were laid out in 6 different stations displayed across the lab. All Arduino codes were original and uniquely written to serve the purpose of displaying sensors' functionality. Students were provided a lab sheet that contained targeted questions regarding each sensor and station, a portion of which is shown below:



**Station 3: Robotic Vehicle**
Sensor's name:
Which line in the code commands forward movement?

Describe how this system works:

**Station 4: Tracking**
Sensor's name:
What is the sensor mainly used for?
Describe how this system works (Explain the " if" condition and when will the LED turn on or off):

**Station 5: Fan Motor**
Sensor's name: Ultrasonic Sensor with fan motor and LEDs
Identify what is connected to the following pins:
7: It is connected to echo which senses the bounceback of the wave.
9: Connected to yellow LED, which signals that the sensor is ready for use.
12: It is a positive wire that gives power to the fan.
Describe how this system works:
- The sensor pushes out sound waves, bounces off an object then recieve an echo back signaling the fan to turn on.
- When the lights are on the sensor is not recieving echo bounce back.

*Figure 1 An example of a lab sheet page*

Each station was labeled and provided a hardcopy of the code used in its respective Arduino processor. Sensors used were: Ultrasonic sensors (with multiple usages), HC-SR501 PIR Motion sensor, Limit switch

and button switch sensors, Line Track sensor, and Temperature and Humidity sensor. After students were finished with the first Arduino lab, the second lab was introduced to them the following week.

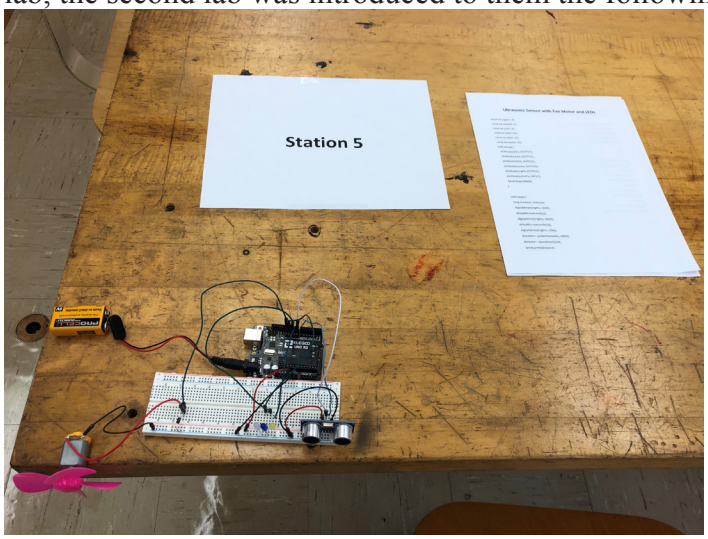



*Figure 2 Using Ultrasonic sensor in station 5 labeled "Fan Motor" with hardcopy of the code provided on the right*

For the second lab, students were given a sheet with instructions to:

1- Upload a given code to the Arduino microprocessor through the Lab's PC and pay attention to procedures
2- Start collecting required parts to build a given project themselves.
3- Follow instructions to connections.

The project was the same as "Fan Motor" from station 5 of the previous week, as shown in Figure 2. This way, students experienced how the station was created and did not just observe it as a display.
Some challenging electronics questions were placed as a bonus in the lab sheet. The aim was to challenge students' ability to research while gaining more information about the electronic parts used.

Students were divided into small groups; assistance was available whenever needed. After a group signals that they were done, an evaluation occurs. The assessment began with checking if the experiment worked and then tracing the connections. Feedback and evaluation from the students were obtained as well.

To create practical step-by-step instructions for the students to understand the steps taken and have a clear visual representation, circuit design programs were used, such as Fritzing. This program allowed us to display pin connections, wires, components used, and other functions accurately. Every required step in the students' lab sheet provided a visual illustration to avoid confusion and acted as a reference while working with the experiments. An example of these student instructions:

## Connecting the Liquid-crystal display (LCD) to the Arduino

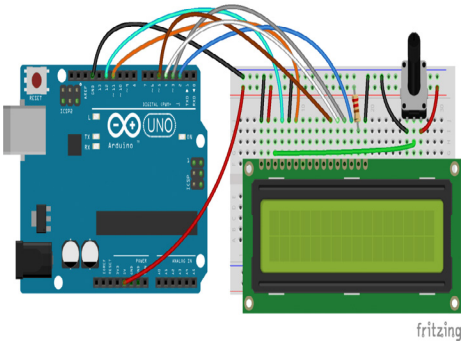



*Figure 3 Arduino and LCD connections*

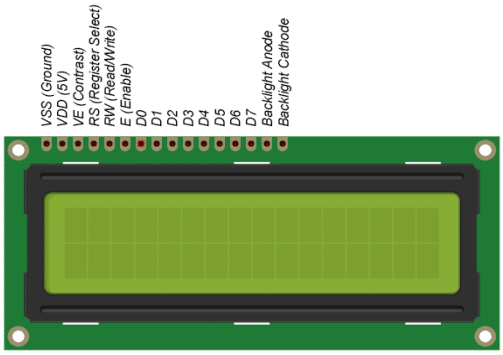



*Figure 4 LCD Pins Definitions*

The resistor, as shown in Figure 3, sets the backlight brightness. A typical value is 220 Ohms, but other values will work too. Smaller resistors will make the backlight brighter. The potentiometer is used to adjust the screen contrast.

## Connecting a Servo with the Arduino


*Figure 5 left: Connecting a Servo Motor with an Arduino through a breadboard. Right: Connecting a servo directly to Arduino*

Connecting a Servo can be done through a breadboard, as shown in Figure 5 when dealing with a multiple component experiment, or directly to the Arduino when dealing with only the servo or minimal components. It is similar whether it is a positional rotational servo (moves by angle definition) or continuous rotational servo. The black wire often indicates a ground (GND) connection, the red wire is the positive (5V) connection, and the yellow/white is the data connection connected to the pin defined by the programmer in the program/code.

## Discussion and Conclusion

Student feedback on the lab experience was solicited and assessed. Students indicated that the hands-on experiences helped them understand the materials well. It will be an excellent start to adopt more robotic projects involving sensors applications for students. Students found the labs to be entertaining while being informative. They also showed interest in using Arduino again in the future. Factors that were noted to play a role; students' interaction with the experiments, clear visual representation, freedom to explore and modify the experiments, assistance availability, and clear instructions. Further studies might be required to show the long-term benefits of adopting these methodologies in class.

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# Drivers of Customer Satisfaction: Sentiment Analysis and Topic Modeling of Online Hotel Reviews

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## Abstract

Online hotel reviews provide an excellent way to help customers' decision-making process, and the customer feedback also contains their experiences on the hotel's services and products. Still, most customers and hotel managers do not have the patience or time to read all the comments shown online. This paper aims to utilize sentiment analysis and text mining approaches to identify hidden information that impacts consumer satisfaction from unstructured data. In this paper, the data is collected from www.hotels.com. More than 280,000 customer reviews are collected from 160 hotels in Las Vegas city. We research the factors that influence customer satisfaction between diverse types of customers. We apply the sentiment analysis via Vader and LIWC and build logistic models to predict customer ratings. Then, we use the Latent Dirichlet Allocation (LDA) model as the topic modeling method to summarize and explore the topics from the online reviews. The findings show that customers are willing to rate a higher review score to a higher hotel price and star class. A longer time staying in the same hotel follows a higher review score. The length of a review has a negative relationship with the review score. We find that the customers with different traveling purposes would pay attention to different aspects of a hotel for the topic modeling. This study can be extended further to discover customer requirements and their satisfaction with the geography-specific and purpose-specific hotels.

*Keywords:* customer satisfaction, sentiment analysis, topic modeling, online hotel reviews

## Introduction

Online review plays an increasingly essential role in our daily life, especially in the service industry, such as the hotel and catering industry, tourism, etc. When people choose a service, they always check the provider's online reviews to ensure that the services meet customers' requirements. Online review is also crucial in hotel booking websites. Word of mouth (WOM) would increase the confidence of the consumer's decision on the hotel selection (Teng et al., 2017; Berezina et al., 2012). The online review scores have a significant impact on the consumer's selection. The efficacy of online reviews as a good proxy for overall WOM is well-established. They are shown to influence consumers' purchasing decisions (Zhu and Zhang, 2010; Teng et al., 2017) and customer satisfaction (Berezina et al., 2012; Berezina et al., 2015). Exploring the factors that impact consumer satisfaction would be an excellent way to help hotels perform better in a competitive and dynamic environment.

This paper focuses on a full online review dataset from a tourist city, Las Vegas, and five types of traveling purposes. Sentiment analysis catches the emotional attitude and calculates the sentiment scores in terms of the semantic orientation associated with the constituents of a text. It is helpful for customers and hotel managers to build a predictive model with the basic hotel information combined with scores from sentiment analysis (Graebner, 2012). Moreover, topic modeling provides a simple and powerful way to analyze massive unstructured data and identify the main topics concerned. We compare these topics between different types of traveling purposes to determine if their requirements are different. Motivated by the above observation, this paper is concerned with the following research questions: (1) What are the relationships between the review score and various factors? (2) What are the drivers of customer satisfaction from online hotel reviews? (3) What are the differences in topics between different traveling purposes?

In summary, this paper aims to examine the factors that impact customer satisfaction by building regression models and comparing the different concerned topics between different traveling purposes by using topic modeling. This study could allow us to identify the factors affecting hotel review scores from the basic hotel information and sentiment scores. Also, the topic modeling provides us with the main topics that customers are concerned about and the difference between different types of traveling purposes.

## Literature Review

This section briefly summarizes the related work on online hotel reviews and the drivers of customer satisfaction, and research gap and contributions.

### Online hotel reviews

It becomes an essential area of research for researchers to explain the helpfulness of online reviews in information systems, operation management, and marketing (Pelsmacker, Tilburg, and Holthof, 2018; Chatterjee, 2019). Online hotel reviews help consumers make better decisions on hotel selection. It also plays a part in encouraging service providers to provide better services. Many studies have researched the helpfulness of online hotel reviews and the affecting factors of customer satisfaction. Chatterjee (2019) focused on explaining and predicting the helpfulness of online hotel reviews based on quantitative and qualitative information generated from a review. The author found that text polarity and title polarity have a negative relationship with review helpfulness. Besides, reviews with negative emotions and low arousals, such as disgust and sadness, have higher helpfulness scores. The length of the review has a negative impact on review helpfulness.

### Research Gaps and Contributions

Previous research provides no adequate insight into predicting regression models of customer satisfaction related to basic hotel information and sentiment scores. Besides, they are rarely focused on the different traveling purposes of the customers. This is the central gap in the literature that we aim to fill. Therefore, we focus on the basic hotel information and sentiment analysis and utilize the topic modeling for different traveling purposes. We collect the basic hotel information, such as a hotel's star class, hotel room price, and days to stay. We use VADER to calculate the sentiment scores, including positive, neutral, negative, and compound scores. We apply LIWC software to get several results, for example, word count, the authenticity of each comment, and words per sentence. These factors might have a relationship with the rating scores. We build regression models to predict the rating score depending on these factors. Meanwhile, we use the LDA model as a tool of topic modeling to compare the results from different groups of customers.

## Hypothesis Development

### Customer satisfaction

Customer satisfaction is a measure of the discrepancy that customers focus on a company's products or services. Customer satisfaction is an important indicator to determine a companies' product and services.

For now, the common way to know customer satisfaction is the online review rating score. This paper uses the review score as customer satisfaction to study the relationships with its related factors.

**Basic hotel information**

We expect the basic information would impact customer satisfaction. Hotel's star class is the most popular system for classifying hotels from 1 to 5 stars. A higher star class means a higher service quality. A positive relationship between customer satisfaction and the hotel's star class should exist; that is, customers would be more satisfied with a higher star class hotel. Normally, it is recognized a higher-star-class hotel provides higher quality service, which affects customer satisfaction and loyalty (Nunkoo, Teeroovengadum, Ringle, & Sunnassee, 2019). Meanwhile, the hotel's room price should also impact the customer's satisfaction. We expect a positive relationship between them, which means a higher room price leads to higher customer satisfaction. Many customers travel to a place staying for 1 or 2 days, they always stay longer, especially in a tourist city. Therefore, the days to stay in a hotel should positively impact the customer's satisfaction. Based on these factors from basic hotel information, the first three hypotheses are listed below:

H1: Customer satisfaction has a positive relationship with the hotel's star class.

H2: Customer satisfaction has a positive relationship with the hotel's room price.

H3: Customer satisfaction has a positive relationship with days to stay.

**Sentiment analysis**

It is important to analyze the customer's online reviews for customers and hotel managers. Sentiment analysis is the process of 'computationally' determining whether a piece of writing is positive, negative, or neutral (AnkitRai01, 2019). In this paper, we use the VADER as a tool to calculate the sentiment scores. We expect there is a positive relationship between sentiment scores and customer satisfaction. Meanwhile, we apply the LIWC to analyze the comments to get related results, including word count, authenticity, and words per sentence. Authenticity is one variable that is analyzed with LIWC. Authenticity scores are meant to detect honest and personal writing (Cohn, Mehl & Pennebaker, 2004). We expect these factors to have a negative relationship with customer satisfaction. An unsatisfied customer might write a longer comment to complain about their experience than a satisfied customer. They are more willing to write unsatisfied details, which means a higher length of a review, lower customer satisfaction (Chatterjee, 2019). We also expect the authen-

ticity of a comment and words per sentence to negatively impact the customer's satisfaction. Based on the factor related to sentiment analysis, we expect the hypotheses below:

H4: Customer satisfaction has a positive relationship with sentiment scores.

H5: Customer satisfaction has a negative relationship with review length.

H6: Customer satisfaction has a negative relationship with authenticity.

H7: Customer satisfaction has a negative relationship with words per sentence.

**Topic modeling**

Another primary purpose of this paper is to identify the main factors that impact customer satisfaction using topic modeling. Then, we compare various groups of traveling purposes. We classify customers into five types of traveling purposes and seek their concerned topics on hotels. We expect the customers from different groups of traveling purpose would have various requirements on customer's satisfaction.

H8: Different groups of customers have different requirements for customer satisfaction.

## Methodology and Data

This study aims to explore the factors that impact consumer satisfaction from the basic hotel information and online hotel reviews. We determine various affecting aspects of consumer satisfaction by building regression models and identifying the difference between different traveling purposes via topic modeling from the unstructured hotel reviews.

**Data**

In our research, we focus on a tourist city, Las Vegas. The data is collected in April 2020. We collect the full online hotel reviews of Las Vegas from www.hotels.com, a leading provider of hotel accommodation worldwide (*Hotels.com*, 2020). The dataset is crawled from more than 170 hotels, including more than 540,000 review records posted from Jan. 2017 to Mar. 2020.

In the raw dataset, there are some reviews without comments or with other languages, for example, Spanish, Portuguese, German, Dutch, etc. We remove these blank records and non-English reviews from the dataset for our research purpose. After we clean the data, we finally use a dataset with 281,799 observations from 169 hotels in Las Vegas.

The dataset contains the hotel's name, price, class-star (Hotel star class, including 1.5-star, 2-star, 2.5-star, 3-star, 3.5-star, 4-star, 4.5-star and 5-star; 5-star meaning best.), individual review score (From 2 to 10,

including 2, 4, 6, 8,10; 2 meaning lowest and 10 meaning highest), review date, review content, and types of traveling purpose (five types of traveling purposes, including family, friend, business, romance, and other).

**Sentiment analysis**

In this paper, we use the document-level sentiment analysis by using VADER to get the sentiment scores. VADER is a lexicon and rule-based sentiment analysis tool which are generally labeled according to their semantic orientation as either positive or negative. Another tool we apply in this research is LIWC. We use three features: word count, the authenticity of each comment, and words per sentence. We combine the sentiment scores and three features from LIWC with the basic hotel information to build regression models to predict customer satisfaction. The variables and their definitions are shown in Table 1.

**Table 1. Variables and definition**

| Variables | Definition |
|---|---|
| *Dependent Variable* | |
| Review score | The rating score by customer |
| *Independent Variable* | |
| Price | Hotel price |
| Star Class | Use number 1-8 to indicate hotel star class as a category variable. Such as 1 represents 1.5-star. |
| Staying Days | How many days the customer stay in the hotel |
| Negative | Sentiment score from VADER |
| Neutral | Sentiment score from VADER |
| Positivew | Sentiment score from VADER |
| Compound | Sentiment score from VADER |
| Review Length | Word count, length of a review |
| Authentic | The authenticity of comment |
| WPS | Word per sentence, how many words in one sentence |

**Regression Model**

Due to our dependent variable being a category variable, we use the logistic regression model in our research. The following Equation (1) is the model of the multinomial logistic regression model:

$$P(Y = i|x, \theta) = \frac{e^{\theta_i^T x}}{\sum_j^K e^{\theta_i^T x}} \quad (1)$$

Then, we transform it into normal forms as described in Equation (2) and Equation (3) below:

$$\ln\left(\frac{P(Review\ Score=i|x)}{P(Review\ Score=Baseline|x)}\right) = \beta 0 + \beta 1 \times Price + \beta 2 \times Star\ Class + \beta 3 \times Staying\ Days + \beta 4 \times Negative + \beta 5 \times Neutral + \beta 6 \times Positive + \beta 7 \times Review\ Length + \beta 8 \times Authentic + \beta 9 \times WPS \quad (2)$$

$$\ln\left(\frac{P(Review\ Score=i|x)}{P(Review\ Score=Baseline|x)}\right) = \beta 0 + \beta 1 \times Price + \beta 2 \times Star\ Class + \beta 3 \times Staying\ Days + \beta 4 \times Compound + \beta 5 \times Review\ Length + \beta 6 \times Authentic + \beta 7 \times WPS \quad (3)$$

$$\ln\left(\frac{P(Review\ Score=4)}{P(Review\ Score=2)}\right) = -0.157 + 0.000 \times Price + 0.127 \times Star\ Class + 0.060 \times$$

**Topic modeling**

In this paper, we utilize the LDA model to explore the main divers that impact the customer's satisfaction. We use the LDA model into four groups (except "Other" group) of traveling purposes and compare the differences between various traveling purposes to determine if customers from a different traveling purpose have different requirements on hotel's services.

## Findings & Discussions

### Descriptive statistics

We list the summary of our dataset and results from VADER and LIWC. Table 2 reports the information of different variables.

**Table 2. Descriptive statistics**

| | N | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Count | 281799 | 43.64 | 52.94 | 1 | 169 |
| Price | 281799 | 113.09 | 124.74 | 31 | 1100 |
| Hotel class star | 281799 | 3.75 | .7 | 1.5 | 5 |
| Star Class | 281799 | 5.49 | 1.39 | 1 | 8 |
| Reviews Score | 281799 | 7.78 | 2.42 | 2 | 10 |
| Reviews date Year | 281799 | 2018.35 | .85 | 2017 | 2020 |
| Staying Days | 281799 | 2.66 | 1.58 | 1 | 28 |
| Negative | 281799 | .05 | .09 | 0 | 1 |
| Neutral | 281799 | .71 | .18 | 0 | 1 |
| Positive | 281799 | .24 | .2 | 0 | 1 |
| Compound | 281799 | .43 | .56 | -1 | 1 |
| Review Length | 281799 | 38.62 | 42.53 | 1 | 325 |
| Authentic | 281799 | 51.37 | 35.89 | 1 | 99 |
| WPS | 281799 | 12.06 | 9.06 | 1 | 313 |

**Correlation Matrix**

We check the correlation matrix and ensure that the variables are not correlated with each other. Table 3 shows the matrix of correlations of the variables we used in this paper.

**Table 3. Matrix of correlations**

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| (1) Price | 1.000 | | | | | | | | | |
| (2) Star Class | -0.021 | 1.000 | | | | | | | | |
| (3) Staying Days | -0.018 | 0.104 | 1.000 | | | | | | | |
| (4) Negative | -0.038 | -0.094 | -0.006 | 1.000 | | | | | | |
| (5) Neutral | -0.042 | -0.074 | 0.049 | 0.024 | 1.000 | | | | | |
| (6) Positive | 0.054 | 0.106 | -0.041 | -0.450 | -0.904 | 1.000 | | | | |
| (7) Compound | 0.056 | 0.119 | 0.016 | -0.687 | -0.411 | 0.661 | 1.000 | | | |
| (8) Review Length | -0.018 | -0.010 | 0.083 | 0.057 | 0.359 | -0.345 | -0.080 | 1.000 | | |
| (9) Authentic | -0.020 | -0.051 | -0.015 | 0.052 | 0.296 | -0.286 | -0.169 | 0.136 | 1.000 | |
| (10) WPS | -0.022 | -0.026 | 0.064 | 0.057 | 0.333 | -0.322 | -0.140 | 0.361 | 0.117 | 1.000 |

**Results of Sentiment analysis**

Table 4 shows the results of the multinomial logistic regression models. In Model (1), we find all the factors are significant at the level of 0.001, except three sentiments, negative, neutral, and positive scores. However, in Model (2), all the variables are significate at 0.001 level. Therefore, we use Model (2) instead of Model (1) to analyze our hypotheses and questions in our research.

**Table 4. Results of the Multinomial Logistic Models**

| | (1)<br>Review Score | (2)<br>Review Score |
|---|---|---|
| 2: | | |
| | (base outcome) | |
| 4: | | |
| Price | 0.000 | 0.000 |
| | (0.572) | (0.551) |
| Star Class | 0.119*** | 0.127*** |
| | (15.432) | (16.525) |
| Staying Days | 0.058*** | 0.060*** |
| | (8.436) | (8.802) |
| Negative | 26.308 | |
| | (0.963) | |
| Neutral | 28.611 | |
| | (1.047) | |
| Positive | 30.717 | |
| | (1.124) | |
| Review Length | -0.002*** | -0.001*** |
| | (-11.743) | (-3.070) |
| Authentic | -0.002*** | -0.001*** |
| | (-7.358) | (-3.584) |
| WPS | -0.006*** | -0.004*** |
| | (-8.083) | (-4.574) |
| Compound | | 0.606*** |
| | | (32.956) |
| _cons | -28.490 | -0.157*** |
| | (-1.043) | (-3.288) |
| 6: | | |
| Price | 0.000*** | 0.000*** |
| | (4.250) | (4.589) |
| Star Class | 0.185*** | 0.202*** |
| | (25.605) | (27.975) |
| Staying Days | 0.114*** | 0.118*** |
| | (17.908) | (18.437) |
| Negative | 13.249 | |
| | (0.521) | |
| Neutral | 17.949 | |
| | (0.706) | |

| | | |
|---|---|---|
| Positive | 24.640 | |
| | (0.970) | |
| Review Length | -0.007*** | -0.005*** |
| | (-38.563) | (-27.677) |
| Authentic | -0.004*** | -0.003*** |
| | (-14.886) | (-10.005) |
| WPS | -0.011*** | -0.005*** |
| | (-13.401) | (-6.118) |
| Compound | | 1.450*** |
| | | (83.326) |
| _cons | -17.506 | 0.200*** |
| | (-0.689) | (4.469) |
| 8: | | |
| Price | 0.001*** | 0.001*** |
| | (11.734) | (12.375) |
| Star Class | 0.297*** | 0.319*** |
| | (40.983) | (43.734) |
| Staying Days | 0.136*** | 0.136*** |
| | (21.449) | (21.086) |
| Negative | 31.147 | |
| | (1.222) | |
| Neutral | 39.252 | |
| | (1.540) | |
| Positive | 51.957** | |
| | (2.039) | |
| Review Length | -0.011*** | -0.015*** |
| | (-61.149) | (-74.853) |
| Authentic | -0.005*** | -0.004*** |
| | (-15.778) | (-15.057) |
| WPS | -0.013*** | -0.011*** |
| | (-15.076) | (-11.881) |
| Compound | | 2.993*** |
| | | (160.687) |
| _cons | -39.433 | 0.153*** |
| | (-1.547) | (3.373) |
| 10: | | |
| Price | 0.002*** | 0.002*** |
| | (20.281) | (20.483) |
| Star Class | 0.543*** | 0.558*** |
| | (72.658) | (74.193) |

| | | |
|---|---|---|
| Staying Days | 0.089*** | 0.079*** |
| | (13.514) | (11.848) |
| Negative | 9.028 | |
| | (0.332) | |
| Neutral | 22.689 | |
| | (0.836) | |
| Positive | 38.090 | |
| | (1.403) | |
| Review Length | -0.013*** | -0.028*** |
| | (-64.259) | (-116.098) |
| Authentic | -0.005*** | -0.005*** |
| | (-15.505) | (-17.289) |
| WPS | -0.010*** | -0.019*** |
| | (-11.325) | (-18.694) |
| Compound | | 4.768*** |
| | | (217.502) |
| _cons | -24.459 | -1.361*** |
| | (-0.901) | (-28.547) |
| N | 281799 | 281799 |
| Pseudo R-square | 0.2059 | 0.2013 |

*** means p<0.001; ** means p<0.01; * means p<0.05; Standard error in parentheses.

We build the multinomial logistic models as follows:

$$\ln\left(\frac{P(Review\ Score=4)}{P(Review\ Score=2)}\right) = -0.157 + 0.000 \times Price + 0.127 \times Star\ Class + 0.060 \times Staying\ Days + 0.606 \times Compound - 0.001 \times Review\ Lengt - 0.001 \times Authentic + 0.004 \times WPS \quad (4)$$

$$\ln\left(\frac{P(Review\ Score=6)}{P(Review\ Score=2)}\right) = 0.200 + 0.000 \times Price + 0.202 \times Star\ Class + 0.118 \times Staying\ Days + 1.450 \times Compound - 0.005 \times Review\ Lengt - 0.003 \times Authentic + 0.005 \times WPS \quad (5)$$

$$\ln\left(\frac{P(Review\ Score=8)}{P(Review\ Score=2)}\right) = 0.153 + 0.001 \times Price + 0.319 \times Star\ Class + 0.136 \times Staying\ Days + 2.993 \times Compound - 0.015 \times Review\ Lengt - 0.004 \times Authentic - 0.011 \times WPS \quad (6)$$

$$\ln\left(\frac{P(Review\ Score=10)}{P(Review\ Score=2)}\right) = -1.361 + 0.002 \times Price + 0.558 \times Star\ Class + 0.079 \times Staying\ Days + 4.768 \times Compound - 0.028 \times Review\ Lengt - 0.005 \times Authentic - 0.019 \times WPS \quad (7)$$

**Table 5. Coefficients and Odd Ratio values of Model (4) to Model (7)**

| | Model (4) | | Model (5) | | Model (6) | | Model (7) | |
|---|---|---|---|---|---|---|---|---|
| Variables | Coeff. | OR | Coeff. | OR | Coeff. | OR | Coeff. | OR |
| Price | 0.000 | 1.000 | 0.000 | 1.000 | 0.001 | 1.001 | 0.002 | 1.002 |
| Star Class | 0.127 | 1.135 | 0.202 | 1.224 | 0.319 | 1.376 | 0.558 | 1.747 |
| Staying Days | 0.060 | 1.062 | 0.118 | 1.125 | 0.136 | 1.146 | 0.079 | 1.082 |
| Compound | 0.606 | 1.833 | 1.450 | 4.263 | 2.993 | 19.945 | 4.768 | 117.684 |
| Review Length | -0.001 | 0.999 | -0.005 | 0.995 | -0.015 | 0.985 | -0.028 | 0.972 |
| Authentic | -0.001 | 0.999 | -0.003 | 0.997 | -0.004 | 0.996 | -0.005 | 0.995 |
| WPS | -0.004 | 0.996 | -0.005 | 0.995 | -0.011 | 0.989 | -0.019 | 0.981 |

Based on Model (4), comparing review scores between 4 points and 2 points, Star Class, Staying Days, and Compound are the three significant factors ($p<0.001$). Then, Review Length, Authentic, and WPS are significant ($p<0.001$). We find these three factors have a very low negative impact on the review score. Price is not significant in Model (4).

Model (5) reports the results of giving a review score of 6 points or 2 points. Price, Star Class, Staying Days, and Compound are the four significant factors ($p<0.001$). We find Price has a low positive effect on the review score. Star Class has a positive impact on choosing a higher score. Meanwhile, Review Length, Authentic, and WPS are negatively significant ($p<0.001$).

We also find a similar effect in Model (6) and Model (7). Price, Star Class, Staying Days, and Compound have significantly positive relationships with customer satisfaction. The same situation exists between 10 points and 2 points in Model (7). Then, Review Length, Authentic, and WPS perform a similar trend of low negative impact on the review score. There are significant and negative impacts on customer satisfaction.

Based on the results above, Table 6 summarizes the level of support for each hypothesis. Compared with grading 2 points, Price, Star Class, and Compound have a significant and positive relationship with customer satisfaction. For Review Length, Authentic, and WPS, there are significant and negative relationships between these factors and customer satisfaction.

**Table 6. Summary of the hypotheses and level of support**

| Hypothesis | Level of Support |
|---|---|
| H1: Customer satisfaction has a positive relationship with the hotel's star class. | Support |
| H2: Customer satisfaction has a positive relationship with the hotel's room price. | Support |
| H3: Customer satisfaction has a positive relationship with days to stay. | Support |
| H4: Customer satisfaction has a positive relationship with sentiment scores. | Partial Support (Support: Compound) |
| H5: Customer satisfaction has a negative relationship with review length. | Support |
| H6: Customer satisfaction has a negative relationship with authenticity. | Support |
| H7: Customer satisfaction has a negative relationship with words per sentence. | Support |

**Results of Topic modeling**

We visualize the ten most common words (shown in Figure 1). These words are "room", "hotel", "stay", "great", "clean", "staff", "nice", "good", "check", and "time". From these words, we can only ensure the customers are talking about hotels, and they are concerned about the room, environment, staff, and time. But this information could not help us identify the detailed aspects of the hotel. Therefore, we utilize the LDA model as a tool of topic modeling to determine the main topics customers are concerned about.

**Figure 1**

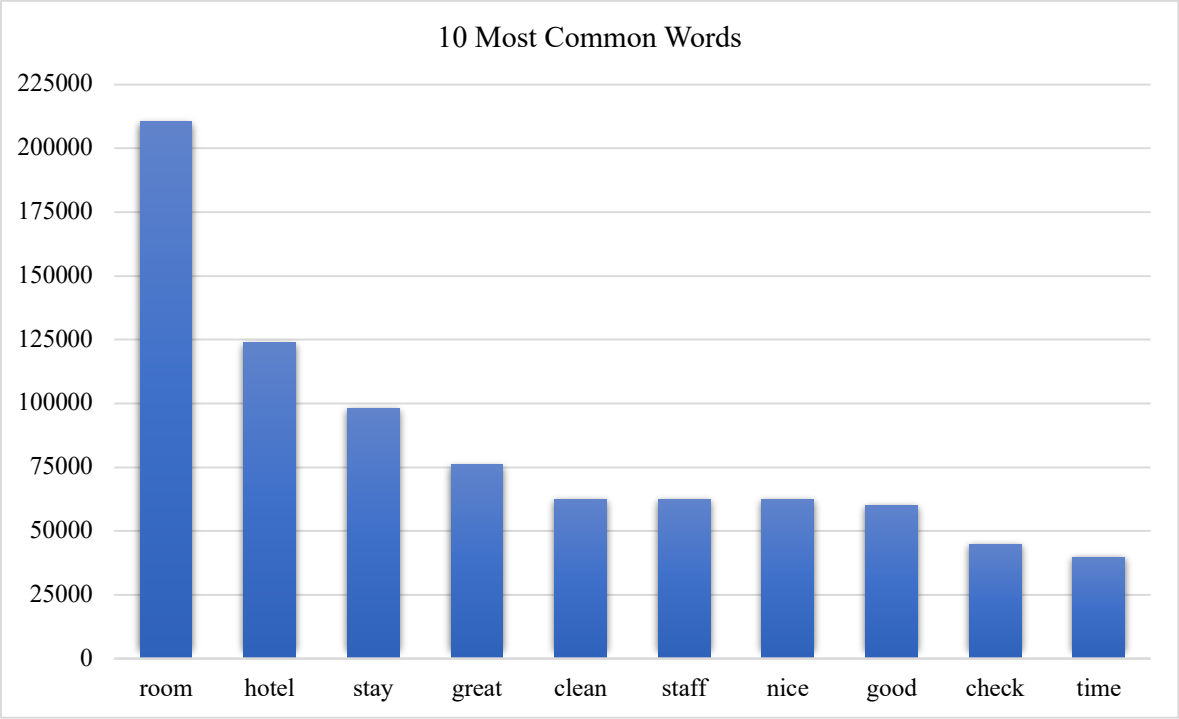


**Figure 1. Ten most common words**

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The LDA model is implemented with the open-source package Gensim (Jelodar et al., 2018). We apply grid search over different numbers of topics to select the optimal model. We classify the customers into five groups, including Romance, Business, Friend, Family, and Other (shown in Table 7). We compare the first four categories. Table 8 to Table 11 show the optimal topics and keywords of each group.

**Table 7. Category and numbers of reviews**

| Category | Numbers of Reviews |
|---|---|
| Romance | 49245 |
| Business | 16967 |
| Friend | 25002 |
| Family | 63550 |
| Other | 127035 |
| Total | 281799 |

**Table 8. Topic modeling results of Romance group**

| Topic 0 | Topic 1 | Topic 2 | Topic 3 | Topic 4 | Topic 5 | Topic 6 | Topic 7 | Topic 8 | Topic 9 |
|---|---|---|---|---|---|---|---|---|---|
| Room/ Bathroom | Location | Staff | Room/ Bed Smell | Resort Fee | Check/ Wait | Recom-mendation | Service | Restaurant/ Casino | Easy Access |
| room | room | staff | room | resort | check | stay | stay | service | parking |
| water | hotel | great | bed | fee | room | great | room | front | walk |
| night | good | friendly | smell | charge | call | place | hotel | desk | easy |
| shower | nice | room | smoke | pay | wait | time | would | customer | access |
| work | great | clean | old | parking | hour | hotel | get | staff | far |
| could | pool | stay | clean | free | day | love | time | check | elevator |
| floor | location | nice | upgrade | extra | long | food | say | help | away |
| bathroom | area | helpful | dirty | pool | take | good | go | key | lot |
| stay | clean | hotel | floor | day | line | back | give | rude | park |
| hotel | close | amazing | need | hotel | early | definitely | never | work | strip |

**Table 9. Topic modeling results of Business group**

| Topic 0 | Topic 1 | Topic 2 | Topic 3 | Topic 4 | Topic 5 | Topic 6 | Topic 7 | Topic 8 | Topic 9 |
|---|---|---|---|---|---|---|---|---|---|
| Room/ Bathroom | Location | Staff | Room/ Bed Smell | Resort Fee | Check/ Wait | Recom-mendation | Service | Restaurant/ Casino | Room Appliance |
| night | great | staff | room | hotel | check | room | time | hotel | room |
| shower | location | clean | bed | pay | room | get | day | nice | need |
| water | good | stay | old | charge | hotel | hotel | stay | casino | stay |
| room | service | nice | smell | room | bad | go | come | room | coffee |
| would | place | room | bathroom | price | wait | stay | back | | upgrade |
| door | stay | friendly | dirty | resort | book | call | work | restaurant | would |
| hot | excellent | good | smoke | fee | service | want | get | good | suite |
| elevator | food | comfortable | floor | parking | say | back | room | love | wonderful |
| sleep | close | property | look | free | line | would | first | pool | night |
| stay | easy | helpful | clean | extra | long | ask | go | walk | want |

**Table 10. Topic modeling results of Friend group**

| Topic 0 | Topic 1 | Topic 2 | Topic 3 | Topic 4 | Topic 5 | Topic 6 | Topic 7 | Topic 8 | Topic 9 |
|---|---|---|---|---|---|---|---|---|---|
| Room/ Bathroom | Location | Staff | Room/ Bed Smell | Resort Fee | Check/ Wait | Recommen-dation | Service | Restauran /Casino | Needs |
| room | room | room | smell | room | check | stay | service | parking | need |
| bathroom | great | service | old | charge | make | definitely | room | area | coffee |
| door | room | love | smell | free | tell | well | work | restaurant | small |
| hot | nice | helpful | also | room | get | nice | call | lot | hotel |
| keep | like | beautiful | dirty | even | day | recommend | ask | great | sleep |
| work | comfortable | excellent | bathroom | drink | hour | overall | first | easy | fridge |
| run | perfect | always | look | extra | wait | really | leave | close | noise |

**Table 11. Topic modeling results of Family group**

| Topic 0 | Topic 1 | Topic 2 | Topic 3 | Topic 4 | Topic 5 | Topic 6 | Topic 7 | Topic 8 | Topic 9 |
|---|---|---|---|---|---|---|---|---|---|
| Room/ Bathroom | Room | Staff/ Location | Room/Bed Smell | Resort Fee/ Appliance | Check/ Wait | Recommendation | Service | Restaurant /Casino | Needs |
| room | room | room | smell | room | check | stay | service | parking | need |
| bathroom | stay | clean | smoke | resort | desk | great | check | free | update |
| shower | night | staff | casino | fee | front | good | customer | hotel | maintain |
| water | hotel | nice | room | charge | wait | hotel | food | breakfast | tower |
| dirty | get | great | area | pay | staff | place | expensive | walk | unique |
| old | bed | friendly | bad | coffee | take | time | fast | lot | property |
| hot | would | hotel | smoking | hotel | call | family | good | casino | old |
| work | day | comfortable | kid | pool | time | would | slow | restaurant | bowl |
| need | go | good | pool | price | hour | price | early | close | upgrade |
| carpet | time | location | hotel | microwave | go | location | excellent | food | accommodate |

**Table 12. Summary of Topics of each Category**

| Category | Romance | Business | Friend | Family |
|---|---|---|---|---|
| **Topic 0** | Room/Bathroom | Room/Bathroom | Room/Bathroom | Room/Bathroom |
| **Topic 1** | Location | Location | Location | Room |
| **Topic 2** | Staff | Staff | Staff | Staff/Location |
| **Topic 3** | Room/Bed Smell | Room/Bed Smell | Room/Bed Smell | Room/Bed Smell |
| **Topic 4** | Resort Fee | Resort Fee | Resort Fee | Resort Fee/Appliance |
| **Topic 5** | Check/Wait | Check/Wait | Check/Wait | Check/Wait |
| **Topic 6** | Recommendation | Recommendation | Recommendation | Recommendation |
| **Topic 7** | Service | Service | Service | Service |
| **Topic 8** | Staff/Service | Restaurant/Casino | Restaurant/ Casino | Restaurant/ Casino |
| **Topic 9** | Easy Access | Room Appliance | Room Environment | Needs |

Based on the results shown in Table 8 to Table 11, we summarize each main topic from the set of ten keywords. Comparing these topics, we find “Room/Bathroom”, “Location”, “Staff”, “Room/Bed Smell”, “Resort Fee”, “Check/Wait”, “Recommendation” and “Service” are the eight main factors for all four groups, that is, all the customers are concerned about these eight aspects of hotels. However, the customers, whose traveling purposes are Business, Friend, Family, pay more attention to “Restaurant/Casino”. Moreover, the Romance group has another main aspect of the hotel, “Easy Access”. The Business and Family groups are more

concerned about "Room Appliance". But the Friend group has an extra aspect, "Room Environment". Even though most of the topics are similar in these four groups of customers, some differences exist. Therefore, the result supports the hypothesis H8 below:

H8: Different groups of customers have different requirements for customer satisfaction.

## Conclusions, Limitations, and Future research

In this research, we focus on analyzing and summarizing the online hotel reviews recorded on the Hotel.com website. This paper utilizes the multinomial logistic regression models to identify the relationships between customer satisfaction and the factors from basic hotel information and corresponding sentiment extraction from the hotel reviews. We find the hotel room price, star class, days to stay in a hotel, and the compound sentiment score has positive and significant relationships with customer satisfaction. The length of the review, authenticity, and word per sentence have negative and significant impacts on customer satisfaction. We also apply the LDA model as the topic modeling method to summarize the topics and explore consumer satisfaction factors. After we compared the four groups of customers with different traveling purposes, "Restaurant/Casino", "Easy Access", and "Room Environment" are the three aspects mentioned by the customers of different traveling purposes.

This research is crucial to the extant literature on hotel customer satisfaction and online hotel review research with the geography-specific and purpose-specific hotels. We believe that it will play an essential role in filling the gap between current knowledge and future research.

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# Employee Burnout and Worklife in the Concrete Industry: Maslach Burnout Inventory and Areas of Worklife Survey

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## Abstract

Concrete industry professionals operate in a fast-paced and high volume niche of the construction industry. Concrete is one of the most commonly used materials in the construction industry. To keep up with demand the work often requires long hours under stressful and dangerous conditions (Alvanchi, Lee, & AbouRizk, 2012; Bowen, Edwards, Lingard, & Cattell, 2014; Leung, Chan, & Olomolaiye, 2008; Maslach & Leiter, 1997; Yang, Li, Song, & Li, 2018). In this study, the researchers used the Maslach Burnout Inventory (MBI) and the Areas of Worklife Survey (AWS) to investigate factors contributing to burnout for professionals in the concrete industry. Two additional questionnaires were developed to record participant demographic information and whether participants were considering leaving their jobs (turnover intentions). A between-subjects multivariate analysis was used to determine whether there were significant differences in the reported roles for respondents, company types (franchise or independently owned), and turnover intentions. The internal consistency was tested for each of the dimensions of the MBI and AWS. Structural equation modeling was applied to analyze the structural relationships between the dimensions of the MBI and AWS. The results showed that respondents experienced heavy workloads and, subsequently, elevated exhaustion, cynicism, and low professional efficacy.

*Author keywords*: Job burnout, concrete industry, construction, workload, exhaustion, cynicism, professional efficacy

## Introduction

Replicated a Burnout and Worklife Context study, previously conducted in 2018 (Avila, Rapp, Dunbar, & Jackson, 2021). The purpose of this research is to replicate the first study conducted in 2018 with newly collected data. In this project, the researchers cleaned data, conducted item level analyses, scored survey instruments, compiled summary statistics, tested research hypotheses, and explored data to answer research questions.

## Background and Theoretical Basis

The construct of burnout it defined as "a prolonged response to chronic emotional and interpersonal stressors on the job, and is defined by the three dimensions of exhaustion, cynicism, and inefficacy" (Maslach, Schaufeli, et al., 2001, p. 397). The World Health Organization includes burnout in its International Statistical Classification of Diseases and Related Health Problems (World Health Organization, 2022). Burnout was first studied in the 1970's by Herbert Freudenberger, a Consulting Psychologist for St. Mark's Free Clinic. Christina Maslach, a preeminent researcher in the field of burnout, began studying burnout shortly after Freudenberger (Maslach, Schaufeli, et al., 2001). Since its inception, burnout transitioned through three phases (a) the Pioneering Phase, (b) the Empirical Phase, and (c) the Expanding Phase.

Developed in the Empirical Phase, the MBI is considered the gold standard for measuring burnout and continues to be the dominant tool to measure burnout (Maslach, Schaufeli, et al., 2012). The instrument consists of 16 total items; five items correspond to the Exhaustion dimension, six items correspond to the Professional Efficacy dimension, and five items correspond to the Cynicism dimension. Participants respond to each item by selecting 0 indicating Never, 1 indicating *A few times a year or less*, 2 indicating *Once a month or less*, 3 indicating *A few times a month*, 4 indicating *Once a week*, 5 indicating *A few times a week*, or 6 indicating *Every day*. Internal reliability for the MBI has been established through Cronbach's alpha values being above .70 for all three dimensions in multiple studies. Validity of the MBI has been demonstrated through the correlation of job conditions, such as job demands and scarcer job resources, that are expected to contribute to burnout. Additionally, scores from the MBI have been correlated to outcomes associated with burnout includ-

ing physical health, work-to-family interference, and turnover. Lastly, scores obtained from the MBI were correlated with data obtained from instruments other than the MBI that were designed to measure constructs similar to burnout (Maslach, Jackson, et al., 2018).

The Areas of Worklife Survey (AWS) was developed to accompany the MBI. The AWS is used to measure employees' perceptions of workplace traits and conditions in order to understand whether these traits and conditions lead to employee engagement or employee burnout. The instrument consists of 28 total items; five items correspond to Workload, four items correspond to Control, four items correspond to Reward, five items correspond to Community, six items correspond to Fairness, and four items correspond to Values. Each of the above listed scales contains positively-worded items and negatively-worded items. Participants respond to each statement by selecting 1 indicating *Strongly disagree*, 2 indicating *Disagree*, 3 indicating *Hard to decide*, 4 indicating *Agree*, or 5 indicating *Strongly agree*. Reliability of the AWS was established through test re-test correlations, which revealed all scales in the AWS indicate strong consistency. Additionally, validity of the AWS was established through examining written comments by participants, with the corresponding AWS measure (Leiter & Maslach, 2011).

This study replicates part of a 2021 published article by Avila, Rapp, Dunbar, and Jackson titled "*Burnout and Worklife in Disaster Restoration: Maslach Burnout Inventory and Areas of Worklife Survey*." Replicating research allows for comparisons to be made with the original study results and can aid in validating/invalidating initial results. Additionally, research indicates replication of studies provides merit in extending understanding of concepts or methods (Creswell & Creswell, 2018; Park, 2004). Researchers cannot generalize results outside of the present, as results are time-bound. Replicating a study at a later time can mitigate this threat to external validity (Creswell & Creswell, 2018). Lastly, replication of research can help control for biases. By replicating the original study, the authors validated the results of the original study and added new findings.

## Research Methods and Results

Respondents provided text-entries to multiple portions of the survey. These qualitative responses were coded. Eight items from the Areas of Worklife Survey were reverse coded. Datapoint labels were created for the SPSS datafile.

A total of 183 persons participated in the survey. Respondents who did not complete the survey ($N = 68$) were removed from the dataset prior to the analyses and were not included in any further quantitative statistical analyses. Specifically, 62 participants did not complete the Maslach Burnout Inventory (MBI), and 68 participants did not complete the Areas of Worklife Survey (AWS). The final usable sample size was $N = 115$.

**Item-level Analyses & Scoring**

Missing values were analyzed on the Maslach Burnout Inventory (MBI) and Areas of Worklife Survey (AWS) to determine if a respondent demonstrated a systematic pattern when missing survey items. Results from the missing value analysis indicated that values were missing completely at random; that is, there was no systematic pattern when skipping items from the survey. Blanks in the survey were replaced with values that were estimated using the expectation maximization algorithm. This was done to keep all respondents who completed the survey, as survey blanks would disqualify and remove the participants from some analyses.

The MBI and AWS were scored according to their testing manuals, respectively. The MBI measures three dimensions of burnout: exhaustion, cynicism, and professional efficacy. Survey participants selected a response on a scale ranging from 0 (*Never*) to 6 (*Every Day*). The AWS measures six dimensions of worklife: workload, control, reward, community, fairness, and values. Respondents indicate their agreement with each survey item on a 5-point scale ranging from 1 (*Strongly Disagree*) to 5 (*Strongly Agree*) with the neutral response of 3 (*Hard to Decide*). For all subscales, the mean score of items for that subscale was calculated and used as a respective subscale score.

Three questions regarding job search status were also included as an index of turnover intentions. Survey respondents were asked to choose between true and false for each question. The turnover intentions index was calculated by taking the sum of the equally-weighted 'true' responses.

**Participant Data**

Survey participants lived in 38 different geographical locations across the U.S. and Canada (i.e., states or provinces). Respondents were primarily male (94%). Participants' age and tenure information was collected as a categorical variable and represented as follows:

**Percent of Participants' Age**

| Category | Percent |
|---|---|
| 18-24 years old | 0.0 |
| 25-34 years old | 10.4 |
| 35-44 years old | 26.1 |
| 45-54 years old | 27.0 |
| 55-64 years old | 31.3 |
| 65 years old and over | 5.2 |

*N* = 115

**Percent of Participants' Tenure with the Employer, Position, And Industry**

| Category | Years worked for the current employer | Years worked in the current position | Years worked in the concrete industry |
|---|---|---|---|
| Less than 2 years | 8.7 | 11.3 | 0.9 |
| 2-5 years | 22.6 | 21.7 | 6.1 |
| 6-10 years | 11.3 | 20.9 | 10.4 |
| 11-15 years | 15.7 | 11.3 | 11.3 |
| 16-20 years | 7.0 | 8.7 | 11.3 |
| 21 or more years | 34.8 | 26.1 | 60.0 |

*N* = 115

Survey participants also reported their current role. Respondent role categories were as follows:

| Role | Percent |
|---|---|
| Sales and marketing | 12.2 |
| Estimating | 5.2 |
| Owner or General Manager | 34.8 |
| Administrative | 26.1 |
| Production Management | 2.6 |
| Field Operations/Technical Services | 19.1 |

*N* = 115

Data on the types of services and/or produces that individuals' current employer provide were also collected. For this question, survey participants could select multiple answers. The type of services and/or produces were as follows:

| Role | Percent |
|---|---|
| Concrete contracting | 52% |
| Specialty concrete contracting | 6% |
| Concrete testing and consulting | 60% |
| Materials | 32% |
| Equipment | 60% |
| Ready mix | 10% |
| Concrete pipe and related products | 14% |
| Concrete block and related products | 28% |
| Precast/prestressed products | 46% |
| Repair and restoration | 24% |
| Other (please specify) | 24% |

*N* = 50

**Summary Statistics**

Mean and standard deviation of the Areas of Worklife Survey (AWS) and Maslach Burnout Inventory (MBI) by subscales are presented in the table below, respectively. The AWS uses a five-point scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The MBI utilizes a seven-point scale ranging from 0 (Never) to 6 (Every Day). Higher scores on workload, control, reward, community, fairness, and values indicate greater levels of worklife issues. Higher scores on exhaustion and cynicism indicate greater levels of burnout, and lower scores on professional efficacy indicate greater levels of burnout.

**Areas of Worklife Survey (AWS)**

| | □ | *M* | *SD* |
|---|---|---|---|
| Workload | 2.96 | 2.57 | 0.80 |
| Control | 3.31 | 3.84 | 0.92 |
| Reward | 3.19 | 3.16 | 0.94 |
| Community | 3.38 | 3.36 | 0.75 |
| Fairness | 2.78 | 3.09 | 0.87 |
| Values | 3.24 | 3.67 | 0.75 |

*N* = 115. □ = Population Mean (Normative Data), *M* = Sample Mean, *SD* = Standard Deviation.

**Maslach Burnout Inventory (MBI)**

| | □ | *M* | *SD* |
|---|---|---|---|
| Exhaustion | 2.26 | 3.30 | 1.47 |
| Cynicism | 1.74 | 2.27 | 1.53 |
| Professional Efficacy | 4.34 | 5.04 | 0.91 |

*N* = 115. □ = Population Mean (Normative Data), *M* = Sample Mean, *SD* = Standard Deviation.

Test manuals of the AWS and MBI provide normative data from the general population. When compared to the normative data, survey participants reported significantly worse workload, $t(114) = -5.29$, $p < .001$, significantly better levels of control, $t(114) = 6.15$, $p < .001$, significantly better fairness, $t(114) = 3.87$, $p < .001$, and significantly better values, $t(114) = 6.16$, $p < .001$. In terms of burnout, participants reported significantly higher levels of exhaustion, $t(114) = 7.57$, $p < .001$, significantly higher levels of cynicism, $t(114) = 3.71$, $p < .001$, and significantly higher levels of professional efficacy, $t(114) = 8.30$, $p < .001$. That is, when compared to the general population, concrete industry professionals have heavier workload, have better control over their work, perceive more fairness at work, and have better person-organization fit. Additionally, persons working in the concrete industry feel more exhausted and more negative attitudes towards work, but they also feel more effective and capable at work.

Correlations between the nine subscale scores (three of the MBI and six of the AWS) were explored. People who reported higher scores in the areas of worklife (e.g., reasonable workload, better control over their work, etc.) reported less frequent feelings of exhaustion and cynicism. On the other hand, higher quality of worklife was associated with higher levels of professional efficacy. See the following table.

**Correlation of the Nine Subscale Scores**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| AWS | | | | | | | | | |
| 1. Workload | 1 | | | | | | | | |
| 2. Control | **.451** | 1 | | | | | | | |
| 3. Reward | **.333** | **.550** | 1 | | | | | | |
| 4. Community | **.338** | **.486** | **.587** | 1 | | | | | |
| 5. Fairness | **.390** | **.595** | **.537** | **.443** | 1 | | | | |
| 6. Values | **.368** | **.537** | **.620** | **.521** | **.687** | 1 | | | |
| MBI | | | | | | | | | |
| 7. Exhaustion | **-.608** | **-.478** | **-.500** | **-.494** | **-.448** | **-.463** | 1 | | |
| 8. Cynicism | **-.429** | **-.539** | **-.545** | **-.372** | **-.527** | **-.522** | **.688** | 1 | |
| 9. Professional Efficacy | .149 | **.485** | **.413** | **.409** | **.336** | **.334** | **-.342** | **-.454** | 1 |

Bolded values are significant at the 0.01 level (2-tailed).

### Analysis 1: Internal Consistency

Cronbach's alpha was estimated using subscale items of the AWS and MBI. All Cronbach's alphas of subscales were above .70. The AWS subscales displayed acceptable levels of internal consistency reliability. The MBI subscales demonstrated good levels of internal consistency reliability. Thus, the AWS and BMI are consistent measures of the areas of worklife and burnout, respectively. See the following table.

| | Number of Items | Cronbach's Alpha |
|---|---|---|
| AWS | | |
| Workload | 5 | .76 |
| Control | 4 | .88 |
| Reward | 4 | .87 |
| Community | 5 | .82 |
| Fairness | 6 | .89 |
| Values | 4 | .81 |
| MBI | | |
| Exhaustion | 5 | .90 |
| Cynicism | 5 | .84 |
| Professional Efficacy | 6 | .81 |

### Analysis 2: Relationship between Areas of Worklife and Burnout

#### Method

In the 2018 study, it was hypothesized that the workload domain of the AWS would be the most important antecedent for predicting burnout. To test the hypothesis, a mediation model was created using subscales of AWS and MBI. The model suggests that an individual's level of six worklife dimensions affects the person's level of exhaustion; then, the level of exhaustion predicts a level of cynicism and professional effi

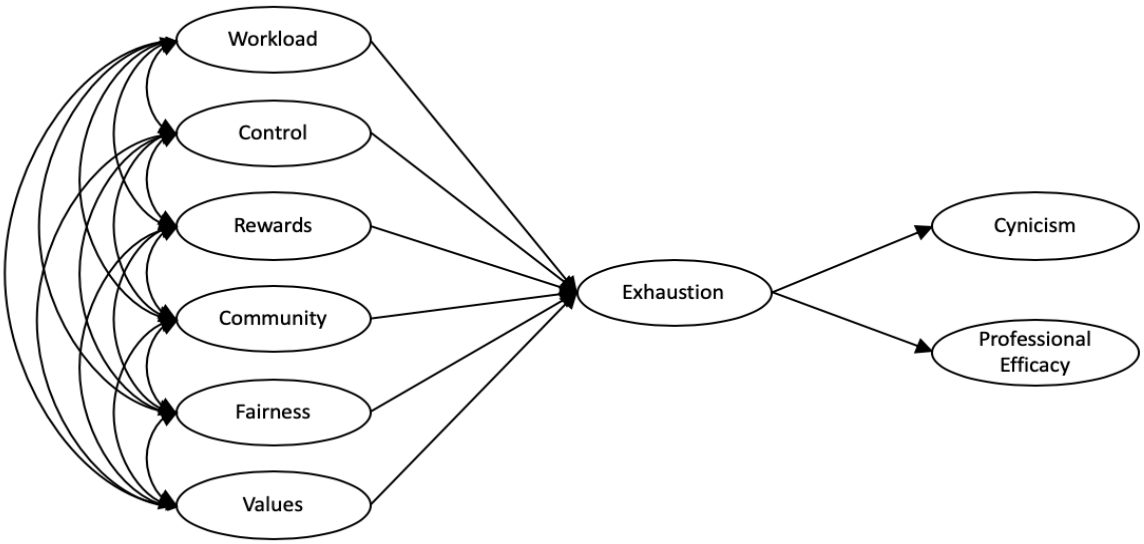


*Figure 2.1*. Mediation Model of Areas of Worklife and Burnout.

A structural equation modeling (SEM) technique was performed through the IBM Analysis of Moment Structure (AMOS, version 25.0.0) statistical package to analyze structural relationships between areas of worklife and burnout. The mediation model from the previous study was adopted and tested with new data, using a maximum likelihood parameter estimation (MLE) method. A total of 115 survey respondents working in the concrete industry were included. Sample demographics are presented in Summary Statistics (on page 4).

**Results**

The chi-square statistic was significant, $c^2(872, N = 115) = 1367.45$, $p < .001$. However, the chi-square to degrees of freedom ratio ($c^2/df = 1.57 < 5$) and Root Mean Square Error of Approximation (RMSEA = .071 < .08) were well inside the recommended limits to show a good fit. The Comparative Fit Index (CFI) fell slightly short on the standard limits that allow the model to be accepted: CFI = .85. It may be worth performing a cross-validation analysis in the future to determine whether the model was well defined.

The workload domain of the AWS was the only significant predictor of the exhaustion domain of the MBI, b = -.49, $p = .011$. Exhaustion significantly predicted cynicism (b = .84, $p < .001$) and professional

efficacy (b = -.37, $p$ = .007). These findings effectively replicate the results of the 2018 study. Further, the observed significant relationships are approximately the same magnitude and direction as those from the 2018 study. See Table 2.1 and Figure 2.2 for results. According to the AMOS analysis guideline[1], observed variables (e.g., survey items) are presented in rectangles, while latent variables and measurement errors are presented in circles.

Table 2.1
*Results of the SEM Analysis*

| Model | □ | *b* | *SE* | *p* |
|---|---|---|---|---|
| Workload ➡ Exhaustion | **-.493** | **-1.720** | .680 | .011 |
| Control ➡ Exhaustion | -.067 | -.088 | .163 | .587 |
| Reward ➡ Exhaustion | -.120 | -.224 | .249 | .368 |
| Community ➡ Exhaustion | -.150 | -.464 | .332 | .162 |
| Fairness ➡ Exhaustion | .095 | .149 | .262 | .570 |
| Values ➡ Exhaustion | -.253 | -.522 | .369 | .158 |
| Exhaustion ➡ Cynicism | **.835** | **1.095** | .137 | < .001 |
| Exhaustion ➡ Professional Efficacy | **-.372** | **-.104** | .038 | .007 |

*Note.* Bolded values are significant at the .05 level (2-tailed). □ = standardized regression coefficients, *b* = unstandardized regression coefficients, *SE* = standard error.

## Interpretation

Similar to the 2018 study, only the level of workload had an impact on burnout. Specifically, heavy workload makes individuals feel more exhausted, and the high level of exhaustion leads to higher cynicism and less professional efficacy. The other areas of worklife (i.e., control, reward, community, fairness, and values) do not show any meaningful relationships with exhaustion.

1 Arbuckle, J. L. (2012). *IBM SPSS Amos 21*. Amos Development Corporation, Chicago, IL. Conceptualization and Measurement (ed. R. L. Schalock), pp. 105–119. American Association on Mental Retardation, Washington, DC.

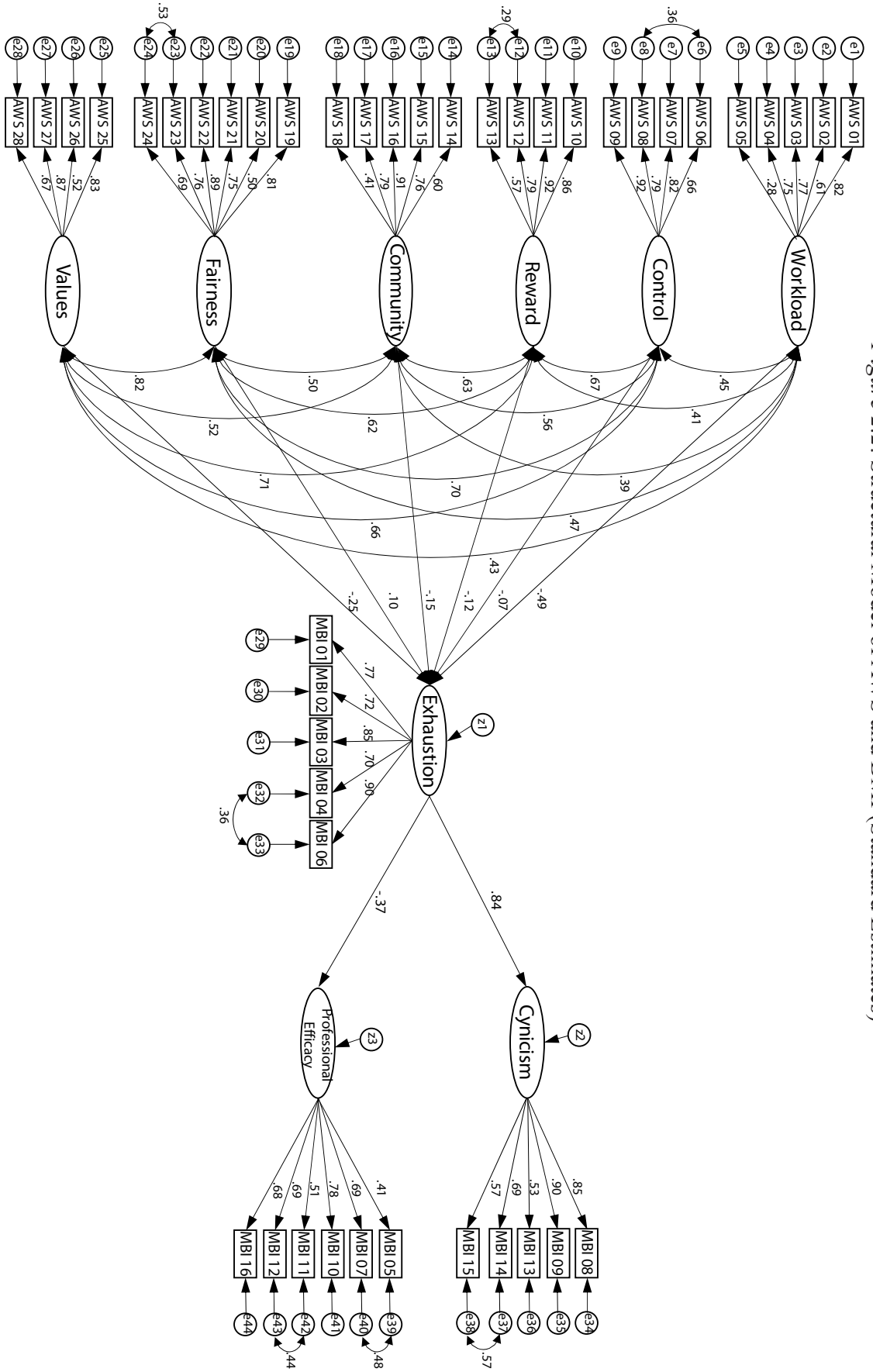


*Figure 2.2.* Structural Model of AWS and BMI (Standard Estimates)

## Recommendations for Future Research

Despite the findings of this project, there is still room for improvement. First, the small sample size limited the statistical analyses and the interpretations of those analyses. For example, a structural equation modeling technique requires "large" sample sizes. With small sample sizes, as in this project, model fit indices tend not to show a good fit to the data. In addition, we only could examine the impact of role/position types by grouping individuals into two groups: owners and non-owners. If each position type were equally sampled and had enough number of individuals, the impact of roles could be further examined.

Demographic information, such as age, tenure, the number of subordinates, and weekly work hour, should be collected as a continuous variable, not as a categorical variable. For instance, survey participants were provided with six different age categories to choose: 1) 18-24 years old, 2) 25-34 years old, 3) 35-44 years old, 4) 45-54 years old, 5) 55-64 years old, and 6) 65 years old and over. In this way, respondents may create less input errors. However, researchers cannot acquire accurate demographic information with this type of data, such as mean and standard deviation. Further, any analyses that include these demographics can only be interpreted within the categories provided. This could be a problem, especially when researchers try publishing an article.

Lastly, one of the hypotheses, "The type of company (Franchise vs. Independently Owned) will be the most important antecedent for predicting burnout among owners or general managers," could not be tested, because survey participants were not asked about a type of company they are working for. There was one item in the survey asking a similar topic: "What services and/or products does your current concrete industry employer provide and/or produce?" (Refer to page 6 of this report for summary statistics.) However, participants could provide multiple responses, so the responses still could not be included in any analyses in the study. Thus, in order to test the hypothesis in the future, researchers should include a survey item specifically inquiring about the type of company (Franchise vs. Independently Owned).

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# Development of a Graduate Technology Project to Teach Advanced Skills Through the Design of a Regional Vaccination Hub

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## Abstract

In response to evolving knowledge and skills utilized in the field of Technology Management, a graduate Technology Management program at a US regional university recently updated their program's core curriculum resulting in the addition of a new course in Project Management Tools and Techniques. The purpose of this course, introduced in the Spring 2021 semester, is to provide greater emphasis on the concepts of pricing, estimating, cost control, risk management, and quality management. The instructor sought to create course activities that would facilitate student engagement and learning in these areas and relate the course activities to real-world situations. To achieve this, a novel case scenario was created to serve as a framework for students to assume the role of project manager and develop realistic plans for the implementation of a regional-scale, mass vaccination hub facility that could be rapidly brought on-line for utilization by official emergency management organizations in the event of another health crisis of a nature comparable to the recent Coronavirus pandemic. Students were presented a real-world, practical challenge requiring them to conduct relevant research and apply advanced skills aligning with course and selected program student learning outcomes. Project deliverables included mile-stone reports for key stages in the planning of the facility including identifying site design specifications, site selection, and facility structures and a final project video presentation directed to the sponsors identified in the project scenario. Students viewed and provided evaluations for project video presentations created by their peers. The project was based on a theoretical concept conceived by the instructor as one with the potential to serve as a baseline model that could be replicated for expedient implementation in any region. Student solutions to the challenges posed in the project would serve as a general proof of concept for the model of this theoretical facility.

*Keywords:* graduate simulation project, project management, emergency response, vaccination hub model

## Regional Vaccination Hub

Evolving knowledge and skills necessary in the field of Technology Management forces instructional programs to regularly assess and adjust their curriculum to ensure continued relevancy. In response to this, the Technology Management Graduate Program Committee at an on-line, graduate Technology Management program at a US regional university recently updated their program's core curriculum and added a new course to provide greater emphasis on specific concepts associated with project management. The course was built around the central concepts of pricing and estimating, cost control, risk management, and quality management. To facilitate student engagement and learning in these areas and relate the course activities to real-world situations, I devised a novel case scenario to serve as the framework for students to develop plans for a regional-scale, mass vaccination hub facility based on a theoretical concept that could potentially serve as a standardized model for expedient duplication and implementation in any region.

### Student Learning Outcomes Alignment

To strengthen the Project Management segment of the Master's Program in Technology Management at the university, general concepts of project management that had been incorporated into a single course were divided into two sets and the concepts of pricing and estimating, cost control, risk management, and quality management removed to form the basis of a new course, Project Management Tools and Techniques. The implementation of the new course required that curricular components be created, revised, or adapted, and new, relevant activities be developed to align with the desired course and applicable program outcomes. Course-specific student learning outcomes defined for this course are stated,

> Upon satisfactory completion of the course, the learner should be able to:
>
> 1. Develop pricing, estimating, and cost control strategies, including life-cycle costing and other quantitative tools.
> 2. Demonstrate techniques for identifying, mitigating, and managing risk in projects.
> 3. Demonstrate the implementation of tools and techniques for managing quality in projects. (Davis, 2021a, p. 2)

Program student learning outcomes state that graduates will,

1. evaluate and defend leadership and organizational strategies associated with technology-intensive enterprises,
2. summarize and explain organizational development and strategies common to technology-intensive enterprises,
3. formulate and assemble component ideas in order to successfully execute a project plan, and
4. analyze information in order to formulate effective solutions. (Davis, 2021a, p. 2)

## Project Scenario Development

My primary goal in devising this project was to present students with a real-world, practical challenge requiring them to conduct relevant research and utilize advanced skills aligning with the student learning outcomes designated for the course. To guide the development of the project, I took cues from the evolving COVID-19 response activities intended to provide a means of quickly and efficiently vaccinating large populations of people. To ensure maximum diversity and portability of the model, I selected a strategic portion of a defined geographic region designated as a Disaster District within one of six regions established by the Texas Division of Emergency Management (n.d.,"Regions") that contained urban, sub-urban, and rural areas to serve as the assigned region in the project.

The multiple approaches and variable functionality and effectiveness of mass vaccination hubs being employed across the country as vaccines became available made it apparent to me that a vaccination hub model that could be implemented quickly, economically, across a variety of regions, and with minimal impact on existing infrastructure would be highly beneficial for emergency response agencies and organizations charged with such a task. The Federal Emergency Management Agency (2021) provides a comprehensive guide, the *Community Vaccination Centers Playbook*, on which vaccination center operations of multiple types are to be based. The scenario I envisioned aligns with FEMA parameters and utilizes a Public Private Partnership (PPP) to facilitate the creation of a versatile drive-through hub facility. A local, full-service contractor would be utilized to identify an appropriate location and prepare the site, within a pre-defined scope of work, for utilization by the lead agency. Upon completion of the facility, the private entity's responsibilities would be complete, and the hub site would be turned over to the public entity for staffing and operation.

## Concept Vision and Premise

The notion driving the creation of this model is summarized in the project's vision statement, provided in the project assignment. The concept vision is to quickly mobilize to provide a functional hub facility to enable high volume vaccination services to be provided over a finite period without occupying existing venues and preempting normal activities while also creating minimal disruption to the neighboring communities. Upon fulfillment of the facility's purpose, it can be quickly cleared from the premises and the property returned to its previous, or better, condition. The ideal outcome is for this and similar facilities to be successful to the extent that they render themselves unnecessary by the end of their two-year operational design and can be decommissioned. (Davis, 2021b, pp. 2-3)

In the rush to quickly implement vaccination hubs in response to the COVID-19 Pandemic, temporary hubs were improvised at facilities designed for a myriad of other purposes such as sporting stadiums, fairgrounds, schools, churches, and similar venues. One would presume that the time would come when these facilities would be needed for their intended purposes and the dual utilization of the facilities could result in interference between the two activities. To help avoid future disruptions of service at vaccination hubs and preemption of primary functions at active, existing facilities, I developed this alternative hub model concept to use an available, and otherwise unoccupied, property for the temporary erection of an expedient, flexible, fiscally responsible, extended-term, non-permanent, drive-through vaccination hub facility. Key criteria of this facility concept include:

- Located appropriately to maximize convenience in access by residents of geographical region (counties) served.
- Utilize real estate that is presently available and of adequate size and configuration for vehicle staging and drive-through service.
- Utilize semi-permanent or temporary structures to shelter vaccination and support workers from sun and inclement weather while allowing for social distancing and the administration of vaccinations while permitting patients to remain in their vehicles.
- All structures can be quickly installed for initial start-up and removed at the time of hub decommissioning such that the property is returned to original condition.
- Ability to replicate facility model across many regions.
- Expectation of two years of operation as a baseline, with possibility of incremental extensions if warranted. (Davis, 2021b, p. 2)

**Project Phases**

The students' assigned role in this simulation project is that of Project Manager and primary contact for the selected private contractor with the responsibility of conducting necessary research, developing the specific plan for implementation, and reporting their justifications and progress to the appropriate public entities at key stages. For the purposes of establishing a practical and realistic framework for the project, the Federal Emergency Management Agency (FEMA) and the Texas Division of Emergency Management (TDEM) are designated as the sponsoring public entities. The project phases for which status reports are required, in the order due, are designated as Site Design Specifications, Site Selection, and Facility Structures. The project culminates with the fourth deliverable, a final video presentation, prepared by the student, with representatives of the receiving entity as the intended audience, which provides an overview of the work performed from the initial proof of concept activities to the final "shovel-ready" plan for implementation.

*Site Design Specifications*

The student is responsible for conducting due diligence through examining regional data and best practices and lessons learned by existing regional hubs to establish further criteria for specifications, functional characteristics, and design elements for the facility. To guide the activity, students were instructed to address the following considerations: volume capacity requirement, number of workers on-site during peak operation, size of tract necessary, traffic management, and utility needs. The deliverable required for this phase is a concise, narrative report of the site specifications determined to be appropriate and the process and rationale for their selection during the design phase of the project.

**Site Selection**

In the second phase of the project, the student is tasked with identifying a suitable parcel of property at an appropriate location. Considerations identified for purposes of site selection included: accessibility, availability of utilities and related infrastructure, topography, all-weather/all-condition surface requirements, presence of existing facilities/structures, possible impact on adjacent communities, and potential zoning conflicts. Students were also asked to consider advantages of various terms of occupancy/utilization (land purchase vs. lease vs. other option). The deliverable for this phase is a narrative report identifying and describing the parcel of property selected for the facility and explaining the process and rationale the student used in making this selection.

*Facility Structures*

Following the identification of an appropriate site, the student's third task is to research and compare practical options for physical structures that could be utilized on the site and identify their recommended option. Students were directed to address the following considerations for this phase: purpose and appropriate size of needed structures, compliance with capacity and social-distancing requirements, temporary vs. semi-permanent vs. permanent structures with an expected lifespan exceeding the facility's projected two-year life-cycle, purchase vs. lease options, structural integrity/quality/durability and safety features, lead/prep time and erection time and expense, recurring expenses, and removal expense and/or residual value. The deliverable required for this phase is a narrative report identifying and describing the necessary structures selected for use at the facility and explaining the rationale for making these selections.

*Project Presentation Video*

The student's final activity and deliverable is an intuitively organized video presentation that provides an overview of the work completed at all project phases. The presentation must address how the plan aligns with and accomplishes the goals of the new hub facility concept. To address the fiduciary accountability expected of public projects, the goals of minimizing Life Cycle Cost (LCC) for tangible assets and investments and maximizing Residual Value (PV Residual) at the conclusion of facility operation were identified as project priorities. The student must also include in the presentation their analysis of Life Cycle Costing for their selected facility options in comparison to options considered but not selected and a description of the strategy they used to plan for a minimal Life Cycle Cost for the overall project. A discussion of the tools or techniques the student used to identify and mitigate any risk factors that could potentially affect the project or facility during the term of its operation is also to be included. The project assignment is completed with a peer-review exercise in which students complete an assessment form to evaluate their own presentation and those of an assigned group of peers.

## Summary

The project guides students through a structured set of staged activities that challenges them to employ advanced skills to design a regional vaccination hub plan aligning with the parameters I established in the conceptual model. Students are required to create and submit progress reports for project phases at three specified intervals during the project. These documents are required to be appropriate for presentation to

specified federal and state emergency response organization partners identified as sponsors for this simulated project. The project phases align with the primary concepts of project management forming the foundation of the course. The projects culminated with students preparing and sharing a final video presentation of their proposed hub facility. Students are given an opportunity to view and evaluate their peer's presentations. This activity component served as an opportunity for students to improve proficiency using advanced modes of electronic communication.

Based on the content of assignment submissions, I have identified the need for greater clarity in the project assignment regarding the required parameters for the facility. The project activity further provides a general proof of concept for the theoretical facility model. A survey of facility plans created through this course project provides an indication that the possibility of implementation of regional vaccination hubs based on this conceptual model warrants further investigation.

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# Developing the Career and Aptitude Assessment for Cybersecurity: Implications for Cybersecurity Education

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## Need statement

Cybersecurity jobs are expected to have a 350% growth rate between 2013 and 2021, with an estimate of 3.5 million unfilled cybersecurity jobs globally by the end of 2021 (Morgan, 2019).

## Overview

Recognizing the increasingly significant role of this sector in protecting both citizen's and the nation's security, this substantial workforce shortage could have damaging ramifications to individuals, organizations, government sector, and corporations. However, rapid skilling of professionals to build a cybersecurity workforce for the nation requires a multipronged effort, especially around identifying the knowledge, skills, and abilities (KSAs) critical for jobs in cybersecurity. The *Career and Aptitude Assessment for Cybersecurity* aims to provide individuals interested in careers in cyber-related fields with a tool for self-assessment about their personality traits, career interests, perceptions on career success and career satisfaction, and knowledge, skills, and abilities related to cybersecurity

**Major Points**

- Cybersecurity jobs are expected to have a gap of 3.5 million unfilled positions globally by the end of 2021
- Rapid skilling of professionals to build a cybersecurity workforce for the nation requires a multi-pronged effort, especially around identifying the knowledge, skills, and abilities (KSAs) critical for jobs in cybersecurity
- *Career and Aptitude Assessment for Cybersecurity* aims to provide individuals interested in careers in cyber-related fields with a tool for self-assessment about their personality traits, career interests, perceptions on career success and career satisfaction, and knowledge, skills, and abilities related to cybersecurity
- The KSAs components of the inventory are directly linked to the NICE Cybersecurity Workforce Framework (NICE Framework)

## Abstract

Rapid skilling of professionals to build a cybersecurity workforce for the nation requires a multipronged effort, especially around identifying the knowledge, skills, and abilities (KSAs) critical for jobs in cybersecurity. Furthermore, from a career development perspective, an aptitude assessment inventory to help the individuals explore their levels of predilection for cybersecurity work prior to pursuing such careers would serve as an early identification mechanism for long term career commitment, especially in a field such as cybersecurity which is experiencing an unprecedent talent crunch. This paper aims to fill the gap in HRD by contributing to career development theory by proposing a conceptual model and developing a new instrument based on previously validated scales to be used for career exploration. The Career and Aptitude Assessment for Cybersecurity aims to provide individuals interested in careers in cyber-related fields with a tool for self-assessment about their personality traits, career interests, perceptions on career success and career satisfaction, and knowledge, skills, and abilities related to cybersecurity. This self-assessment inventory is composed of the following components and respective tests: The Big-Five Factor Structure (Goldberg, 1990) is an inventory that measures an individual on the Big Five Factors (dimensions) of personality; O*NET Interest Profiler is a family of self-assessment career exploration tools that can help individuals discover the type of work activities and occupations that they would like and find exciting (Holland, 1985); Subjective Career Success Inventory – SCSI (Shockley et. al, 2016) measures individuals' perceptions regarding their own career progress and status; Career Satisfaction Scale (Greenhaus, Parasuraman, & Wormley, 1990) measures individuals' perceptions on career satisfaction; Proactive Personality Scale (Seibert, Crant, and Kraimer, 1999) measures individuals' dispositions towards proactive behavior; Cybersecurity Aptitude Assessment section is composed of three sub-sections with specific items on Knowledge, Skills, and Abilities related to the cybersecurity field. Participants' responses are scored through a weighted score model to classify respondents' level of knowledge as beginner, intermediate, and advanced. The KSAs components of the inventory are directly linked to the NICE Cybersecurity Workforce Framework (NICE Framework), "the blueprint to categorize, organize, and describe cybersecurity work" (NICCS, 2020).

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# The End of Office Centricity: Establishing A Virtual Workplace Environment

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## Abstract

The global pandemic left lasting impressions on the way business is conducted. A large number of companies failed because the effects of the global health crisis proved to surpass the bounds of their business services and/or technological competences. The ability to quickly shift from an office-centric climate to a remote environment became critical. Large corporations and tech companies had a technical advantage, as many employees had been doing so for years. However, for a small company unfamiliar with this type of work structure, the pandemic brought rise to an unprecedented set of challenges in a short amount of time. Both the worldwide economic slowdown due to the pandemic and federal environmental regulation rollbacks have caused significant declines in the environmental sector, causing a more competitive market to arise. The industry reached a critical nexus, in order to survive the economic downturn, a small environmental group (Group R) found it necessary to expand beyond the States. Utilizing a quantitative method, survey questionnaires were sent to 75 current employees to gather employee perspectives on the pros and cons of different work environment; SWOT analysis was conducted to take into consideration of factors such as cybersecurity, cost, etc. A conclusion was reached that switching to virtual workplace environment was required to reach a global client base and keep the business thriving.

*Keywords:* remote work, virtual workspace environment

## Introduction

The worldwide economic slowdown due to the pandemic and federal environmental regulation roll-backs have caused significant declines in the environmental sector, causing a more competitive market to arise. Group R, a small environmental consulting company of environmental consulting professionals that works with regulatory agencies at the local, state, and federal levels to issue permits, ensure environmental compliance, remediation, and site investigations was no exception. The small company did not have the automation and securities in place necessary to maintain a sustainable virtual workplace environment. The previous database utilized multiple systems and subsystems that were difficult to navigate, and the server was often overloaded due to user traffic. The company also relied heavily on out-of-date methods of data retention and information storage, utilizing hard copies of notebooks and books for information retrieval.

The objective was to create a core technological infrastructure capable of sustaining all work processes while building a productive remote work culture capable of enduring the new work practice long term in ninety days or less. The belief was that creating a remote work environment would not only allow the company to remain relevant during the global health crisis, but the potential cost savings and profitability benefits could make the transition a permanent workplace solution for the company. The project deliverables included a secure, unified, digital workspace platform that would enable employees to remote login to a company server and reach out to clients from anywhere (where Wi-Fi is enabled) around the globe. Content collaboration features created an avenue for employees to share and collaborate remotely. The project also included a unified endpoint management system that allowed users to utilize device and operating system management (iOS, Android, win 10, Mac OS, and Chrome); as well as a data transfer process that would digitize existing documents into a cloud-based platform so that all documents and/or information can be stored in an encrypted digital library.

## Problem Statement/Proposal

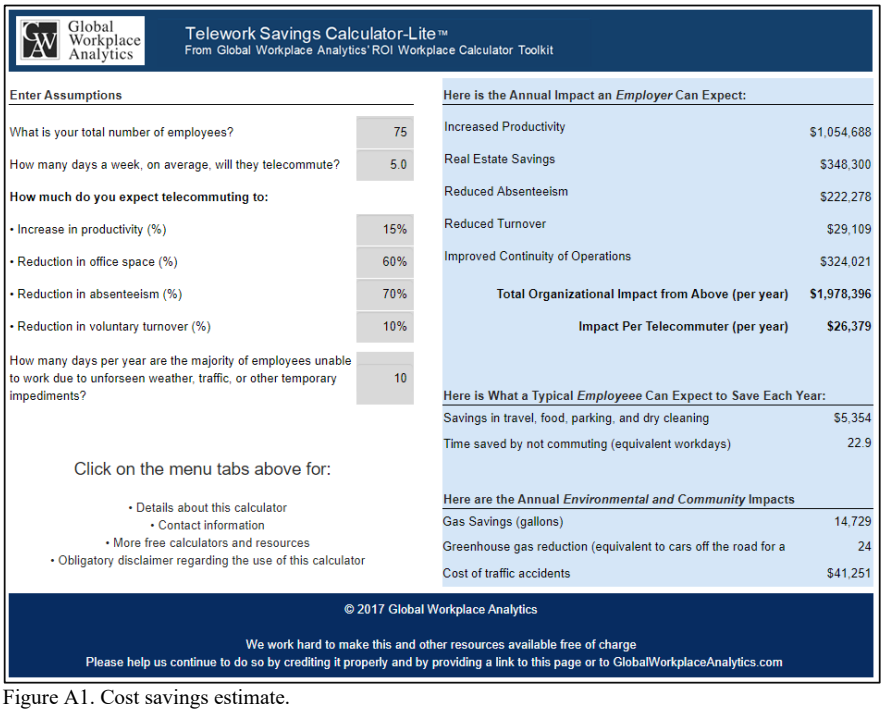
The assumptions for embarking on the Virtual Workspace project were that the company would see greater than a $1.9 million annual savings impact (via real estate savings, increased productivity, reduced absenteeism, reduced turnover, and improved continuity of operations) by switching from in-person to a remote platform as well as gaining the ability to reach global clientele.

Currently there are a total of 75 in person employees that each work an average of 5 days (40 hours) a week. There are offices in use, instead of selling the current office building, additional income could be generat-

ed by utilizing 40% of the space for conference and general office usage (for those that would like to occasionally come in to work). Additional income could be generated by renting out the remaining 60% (total office space reduction) of available office space. The $348K real estate savings could be used to offset company overhead by applying those savings towards increased database security and Citrix Workspace user costs.

If a more conservative approach is adopted and productivity for Group R is increased by at least 15%, there could be an increased productivity savings of nearly $1.05 million. Remote work would give employees the ability to continue working despite the weather or other unforeseen impediments and provide the company with an improved continuity of operations savings of nearly $324K.

Figure A1 provides the cost and savings features of the Virtual Workspace Environment (VRE) project for Group R. The values were calculated at an end user count of 75 employees. The table is broken down to identify the anticipated cost savings action, action type (cost or savings), description of the action, and the annual cost or savings stemming from that action. The company is expected to earn roughly $14.2 million this year and will spend $5.6 million in wages, around $3 million in other overhead costs, and about $475K on the VRE project. These costs along with the $1.9 million savings impact and a $750K rental value could generate a VRE first year net of more than $7.8 million.



Global Workplace Analytics

Telework Savings Calculator-Lite™
From Global Workplace Analytics' ROI Workplace Calculator Toolkit

**Enter Assumptions**

| | |
|---|---|
| What is your total number of employees? | 75 |
| How many days a week, on average, will they telecommute? | 5.0 |
| **How much do you expect telecommuting to:** | |
| • Increase in productivity (%) | 15% |
| • Reduction in office space (%) | 60% |
| • Reduction in absenteeism (%) | 70% |
| • Reduction in voluntary turnover (%) | 10% |
| How many days per year are the majority of employees unable to work due to unforseen weather, traffic, or other temporary impediments? | 10 |

Click on the menu tabs above for:

- Details about this calculator
- Contact information
- More free calculators and resources
- Obligatory disclaimer regarding the use of this calculator

**Here is the Annual Impact an *Employer* Can Expect:**

| | |
|---|---|
| Increased Productivity | $1,054,688 |
| Real Estate Savings | $348,300 |
| Reduced Absenteeism | $222,278 |
| Reduced Turnover | $29,109 |
| Improved Continuity of Operations | $324,021 |
| **Total Organizational Impact from Above (per year)** | **$1,978,396** |
| **Impact Per Telecommuter (per year)** | **$26,379** |

**Here is What a Typical *Employeee* Can Expect to Save Each Year:**

| | |
|---|---|
| Savings in travel, food, parking, and dry cleaning | $5,354 |
| Time saved by not commuting (equivalent workdays) | 22.9 |

**Here are the Annual *Environmental and Community* Impacts**

| | |
|---|---|
| Gas Savings (gallons) | 14,729 |
| Greenhouse gas reduction (equivalent to cars off the road for a | 24 |
| Cost of traffic accidents | $41,251 |



Figure A1. Cost savings estimate.

## Literature Review

Remote work has been proven to bring clear benefits to employees' work-life balance, by allowing employees to arrange time for work, private, and family-related needs to their own specifications (Hart, 2020;

Popovici & Popovici, 2020). A study conducted by the American Sociological Review concluded that employees that were given lots of work flexibility were happier with their work-life-balance, missed fewer days, and were more interested in staying with the company long-term (Courtney, 2020). As the telework trend increases, employers are now realizing that the introduction of a digital nomad culture could help the company expand the talent pool and retain top talent (Jacoby & Holland, 2019). Work from home/remote work models are known to increase productivity and employee happiness long term, but employees must continuously find ways to keep employees engaged especially during times of hardship (Howard-Grenville, 2020; Swan, 2020). According to new research, companies that let their workers decide where and when to do their jobs (whether in another city or in the middle of the night) increase employee productivity, reduce turnover, and lower organizational costs (Senz, 2019). Working remotely affords one the opportunity to travel without missing work, the person gets to live in different cultures and enjoy life experiences without worries of how many vacation days (PTO) are left. Having coverage across time zones creates a 24/7 workflow and comes in handy when needing to meet tight deadlines and location flexibility provides the employer an opportunity to expand business outreach (Jacoby & Holland, 2019).

## Analysis

As with any project the switching from an in-person to a remote workspace has its pros and cons. A SWOT analysis was completed, see Figure A2, to identify the strengths vs. weaknesses as well as the opportunities vs threats this project would bring to Group R.

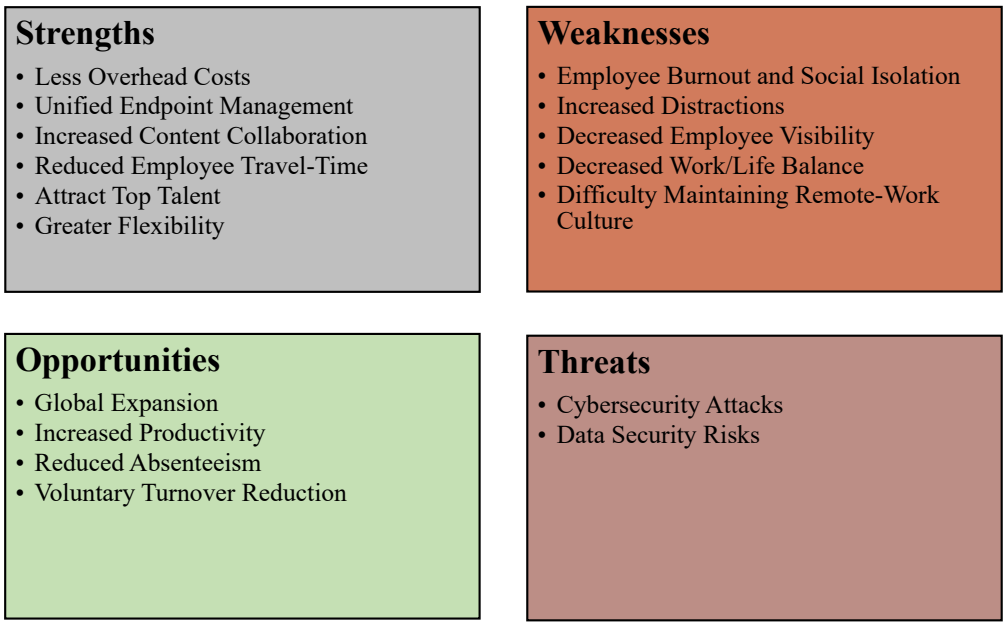



Figure A2. SWOT Matrix.

A major strength for the company includes reduced overhead costs, the savings generated by switching to remote work would more than cover the costs of working remotely, while generating additional revenue. Other strengths include the formation of a unified endpoint management system, increased content collaboration tools, and the ability to attract a wider poor of talent. Employees would also be drawn to the increased flexibility of remote work as well as the significant reduction to near elimination of workday travel time.

Weaknesses mostly relate to the emotional aspect of being disconnected from a traditional work setting, such as, burnout and social isolation, distractions, and difficulty managing work-life balance. The company has also had to compensate for decreased employee visibility and has had to figure out ways to create, establish, and maintain a remote-work culture.

Creating a remote environment has given Group R the opportunity to expand. The Environmental Consulting and Remediation and Site Investigation teams are now providing services for multiple countries.

Security has been the greatest threat with transitioning to remote work. The increase of network activity has increased system vulnerability, which has increased the number of attempted cybersecurity attacks and data security risks. These risks include increased phishing schemes, weak user passwords, unencrypted file sharing, unsecure home Wi-Fi, and the increased use of personal devices.

A cost benefit analysis evaluated the company in terms of the relationship between the resources it consumed versus the benefits it produced by summing up the produced benefits of the remote workspace environment project, then subtracting consumed resource costs. The implementation of this project saved Group R saved an estimated $2,730,196 in the first year, see Table A1.

Table A1.
*Cost benefit analysis*

| COST BENEFIT ANALYSIS | | | |
|---|---|---|---|
| **Action** | ***Action Type*** | **Description** | **Annual Costs (indicates anticipated savings)** |
| Citrix Workspace Premium plus | ***Cost*** | "Comprehensive workspace solution inclusive of hybrid deployment options for Citrix Virtual Apps and Desktops.<br><br>Includes Workspace Premium functionality, plus a cloud management option for Citrix Virtual Apps and Desktops."[4] | **$22,500** |
| Real Estate Costs | ***Cost*** | Property Taxes (0.024) | **$46,320** |
| Rental Value | ***Savings*** | approx 21,480 sqft of rental space $35 SF/YR[5] | **($751,800)** |
| Real Estate Savings from Office Space Reduction | ***Savings*** | Cost of Maintaining Office Space | **($348,300)** |
| Reduced Absenteeism | ***Savings*** | | **($222,278)** |
| Reduced Turnover | ***Savings*** | | **($29,109)** |
| Improved Continuity of Operations | ***Savings*** | Workspace should reduce downtime from disaster recovery | **($324,021)** |
| Increased Productivity | ***Savings*** | Maintenance productivity; planning, scheduling, and mechanical coordination | **($1,054,688)** |
| Project Management Team | ***Cost*** | 3 members | **$450,000** |
| Overhead Costs | ***Cost*** | Building utilities, Maintenance, Services, and Supplies | **$2,942,860** |
| Wages | ***Cost*** | Employee Earnings | **$5,625,000** |
| Revenue | ***Savings*** | Company Earnings | **($14,220,000)** |
| **Investment Gains** | | | **($16,950,196)** |
| **Total Costs** | | | **$9,086,680** |
| **Net First Year** | | | **($7,863,516)** |

An alternative analysis was conducted to determine and recommend the best alternative to the chosen solution, see Table A2. The two options were (1) maintain the status quo, which is to do nothing, or (2) switch to a remote work environment while utilizing the then current infrastructure. Maintaining the status quo would prove to be disastrous for the company. Bankruptcy and/or complete failure would have been inevitable. Likewise, keeping the infrastructure "as-is" would have caused a catastrophic system overload that could have resulted in non-recoverable data loss and total system shutdown.

Table A2.
*Alternative analysis*

| No Project (Status Quo) | Reasons for Not Selecting Alternative |
|---|---|
| Do nothing; remain in person. | The company would fail to remain relevant and eventually succumb to bankruptcy. |
| **Alternative Option** | **Reasons for Not Selecting Alternative** |
| Switch to a remote work environment, but utilize the current infrastructure | From an operational point of view, the current systems were performing well, but the current database utilizes multiple systems and subsystems, long-term use would cause the server to overload due to user traffic. The current security system is not designed for 100% online, long-term user capacity and could potentially create a cybersecurity threat for the company. |

In order to prove that the remote workspace environment was worth the investment, the Return on Investment (ROI), Figure A3, was calculated using the values from the Cost Benefit Analysis, Table A1. The company had a ROI of 86.5%, signaling that the company utilized its resources properly and switching to a remote work environment was a worthwhile investment.

$$\text{ROI} = \left( \frac{\text{(Investment Gains)} - \text{(Investment Cost)}}{\text{(Investment Cost)}} \right) \text{X } 100$$

$$\text{ROI} = \left( \frac{(\$16{,}950{,}196) - (\$9{,}086{,}680)}{(\$9{,}086{,}680)} \right) \text{X } 100 = \mathbf{86.50\%}$$

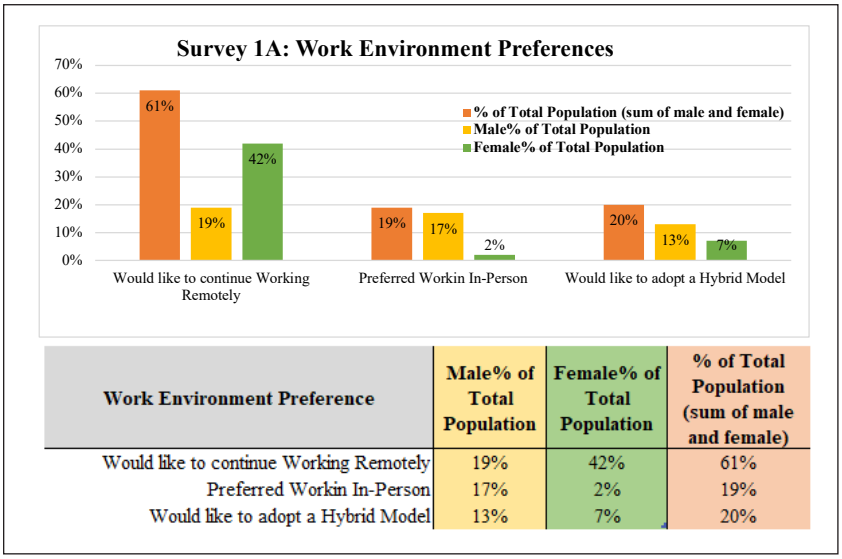
Figure A3. ROI analysis.

## Methodology

A quantitative research design approach was chosen because it best emphasizes the objective measurement of data. Due to its structured design, descriptive research was utilized to collect data in the form of surveys with predefined answers for the respondents to choose from. Although formatting the questions in this manner is not meant to give unique insight or provide the company with the specific feelings or emotions of each participant, it has provided statistical data that can be applied to the overall population. This approach has also allowed for the measurement of the participants responses over time. The sample population consisted of 58 male and 17 female participants.

## Results

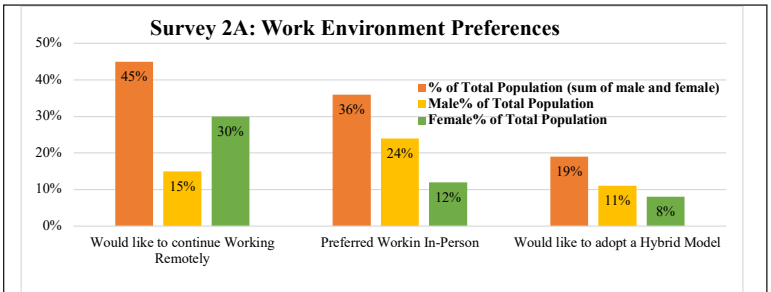
The initial survey included a question related to work environment preferences. At rollout (Figure A4), 61% of the total population of participants wanted to continue working remotely (breakdown: 19% male, 42% female); a total of 19% of the total population participants preferred the previous work in-person environment (breakdown: 17% male, 2% female); and the remaining 20% preferred to adopt a hybrid model where they could have the option of working both in-person and remotely (breakdown: 13% male, 7% female).




| Work Environment Preference | Male% of Total Population | Female% of Total Population | % of Total Population (sum of male and female) |
|---|---|---|---|
| Would like to continue Working Remotely | 19% | 42% | 61% |
| Preferred Workin In-Person | 17% | 2% | 19% |
| Would like to adopt a Hybrid Model | 13% | 7% | 20% |

Figure A4 - Survey 1A detail.

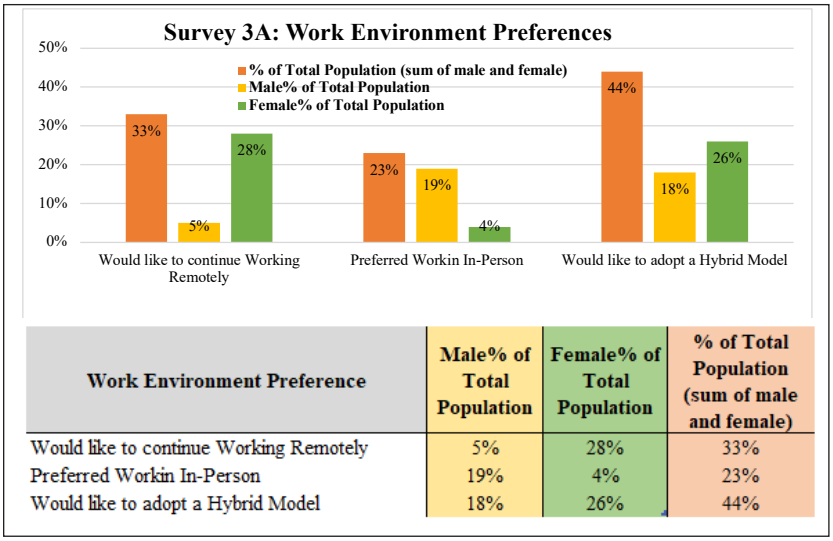
The results of the second round (Figure A5), provided the following results: 45% of the total population participants wanted to continue working remotely (breakdown: 15% male, 30% female); a total of 36% of the total population participants preferred the previous work in-person environment (breakdown: 24% male, 12% female); and the remaining 19% preferred to adopt a hybrid model where they could have the option of working both in-person and remotely (breakdown: 11% male, 8% female).




| Work Environment Preference | Male% of Total Population | Female% of Total Population | % of Total Population (sum of male and female) |
|---|---|---|---|
| Would like to continue Working Remotely | 15% | 30% | 45% |
| Preferred Workin In-Person | 24% | 12% | 36% |
| Would like to adopt a Hybrid Model | 11% | 8% | 19% |

Figure A5. Survey 2A detail.

The results of the third survey (Figure A6) are as follows: 33% of the total population participants wanted to continue working remotely (breakdown: 5% male, 28% female); a total of 23% of the total population participants preferred the previous work in-person environment (breakdown: 19% male, 4% female); and the remaining 44% preferred to adopt a hybrid model where they could have the option of working both in-person and remotely (breakdown: 18% male, 26% female).




| Work Environment Preference | Male% of Total Population | Female% of Total Population | % of Total Population (sum of male and female) |
|---|---|---|---|
| Would like to continue Working Remotely | 5% | 28% | 33% |
| Preferred Workin In-Person | 19% | 4% | 23% |
| Would like to adopt a Hybrid Model | 18% | 26% | 44% |

Figure A6. Survey 3A detail.

Based on the tables mentioned above, female employees overwhelmingly preferred a remote work option for the first two surveys, but after six months, became split over remote vs. hybrid work. On the contrary, their male cohorts seemed to prefer working in person.

The next question highlighted areas involving the struggles of remote work across all three surveys (Figure A7 and Table A3).

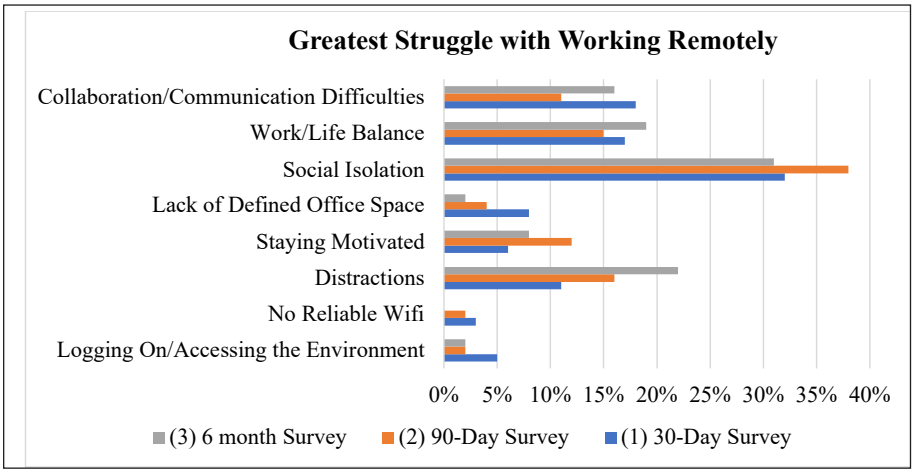



Figure A7. Survey B overview.

Table A3
*Survey B details*

| Greatest Struggle with Working Remotely | (1) 30-Day Survey | (2) 90-Day Survey | (3) 6 month Survey |
|---|---|---|---|
| Logging On/Accessing the Environment | 5% | 2% | 2% |
| No Reliable Wi-Fi | 3% | 2% | 0% |
| Distractions | 11% | 16% | 22% |
| Staying Motivated | 6% | 12% | 8% |
| Lack of Defined Office Space | 8% | 4% | 2% |
| Social Isolation | 32% | 38% | 31% |
| Work/Life Balance | 17% | 15% | 19% |
| Collaboration/Communication Difficulties | 18% | 11% | 16% |

For the first survey, social isolation was marked as the greatest struggle with 32% of participants selecting that choice. Collaboration/communication difficulties and struggles with work/life balance came in at 18% and 17%, respectively. Distractions garnered 11% of the vote, while the remaining 22% could be attributed to struggles with logging on/accessing the environment, lack of a reliable Wi-Fi connection, struggles with motivation, and not having a designated office space. For the second survey, social isolation increased to 38% of participants selecting that choice. Collaboration/communication difficulties drastically improved and accounted for only 11% of struggles; while, struggling with work/life balance decreased minimally to 15%. Distractions increased to 16% of the vote and staying motivated doubled to 12%. The remaining 8% could be attributed to

struggles with logging on/accessing the environment, lack of a reliable Wi-Fi connection, and not having a designated office space. For the third survey, social isolation went back down to 31% and Collaboration/communication difficulties went back up to 16%. Struggling with work/life balance also increased, with 19% of employees now experiencing it as the greatest struggle. While distractions increased once again to 22% of the vote, staying motivated reduced to 8%. The remaining 4% was split between issues with logging on/accessing the environment and not having a designated office space.

By far, social isolation is the greatest struggle participants felt across all three surveys, with it peaking at the 90-day point. These feelings seemed to diminish by the time the six-month survey was issued, but distractions, work/life balance, and communication difficulties increased at the six-month survey.

The final question on each survey asked what each participant felt would be the greatest benefits of working remotely (Figure A8 and Table A4).

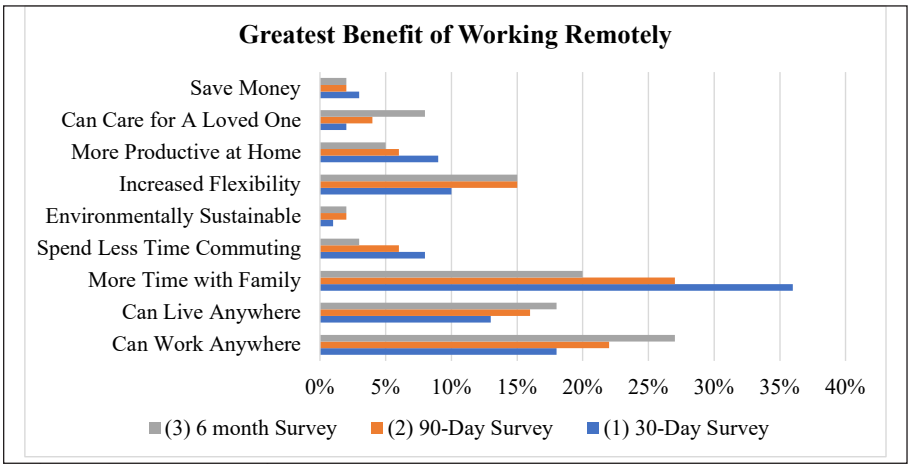



Figure A8. Survey C overview.

Table A4
*Survey C detail*

| Greatest Benefit of Working Remotely | (1) 30-Day Survey | (2) 90-Day Survey | (3) 6 month Survey |
|---|---|---|---|
| Can Work Anywhere | 18% | 22% | 27% |
| Can Live Anywhere | 13% | 16% | 18% |
| More Time with Family | 36% | 27% | 20% |
| Spend Less Time Commuting | 8% | 6% | 3% |
| Environmentally Sustainable | 1% | 2% | 2% |
| Increased Flexibility | 10% | 15% | 15% |
| More Productive at Home | 9% | 6% | 5% |
| Can Care for A Loved One | 2% | 4% | 8% |
| Save Money | 3% | 2% | 2% |

For the first survey, the ability to spend more time with family garnered the majority of the vote with 36%. The ability to work anywhere was next at 18%, while the ability to live anywhere followed at 13%. Ten percent of participants appreciated the flexibility that come with remote work. Eight percent voted in favor of reducing commute times, 9% believed they were more productive at home, 2% preferred to be home to care for a loved one, 3% believed remote work saved them money, and 1% were in favor of remaining environmentally sustainable. On the second survey, the ability to spend more time with family still garnered the majority of the vote with 27%. The ability to work anywhere followed with 22% and the ability to live anywhere came in at 16%. Fifteen percent of participants appreciated the flexibility that come with remote work. Six percent now voted in favor of reducing commute times and another 6% believed they were more productive at home, 4% preferred to be home to care for a loved one, 2% believed remote work saved them money, and 2% were in favor of remaining environmentally sustainable. For the third survey, the ability to spend more time with family dropped to the second highest priority, 20%; and with the greatest benefit transitioning to the ability to work anywhere, 27%. The ability to live anywhere increased to 18%. Flexibility remained consistent and is still at 15%. Caring for a loved one increased to 8%, while feeling more productive at home reduced to 5%. Three percent voted in favor of reducing commute times, 2% believed remote work saved them money, and another 2% were in favor of remaining environmentally sustainable.

For this question, participants on the first survey favored the increased family time, but as time progressed that selection decreased. By the six-month marker, most employees valued the ability to work anywhere over all other choices, others still appreciated time with family, followed by geographic freedom and work flexibility.

## Conclusion

Various solutions, i.e. in-person, remote, and hybrid work modes were analyzed when determining the best way to address evolving business needs based on employee's perceptions surveys and SWOT analysis. The solution chosen has thus far allowed Group R to adhere to a business model of growth and opportunity. By adopting a virtual workspace platform, the company has been able to expand globally and flourish despite the current challenges created by the ongoing pandemic. It's worth mentioning that results showed that social isolation was the greatest struggle participants felt across all three surveys, peaking at the 90-day point but seemed to diminish by the time the six-month survey was issued; however, other struggles like distractions, work/life balance, and communication difficulties increased at the six-month survey. Based on the data obtained, it is recommended that Group R should continue working remotely but allow for future provisions with hybrid work options (for those that so choose) post pandemic. Potential future research could collect the same set of data and follow up questions to gauge the long-term impact of a virtual work environment in the organization and employees thus to decide the best option to choose as the pandemic is still an evolving issue.

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# The Framework For Remote Training And Continuing Professional Development

Author:

**Lu Wei**

**Abstract**

A new system is needed to successfully deliver effective training and development utilizing digital platforms. Like many of our other programs a commercial off-the-shelf solution will not work since our security requirements demand a proprietary system. The custom solution content creation would tailor content to employees' training level and deliver real-time feedback for users. Changing the methods used to implement training and development will also require training managers to alter the thought processes and the practices applied in training and development. This digital transformation will provide scalability, adaptability, and flexibility for a globally dispersed workforce. As more employees move to teleworking on a permanent basis this system will become the default way of delivering training going forward. The scope of implementation will begin with one department before it is rolled out through the rest of the organization. During this extended telework period, this has specifically impacted the newest members of my team. We are currently discussing the conversion of a majority of roles in my department from onsite to permanent telework and increasing telework for everyone. The implementation would impact team members located in Washington DC, Virginia, South Carolina, and Texas.

*Keywords:* remote training, career development, Navy Marine Corps Intranet (NMCI), telepresence

## Introduction

Research reveals that the success of the organization is dependent upon employee performance. Therefore, a multidimensional approach is necessary to ensure effective education, training, resources, and support are put in place to encourage career-long learning and professional development at every level within an organization. However, when a disruption interrupts the way an organization traditionally operates, how does it continue providing stability, support, and productive training and development to its employees?

Most organizations worldwide have or will implement measures to promote social distancing. The unknows of a global pandemic and uncertainty of viable treatment options led many countries to take action to mitigate the spread of the virus. The amount of time it will take humankind to conquer COVID-19 is unknown. More specifically, when will there be an opportunity to provide services like training and development without health concerns or government-imposed regulations? Again, none of these factors can be predicted. Alternatively, restructuring the ways in which organizations deliver training and development will benefit them now and provide opportunities for growth in the future. Including a plan that addresses training and development in an organization's response to COVID-19 delivers a prompt solution to an emergent need, but also tackles the uncertainty of the future.

A paradigm shift is required that allows for the uninterrupted onboarding of new hire professionals and the continual development of the workforce. A move from one-on-one training to a uniform curriculum, interactive software, and telepresence capabilities is needed. This creates a strong and educated workforce that can deliver services under any circumstances, including during the midst of a global crisis. Moving training and development resources online offers a means to deliver training to employees. Increased job satisfaction, morale, motivation, retention, efficiencies in processes that result in financial gain, innovation, and capacity to adopt new technologies and methods are widely accepted benefits of training and development. It is necessary for an organization to invest in talent and that investment will create growth and success. There is not a time more vital than now to make this investment.

## Background

Prior to 2000, Former Secretary of the Navy Gordon England described the U.S. Navy's IT environment in this manner: "We basically had 28 separate commands budgeting, developing, licensing, and operating IT autonomously. It was inefficient and, from the larger Department perspective, produced results that

were far from optimal." In response, Navy Marine Corps Intranet stakeholders called for the creation of a program that would deliver most IT services to the Department. The Navy Marine Corps Intranet (NMCI) contract was awarded to Electronic Data Systems, now Hewlett Packard Enterprise Services. Through a series of mergers and acquisitions, Perspecta is now the private sector partner that manages the largest intranet in the world. NCMI combined 6,000 networks into a single integrated and secure IT platform that currently serves 800,000 users in 2,5000 locations with 400,000 computers (Perspecta Inc., 2020). My role is to supply NMCI services, which include network infrastructure, hardware, and software, to locations that are strategically located near the U.S. Fleet.

*The Framework for Remote Training and Career Development* leverages the Organization's unmatched technical competence to propel the guiding principles of meeting commitments, being the technical expert, being a trusted partner, and developing people and the organization to provide training for onboarding personnel, seasoned professionals, subject matter experts, and training developers. The goal is to create high-quality, standardized programs that are delivered in a remote multi-dimensional platform. The need to create remote computer-based training resulted from a response to the rapid changes the Navy required in response to the COVID-19 pandemic; however, paradigm shift to training outlined in this framework allows for opportunities of implementation beyond the telework policies mandated by the Navy.

## Literature Review

Murphy (2020) examines the difficulties associated with poor online teaching infrastructure, and Bozkurt and Sharma (2020) highlight emergency remote teaching. It is necessary to move beyond the rapid pandemic response and evolve into high-quality online teaching and learning crafted from careful instructional design and planning. To ensure support and mentoring are meaningfully present during the training and professional development process, drawbacks often associated with remote platforms are addressed in a proactive manner by utilizing expert guidance. This paradigm shift will reinvent training and professional development models from the past and transform them into a framework for the future.

American educational psychologist Benjamin Bloom (Eisner, 2000) asserted that "it made no pedagogical sense to expect all students to take the same amount of time to achieve the same objectives." The outset of this new era lends itself to future training and professional development practices that are evidence-based and effective in an online platform. This review will center on the elements needed to create a comprehensive cur-

riculum that contains a diverse array of learning opportunities distributed via a remote platform that leverages Adaptive Information Technology System (or Massive Adaptive Interactive Text, MAIT).

One obvious drawback to using an entirely online platform is the lack of social and networking opportunities that users will face. To address this drawback, the framework also calls for synchronous communications and telepresence implementation for users that are actively participating in training. An authentic discussion will permit users to take past experiences and construct new takeaways applied to workplace situations.

Telepresence has already been playing an important role in a mediated learning environment, as evidenced in the (Su & Zou, 2020) study documenting students' responses towards the converted telepresence. The results indicated that the students accepted the presence of their peers in their converted telepresence and that it boosted their interest in the related activity conducted in the mediated learning environment. The results of this study substantiate the profound effects that a telepresence catalyst construct for human expression.

## Methodology

The hypothesis for this study was that insights from new hires currently enrolled in an online course could be paired with already proven academic online educational courses to make informed improvements in the current training and professional development program. Accordingly, this research looked beyond traditional computer-based training to an innovative adaptive learning system. The purpose was to access digital training models to derive effective learning strategies to the new demands of those enrolled a new hire training program that will now be completed entirely online. This methodology will answer each of the following questions: When an organization's traditional operation is disrupted, how does it continue to provide stable, supportive, and productive training and development to its workforce?

## Discussion

A focus group will be assembled to gather data directly from the people who are most affected by the training and career development program. These semi-structured conversations bring clarity to existing documentation and provide innovative views that will be incorporated into the framework. Additional developmental source data that contributed to the solution presented in this framework includes press releases, Navy messages, NMCI program documents, academic journals, and various online publications.

## Data Analysis and Results

The focus group produced a large amount of data in a short period of time. The process of qualitative analysis aims to bring meaning to the focus group transcript. Additionally, the data will be used to generate quantitative procedures. Krueger and Casey (2020) suggest that a helpful way of thinking about this role is to consider a continuum of analysis ranging from the mere accumulation of raw data to the interpretation of data on an analysis continuum: raw data; descriptive statements; interpretation. Moreover, the researchers stress the need to remove bias so that the analysis should be systematic, sequential, verifiable, and continuous. The findings will be presented in a straightforward manner using meaningful quotes from the participants. They advise that the researcher read each quote and answer these four questions:

1. Did the participant answer the question that was asked? If yes, go to question 3; if no, go to question 2; if you don't know, set it aside and review it later;
2. Does the comment answer a different question in the focus group? If yes, move it to the appropriate question; if no, go to question 3;
3. Does the comment say something of importance about the topic? If yes, put it under the appropriate question; if no, set it aside;
4. Is it something that has been said earlier? If yes, start grouping like quotes together; if no, start a separate pile.

Finally, the data collected will be interpreted using established criteria: frequency, motion, specificity of responses, and big ideas (Kruger & Casey, 2000). Under frequency, the actual words, their meanings, and how often a word is used should be considered. The phrasing of the questions and comments made by participants influence the group and the context of the responses should be considered. Motion takes into consideration the dept of feeling in which a comment was made. Were more negative or positive terms used? The consistency of the response should also be noted. Did the participant's opinion change during the course of the focus group? Next, more attention is needed when reviewing the participant's personal experiences instead of hypothetical examples given for the response's specificity. Lastly, to recognize big ideas, trends will emerge while reviewing the accumulation data.

The establishment of the Distance Onboard Training program, or DOT base on *The Framework for Remote Training and Career Development* has been able to identify critical gaps and potential solutions in

training and professional development for a globally distributed workforce. Furthermore, the framework's current and near-term capabilities develop efforts for the Organization's Strategic Vision 2018 -2027. Taking an integrated and collaborative approach to achieve the vision described in this paper and engender the creativity and innovation of the Organization's technical expertise, passion for innovation and professionalism. Training can be complex but must be delivered in a scalable, adaptable, and flexible manner. Leaders will use existing training materials and pair with novel technology to support enablers must be scalable to different size formations. Training must also have surge capacity to meet mobilization needs.

While operating in a near constant state of transition, agility and adaptability are essential to meeting mission requirements and future challenges in a complex and uncertain world. History shows that this moment is a unique window of opportunity during a period of unprecedented global change to exploit technology for the transformation of training and professional development. Their transformation must move forward even in these circumstances to meet readiness requirements to better serve the warfighter. Managing the dissemination of training materials in a constantly changing environment can be accomplished through the framework presented in this paper. The benefits of doing so are too significant to ignore. Now is the time to seize this opportunity and prepare our profession for the next uncertainty of the future. Stewarding the training program is a requirement for the present, not in the aftereffects of the next crisis.

## Conclusions

While operating in a near constant state of transition, agility and adaptability are essential to meeting mission requirements and future challenges in a complex and uncertain world. History shows that this moment is a unique window of opportunity during a period of unprecedented global change to exploit technology for the transformation of training and professional development. Their transformation must move forward even in these circumstances to meet readiness requirements to better serve the warfighter. Managing the dissemination of training materials in a constantly changing environment can be accomplished through the framework presented in this paper. The benefits of doing so are too significant to ignore. Now is the time to seize this opportunity and prepare our profession for the next uncertainty of the future. Stewarding the training program is a requirement for the present, not in the aftereffects of the next crisis.

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## Addendum- Focus Group Notes

**Focus Group Questions**

- Culture
    - How would you describe the Organization to other people?
    - How would you describe your onboarding process?
    - How would you describe the program organizations?
- Curriculum and learning outcomes
    - How would you describe your new hire training?
    - What is one trend you have noticed in your initial training and continued professional development?
    - What specific sources do you use for training information?
    - What gaps do you see in the initial training content?
    - Do you know what you are expected to know and be able to do at the end of the initial training program?
    - Did the expectations of the initial training program correspond to the learning outcomes and subject content?
- Teaching and Learning Styles
    - Was there a range of teaching and learning styles presented over the course of the program?
    - Did you find the presentation of the program engaging?
    - Was there effective support and guidance during the course of the program?

- Program Progression
    - Did you receive prompt and effective feedback throughout the course?
    - Do you understand the criteria used to assess your work?
    - Did members of your training and/or leadership team discuss your progress?
- Summary
    - What elements have you found to be most effective about the program?
    - What are the areas for improvement?

**Summary of Responses**

- Culture
    - How would you describe NWIC to other people?
    - How would you describe your onboarding process?
    - How would you describe the program organizations?
- Curriculum and learning outcomes
    - How would you describe your new hire training?
    - What is one trend you have noticed in your initial training and continued professional development?
    - What specific sources do you use for training information?
    - What gaps do you see in the initial training content?
    - Do you know what you are expected to know and be able to do at the end of the initial training program?
    - Did the expectations of initial training program correspond to the learning outcomes and subject content?

- Teaching and Learning Styles
    - Was there a range of teaching and learning styles presented over the course of the program?
    - Did you find the presentation of program to engaging?
    - Was there effective support and guidance during the course of the program?
- Program Progression
    - Did you receive prompt and effective feedback throughout the course?
    - Do you understand the criteria used to assess your work?
    - Did members of your training and/or leadership team discuss your progress?
- Summary
    - What are the things you found to be most effective about the program?
    - What are the areas for improvement?

# Implementing Lean Six Sigma Principles in the Automotive Collision Repair Industry: A Multiple Case Study Analysis

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## Abstract

This research provides the automotive collision industry empirical evidence of the effects of Lean-for-Collision Training and Development Initiatives facilitated by a targeted sample of three automotive collision repair centers. Through formal interview and review of artifacts, the findings showcased in this study are in terms of automotive collision industry metrics; a balance in cost, quality, and service delivery; specifically, vehicle cycle-time, vehicle touch-time, employee turnover, and the Return-on-Investment (ROI) of their Lean training. In addition, this research provides automotive collision centers with critical knowledge and understanding of how to successfully navigate and progress through the Framework for Six Sigma Implementation in SMEs to achieve and develop a Lean culture in order to ultimately sustain the results of Lean Six Sigma training implementation.

*Keywords:* Small-to-Medium-Sized Enterprises (SMEs), Lean Six Sigma, Learning Organization, Training and Development, Return-on-Investment (ROI)

Since its development and practical application by Motorola and Toyota in the early-to mid-1980s, the Lean Six Sigma methodology and its variants have been utilized by thousands of organizations across the world (Kumar, Antony, Madu, Montgomery, & Park, 2008). Most notable for its application in large-scale manufacturing companies, Lean Six Sigma continues to evolve as a quality improvement initiative for a variety of organizations in healthcare and financial services, as well as an array of fields in the public sector (Kumar, Antony, & Tiwari, 2011). While the available literature chronicles a seemingly endless number of instances where Lean principles have been successfully utilized by large organizations, only recently has its use been investigated in the context of small-to-medium-sized enterprises (SMEs). Furthermore, most of the current research has been conducted in the United Kingdom (Kumar, Antony, & Douglas, 2009), and a select few European countries (Thomas, Ringwald, Parfitt, Davies, & John, 2014) with a focus on SME manufacturing.

SMEs could benefit from Lean production models utilized in larger businesses, but often SMEs have non-standardized procedures. Unlike much larger organizations with specialized tasks, employees of SMEs execute many different functions, making the full-scale adoption of Lean Six Sigma principles seem impractical. However, according to Kumar et al. (2011), successful implementation of Lean Six Sigma is possible if a clear, systematic model for Six Sigma adoption were utilized.

Figure 1 (found in Appendix A) illustrates the framework proposed by Kumar et al. (2011). This systematic approach in the Five Phase Six Sigma framework for SMEs was developed from the critical analysis of available quality improvement frameworks such as Total Quality Management (TQM). This model illustrates a series of phases an organization must complete in order to firmly entrench the Lean Six Sigma methodology for long-term sustainability of the initiative (Kumar et al., 2011). From determining the organization's level of readiness for Lean Six Sigma implementation in Phase 0, to the progression towards a learning organization in the final stage of Phase 4, Kumar et al. (2011) asserted that this model serves as a "roadmap or guideline for SMEs to follow in their effort to improve continuously, maintain high standards of quality, and enhance their chance of success in embracing the initiative" (p. 5454).

This research utilized this framework for SMEs to identify automotive collision repair shop progression levels towards the implementation of Lean Six Sigma after a Lean Six Sigma Training and Development program had been initiated.

## Statement of Purpose

The purpose of this research was to evaluate the effects of Lean-for-Collision Training and Development Initiatives from participating automotive collision repair centers that have completed their training at *MVP Business Solutions*. This study also determined what benefits each center incurred from their Lean-for-Collision Training and Development Initiative and what barriers existed that delayed each center's progression from one identified phase of the Six Sigma framework for SMEs to the next.

## Methodology

In order to address the research questions and hypotheses (found in Appendix B), this study utilized mixed-method research, incorporating both qualitative and quantitative methods of inquiry (Creswell, 2018) with a multiple case study design. Mixed-method data collection allowed research from one phase to compliment the next, by elaborating, expanding, and clarifying the findings from one phase to another (Greene, Caracelli, & Graham, 1989). Creswell (2018) described characteristics of a case study as "a design of inquiry in which the researcher develops an in-depth analysis of the case, often a program, event, activity, process, or one or more individuals" (p. 14). This design allowed the researcher to understand and describe the conditions existing within the three case subjects and discover commonalities and differences that could apply in a more generalized body of knowledge (Yin, 2014).

Data collection and analysis was conducted in two phases, including the facilitation of interviews and a review of artifacts at each automotive collision repair center. A primary benefit of a multiple case study is the ability to make comparisons across cases. The researcher utilized cross-case synthesis, allowing the data to come together and form a snapshot of each collision center, as well as provide a mechanism to analyze the individual cases as a combined view, revealing common themes and contrasting issues among the individual cases (Creswell, 2018; Yin, 2014). This was achieved through summative evaluations containing a detailed description of each case based on empirical material gathered from the interviews and the review of artifacts. In addition, visual representations such as tables were developed to highlight themes or issues within each case. Parts of the summative evaluations were used in key issues or themes among the three cases.

## Literature Review

With regard to research literature associated with Lean implementation in SMEs, Hu, Mason, Williams, and Found (2015) concluded 101 papers existed in this specific research field. Among these research

publications, 35% utilized the single case study research method, 32% employed survey research, 17% were conceptual studies, 11% facilitated multiple case studies, 4% used mix methods, and 1% involved action research. (Hu et al., 2015, p. 988). While research in this field has been addressed by a significant number of studies utilizing a variety of research methodologies, Hu et al. (2015) noted that 93% of the papers published were primarily associated with automotive, mechanical, electrical, and electronics manufacturing (p. 989). Therefore, there exists a significant research literature gap (less than 3% of studies) related to Lean implementation in SMEs in service industries.

In the case of automotive collision repair, there is no perceived way to standardize the collision repair process since every car that comes in has a different level and type of damage. However, the challenges remain constant: high employee turnover, disorganized and unkempt collision centers, employees' tendency to hoard parts and clutter a workspace, wasted time looking for lost items, and a commission pay structure that does not promote quality work (Jensen, Houseworth, & McCord, 2017). The automotive collision repair industry has begun to consider the practical use and potential benefits of Lean Six Sigma as Lean-for-Collision Training Programs are now available, and several collision repair centers in various stages of Lean Six Sigma implementation have been featured in industry publications and academic case studies. One such repair center, chronicled in the case study from Jensen et al. (2017), increased annual revenues from $700,000 to $2.5 million, drastically reduced employee turnover, decreased its repair shop footprint, and cycle time customer delivery average well below the industry standard in just under three years. Another example of successful Lean Six Sigma implementation at an automotive collision repair center includes a collision center in Lubbock, TX. According to Guyette (2016), because of their Lean Six Sigma training and development, Collision King boasted an average cycle time of five days, $12.5 million in annual revenue, and a staff that is committed to "superior quality and service," as well as a leadership in place that is committed to maintaining this high level of service (p. 26). While these successes continue to frequent industry news, little to no academic literature discussing the successful implementation of Lean Six Sigma in the automotive collision repair industry is available.

## Results and Discussion

This study reviewed what benefits each automotive collision center realized from their Lean-for-Collision Training and Development Initiative and what barriers each center encountered that hindered their

progression from one identified phase to the next. Interviews with Vice Presidents of Operations (from three different collision centers) were used to capture their experiences and perceptions of the impact the training had on the overall performance of the automotive collision repair centers. The analysis of the artifacts and the total costs associated with the Lean-for-Collision Training and Development Initiative was used to determine if the automotive collision repair centers experienced a return on their initial investment. A full review of the results of this study can be found in Appendix C.

The problem addressed by this study was to resolve the lack of standardization in the automotive collision repair process. Challenges such as disorganized and unkempt collision centers and employees' tendency to hoard parts and clutter a workspace led to wasted time looking for lost items. High employee turnover carries a high cost, and many automotive collision repair centers use a commission pay structure that does not promote quality work (Jensen et al, 2017). Interviews with Vice Presidents of Operations and a review of artifacts at each collision center in this study revealed ways to address these challenges.

**Lean-focused leadership and Lean-engaged employees**

The automotive collision repair center leadership suggested the speed and level of success to which a collision center progresses through the Six Sigma Framework is dependent upon two important factors: Lean-Focused Leadership and Lean-Engaged Employees.

*Lean-Focused Leadership.* All three collision centers expressed the need for someone on staff to be designated the resident Lean Champion or Lean Leader of the collision center. While it may be difficult to move this individual from their normal responsibilities, this leader needs to be solely responsible for the integration of Lean training, the development of the Lean culture, and sustaining the results. Confirming the building blocks of a learning organization from Garvin et al. (2008), the participants stated this staff member must provide the steady and persistent leadership needed to drive the Lean-for-Collison Training and Development Initiative at the collision center. In each of the cases, the Vice President of Operations was assigned to this role, but this was in addition to his current responsibilities which made the process even more challenging. It is interesting to note, that one collision center, Case Study #1, was able to progress through the Six Sigma Framework is just a year and a half, while the other two cases took an average of four and half years. Having the Vice President of Operations focused on Lean implementation only, removing the additional daily responsibilities from this person's job description, could partially explain this fast progression through the Six

Sigma Framework. This conclusion is also consistent with both the Six Sigma Framework for SMEs, specifically in Phase 1 needing "Strong Leadership and Top Management Commitment," but also the notion that Six Sigma implementation works best with a "top-down approach" meaning when senior leadership buys-in, supports it, and drives the Lean implementation process (Kumar et al. 2011, p. 5457).

*Lean-Focused Employees.* Without the right team of employees, Lean implementation and progression through the final phase of the Six Sigma framework is incredibly difficult. Leadership must make another tough decision associated with the Lean process, finding the right staff for the Lean culture. Current employees may be laid-off or terminated and highly skilled candidates may be turned away during the on-boarding process. The employee must fit the Lean culture above all else. If the collision center is committed to continuous improvement, so should the employee. If the collision center facilitates "Lean Learning" meetings at 7:30am (Jensen et al., 2017) every weekday, the employee must participate. Even if he or she is the best collision repair technician in the industry, or maybe the best painter in the country, it will not work out if the individual does not make the commitment to a Lean process and Lean culture. Nowhere is this idea of Lean-focused employees more apparent than in Phase 4 (Sustain) of the Six Sigma Framework. Each step in this phase of the model is associated with building and sustaining a strong commitment to Lean among employees, whether that be developing current employees into future managers with a dedication to continuous improvement (Step 10: Commitment to continuous improvement), empowering employees to take initiative in their own improvement projects (Step 11: Linking Six Sigma to intrinsic motivation of employees), or fostering a passion and commitment for life-long learning (Step 13: Progression towards learning organization) (Kumar et al., 2011).

**Direct Repair Programs (DRP) are in direct conflict with Lean culture.**

Identified as a prominent theme, it was concluded that DRP contracts with insurance companies, while significantly increase revenue for participating collision centers in the short-term, are not conducive to operating a sustained Lean-for-Collision repair process or maintaining a Lean culture. One salient recommendation speaks volumes to this conclusion. Once Lean implementation has begun, the leadership, technicians, and support staff must never revert to pre-Lean processes if Phase 4 of the Six Sigma Framework is to be achieved. Prioritizing the demands and expectations of insurance companies in terms of performance efficiency, while disregarding your collision center's Lean process, culture, customer experience, (even if only mo-

mentarily) will negatively affect your progression as a Lean collision center. Realizing the long-term benefits of Lean-for-Collision takes the intestinal fortitude to sacrifice the quick financial returns of DRPs and commit to the Lean-for-Collision.

**Utilize performance metrics that are applicable to your collision center process.**

Identifying methods to evaluate progress is a critical component of Phase 3 of the Six Sigma Framework model. In terms of the Lean-for-Collison repair process, there are several performance metrics that are generally utilized to track performance progression, including vehicle touch-time, vehicle cycle-time, work-in-process, etc. There was a consensus among collision center leadership that among the performance metrics available, the vehicle touch-time metric provided their collision center the most accurate measure of process efficiency. The justification for such a claim was that a collision repair center could have a low cycle-time and a horrible touch-time, or it could have a high cycle-time with a horrible touch-time. It was this discrepancy that led each collision center to a conclusion that reinforced ASQ's (2017) and Ortiz's (2009) suggestion for the establishment of metrics (such as floor shop metrics) and key performance indicators. In addition, it has also inspired these collision centers to seek and out and develop performance metrics that evaluate their own unique Lean-for-Collision processes. This level of creativity and innovation among Lean collision centers could not only assist *MVP Business Solutions* instructors in developing improved performance metrics for training program and development purposes, but also help *MVP Business Solutions* consultants and collision center leadership reach Phase 4 of the Six Sigma Framework, implementing Lean-for-Collision training more effectively.

**A Lean-for-Collision Training and Development Initiative is worth the investment.**

As result of their Lean-for-Collision Training and Development Institutive, each collision improved work/life balance for their leadership and employees, increased employee compensation, realized significant improvement in process efficiency, and posted substantial Return-on-Investment percentages from Lean training and development.

First, from an employee work/life balance and compensation perspective, each Vice President of Operations noted that overall employee workload decreased in terms of total hours worked or reduced physical activity during work hours, and employee compensation increased as gains in efficiency produced more revenue for the collision center. Second, in terms of process efficiency, each collision center increased its vehicle

touch-time beyond the industry average of 2 hours per day per vehicle, and all but one collision center evaluated in the study was able to able to reduce its vehicle cycle time below the industry average of 12.5 days. Finally, regarding a collision center's Return-on-Investment from Lean training and development, in all cases evaluated in this research study, the collision center realized a positive Return-on-Investment (ROI).

## Conclusion

This research study not only illustrated the value and feasibility of implementing Lean-for-Collision methods at an automotive collision repair center, but also the practicality of facilitating a Return-on-Investment (ROI) analysis of a Lean Training and Development Initiative at a small business in a service industry. While the findings of this study would certainly be of interest to collision centers considering Lean implementation, it cannot be overlooked that entrepreneurs and small businesses, from a variety of sectors, could also utilize the Six Sigma Framework to organize, track, and implement their own Lean training and development initiative, yielding the benefits from Lean and striving for a balance in cost, quality, and service delivery.

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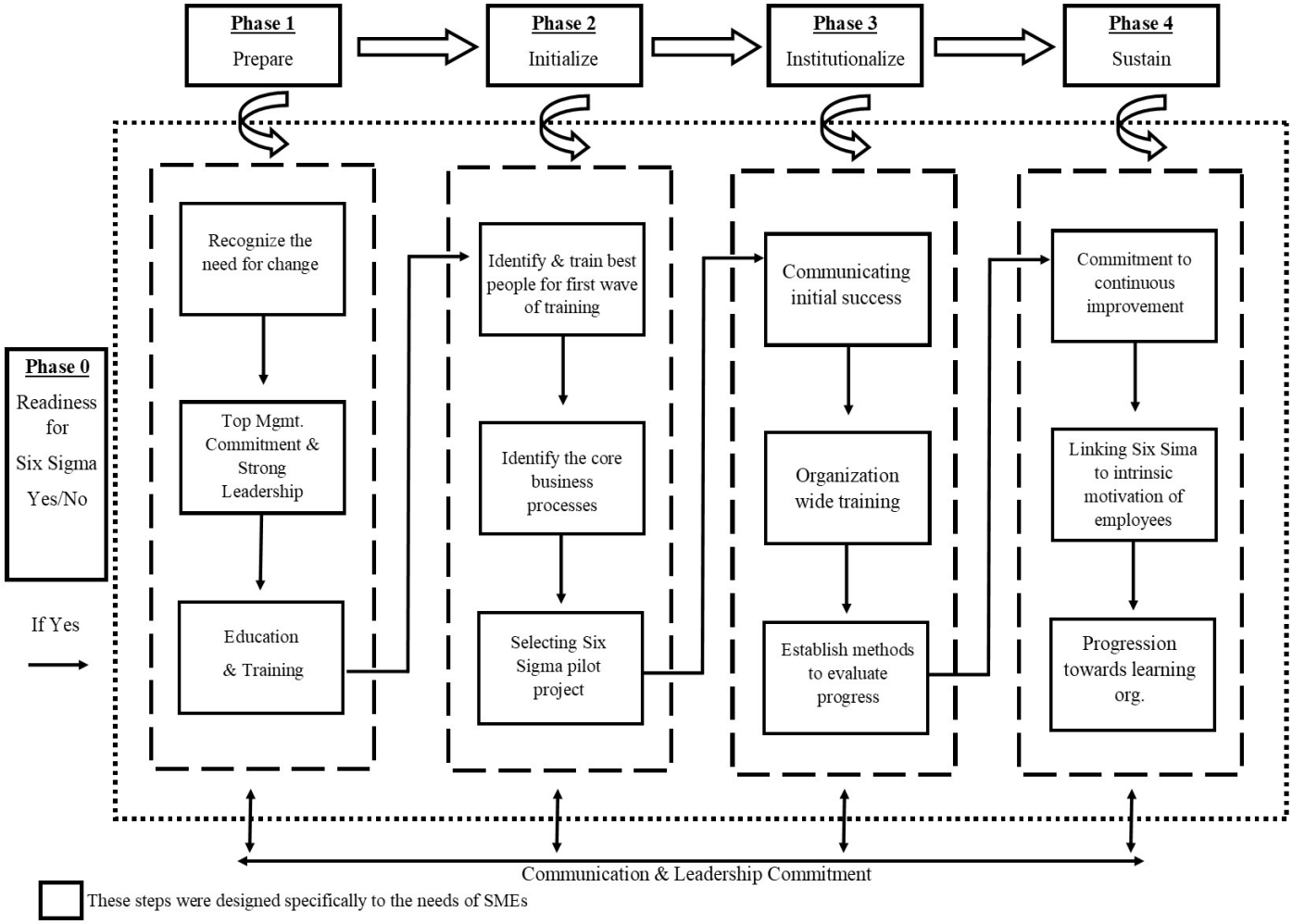
Appendix A

*Figure 1*. Step-By-Step Approach in the Five Phase Six Sigma Framework for SMEs (Kumar et al., 2011, p. 5454).



Appendix B
Research Questions and Hypotheses

**Phase One: Qualitative Design**

Research questions in this phase will be answered with data collected in personal interviews with Vice President of Operations at each collision center.

**RQ1:** How did the automotive collision repair centers conceptualize their progression through the Six Sigma framework for SMEs model?

**RQ2:** What barriers exist among the automotive collision repair centers that impede progression from one phase of the Six Sigma framework to the next phase?

**RQ3:** What perceptions do Vice Presidents of Operations have regarding the impact of the training upon the overall performance of the center?

**Phase Two: Quantitative Design**

The Research question and corresponding hypotheses in this phase will be answered with data collected from the review of artifacts at each collision center.

**RQ4:** How has the Lean-for-Collision Training and Development Initiative and progression to Phase 4 of the Six Sigma Framework for SMEs impacted the automotive collision repair centers?

**$H1_a$:** Automotive collision repair centers experience a lower than industry average "key-to-key" vehicle cycle time rate of 12.5 days.

**$H1_b$:** Automotive collision repair centers experience a higher than industry average collision repair touch-time rate of 2 hours per day, per vehicle.

**$H1_c$:** Automotive collision repair centers experience a lower than industry average automotive repair technician annual turnover rate of 14.5%.

**$H1_d$:** Automotive collision centers who have implemented Lean Six Sigma methods and have progressed to Phase 4 of the Six Sigma Framework for SMEs model, experience a positive Return-on-Investment (ROI) on their Lean-for-Collision Training and Development Initiative.

Appendix C

# Results

The purpose of this study was to evaluate the effects of Lean-for-Collision Training and Development Initiatives on participating automotive collision repair centers that completed their training at *MVP Business Solutions*. This study reviewed what benefits each automotive collision center has realized from their Lean-for-Collision Training and Development Initiative and what barriers each center encountered that hindered their progression from one identified phase to the next. Interviews with Vice Presidents of Operations were used to capture their experiences and perceptions of the impact the training had on the overall performance of the automotive collision repair centers. The analysis of the artifacts and the total costs associated with Lean-for-Collision Training and Development Initiative was used to determine if the automotive collision repair centers experienced a return on their initial investment.

# Findings

## Phase One Analysis

Phase One of data analysis provided evidence to answer Research Questions 1, 2, and 3. Data were organized in the order of the research questions and indicated the presence of emerging themes. Evidence supporting each theme was presented in the form of direct quotations from the interviewees' responses. A narrative of each interview was created and included as Appendix D for Case Study #1, Appendix E for Case Study #2, and Appendix F for Case Study #3. Within the narratives, pseudonyms were utilized for both the collision centers and study participants to ensure confidentiality.

## Research Question 1

To answer Research Question 1: *How did the automotive collision repair centers conceptualize their progression through the Six Sigma framework for SMEs model?,* the researcher asked participants questions such as "Please explain the business methods you have implemented in the collision center," and "If you could go back and do things over again, what would you do differently in terms of how the collision center has operated?" Several reasons for change were varied; however, four themes emerged from the analysis of the data: nominate a full-time Lean Champion or Lean Leader, expect to lose employees during Lean implementation, employees can drive the training experience, and Phase 3 and 4 of the Six Sigma Framework are considered the most challenging.

*Nominate a Full-time Lean Champion or Lean Leader.* One participant spoke emphatically, "One person has to oversee this process and that's all he should be focused on. There were so many times that I took my eye off the ball and let things (processes) slip back into the old way of doing things (Pre-Lean processes) because I was trying to do my other jobs. I know because of this that it took us longer to implement Lean at the shop. That person's job should just be to implement Lean, and that's it." Another study participant added, "My primary focus here is to make sure we continue to get better. It took us awhile to figure out what my role was going to be as the VP of Operations, but for now it's just implementing Lean. It's nice not having to worry about anything else and I can just focus on this process. I can lead training and help technicians troubleshoot and come up with better ways to implement Lean around the shop."

*Expect to Lose Employees During Lean Implementation.* The study participants cautioned those collision centers considering Lean to expect to lose employees during implementation. In this study, participants experienced both employee lay-offs and terminations. One study participant explained, "During our implementation period, we actually got extremely slow and we had to lay off employees for the first time in nine years. There were a couple employees that were eliminated mainly in the front office operations. However, this wasn't necessarily a bad thing, as we found out that we had way too much overhead in the office for what we needed, so it came at a perfect time to restructure the company." Another participant noted he had to let his most senior painter go. His painter would express his dissatisfaction with the new Lean process, "I've been making my living the same way for 22 years and I'm not changing now." The participant would respond, "Man, you're backing me into a corner because I'm out of ideas, and we are not staying the same, so I'm going to have to let you go").

*Employees can drive the training experience.* During the implementation of the Lean training on site at the collision center, study participants recommended the training must be employee (training participant) driven. It was discovered during interviews that the most effective means of transferring the training content to practice in the collision center was giving the employees the opportunity to lead their own training sessions. One participant noted, "Putting your technicians in a classroom or the conference room and talking at them or making them read books isn't going to work. The training experience must be hands-on, and they must participate. Another participant spoke to this notion. "I would recommend having staff members (technicians) lead specific Lean projects around the shop. For example, that could be Leaning out the paint booth process, using 5S for the parts area, re-organizing the entire layout of the shop."

**Research Question 2**

To answer Research Question 2: *What barriers exist among the automotive collision repair centers that impede progression from one phase of the Six Sigma framework to the next phase?* The researcher asked participants the question: "What specific factors impeded/ promoted your progression through each phase of the model?" Several barriers to implementation were identified; however, three themes emerged from the analysis of the data: insufficient employee engagement or buy-in of Lean methods and the necessary and consistent leadership to drive and maintain the culture of Lean, as well as the adoption of Direct Repair Programs (DRPs) with insurance companies.

*Insufficient employee engagement.* One study participant explained his experience. "In addition to our new pay structure, we had staff members that didn't like being in a culture where we read books every morning, and where we spend time and energy working on improvements. Those employees just wanted to come in and fix cars". Another participant would add, "I knew who the disassembly technician was going to be, but I did not know who the estimator was going to be. At the time, we had an estimator that was very old school in his methods, and unfortunately didn't get along the best with the technicians or have the best attitude towards the new processes. I knew that if we put him out there, we were going to fail. We struggled on how to maneuver those waters. In fact, we did not x-ray a car until April of the following year. There was a period during the initial stages of Lean implementation that some of the guys were like, when are we going to get this thing going? I mean, we cleaned up and organized our shop (5S) and brought our Work-in-Process (WIP) number down, but when are we going to do everything else?"

*Inconsistent leadership.* One participant described his experience. "It was the commitment to continuing to find ways to improve that I know I failed as a leader. These are the things that increased the amount of time needed to implement Lean at our shop. You know the old Cortez saying right? If you burn the ships, there's no chance of retreat. I think that's what I would've done differently as a leader and as a manager. I would've done a better job of being more steadfast at saying, we're not going to go back to the way things were."

*Direct Repair Programs (DRP).* A Direct Repair Program (DRP) is an agreement between an insurance company and a collision repair center that lets the insurance company control most of the costs associated with a collision repair process. While adding significant annual revenue to a collision center's bottom line,

DRP agreement provide the insurance company the ultimate control. One participant explained, "Once this DRP contract grew to be nearly 56% of our business and they (insurance company) still wanted more control. We started working for them and not our customers. This jeopardized all the work we had put in to building our Lean culture and reputation." This participant described one experience in particular, "I remember we had customers that would slam the panic bar door open and walking out our facility, "What happened to this collision center?" Because we couldn't take care of them, right? We would have to tell them, "Sorry Sir, it's going to be four weeks before you can get in because I have to make this insurance company a priority. It was a horrible and ugly relationship. One of those, that I knew if we asked to cut back on volume, or if we asked them to add another shop, they would tell us, "Go open a second store." In the end, I was like, no way man. I'm out." This participant understood at the time that this decision would lose the shop revenue in the short term, and set them back in the Six Sigma Framework model, but was confident that revenues would increase and performance metrics would improve as the collision center would take back control of their processes. Another study participant agreed, "You have to be careful what you wish for" (when speaking on DRPs), "They make you a lot of money overnight, but at what cost?" If you start working for the insurance company and not your customer, you going to lose what you've built."

**Research Question 3**

To answer Research Question 3: *What perceptions do Vice Presidents of Operations have regarding the impact of the training upon the overall performance of the center?* The researcher asked participants questions such as: "What performance metrics are you tracking?" and "Do you think your business growth is because of your implementation of Lean-for Collision Principles or additional factors?" Several examples of the impact were identified; however, two themes emerged from the analysis of the data: use appropriate industry metrics to accurately track performance, and most new business growth was due to implementing a Lean process.

*Use applicable industry metrics to accurately track performance.* While each case participant noted that they were tracking the typical collision industry performance metrics such as vehicle cycle-time, work-in-process, and vehicle touch-time, each expressed a desire for metrics that were appropriate or applicable for their own center. For example, each preferred vehicle touch-time as the metric to most accurately measure collision center performance. One participant explained, "If you've got a 30-day vehicle cycle time, but your

vehicle touch-time is four hours per vehicle per day, well that just means you're working on great big jobs, right? This is compared to when an insurance company or collision center quotes you an average cycle time of 11.8 days. Well, that's great, that's lower than the industry average, but what's the touch-time? Oh, it's 1.8. Well, that's not great. But if I've got 11.8-day cycle-time and I've got a touch-time at 3.5 then we're crushing it. So, the touch time really becomes the key indicator."

Another study participant also agreed. "Cycle times can be misleading. I won't even talk to other shops in our industry because they don't know what they're talking about. They say, oh we got a four-day cycle-time. No, you don't. You don't even know what that means. How did you calculate that? And then you'll see shops that you know don't perform well, and they're like, "oh yeah, six days," well how'd you get that? "State Farm told me." Okay so you're six days for State Farm in your DRP agreement but you're not for your other customers?" Gordon would also emphasize that you could have a low cycle-time and a horrible touch-time, or you could have a high cycle-time with a horrible touch-time."

*Most of new business growth was due to Lean.* Each collision center was able to assign a percentage of impact from their Lean-for-Collision Training and Development Initiative. Both Case Study #1 and Case Study #2 expressed that 100% of their growth and increase in efficiency was due to the implementation of Lean. The participant from Case Study #2 elaborated,

"I think there are two main factors that drive business growth and revenue. One is employee engagement and the second is customer engagement. Had we not implemented Lean and instituted ways to improve, we wouldn't have the level of employee engagement we have now, and the culture wouldn't be there for our customers."

While the participant from Case Study #3 noted that their Lean implementation contributed 85%, emphasizing "I really think Lean is the bulk of our growth," he would also note that some creative advertising ideas from his staff have certainly contributed to their success as well. Furthermore, in all cases evaluated in this study, each collision center was able to reduce stress for formal leadership and employees by standardizing processes, reducing hours, and increasing incomes, thus increasing quality of life for everyone.

*Summary.* The emergent themes (see Table 6) provided valuable insight to address how each automotive collision repair center conceptualized their progression through the Six Sigma framework for SMEs model (RQ1) as well as a cross-case synthesis, what barriers existed among the automotive collision repair centers

that impeded progression from one phase of the Six Sigma framework to the next (RQ2), and ultimately what perceptions the Vice President of Operations had regarding the impact of the training upon the overall performance of the center (RQ3).

**Table 1**

*Individual and Cross-Case Synthesis of Emergent Themes*

| Case Study | Codes from Each Case Study | Prominent Themes |
|---|---|---|
| Case Study #1 | • Vice President of Operations is in charge of Lean implementation only<br>• Cycle time metric is misleading<br>• Use vehicle touch-time and Work-In-Process as primary performance metrics<br>• Experiment with new performance metrics<br>• Current industry metrics don't tell the whole story<br>• Phase 3 and 4 is the most difficult to reach<br>• Experienced information overload from MVP training<br>• MVP Training Consultants helpful and important to implementation<br>• Lean improves work-life balance for employees<br>• Use employee incentives to boost Lean progression and performance | 1. Nominate full-time Lean Champion or Lean Leader<br>2. Expect to lose employees during Lean implementation<br>3. Employees can drive the training experience<br>4. Barriers to phase progression include lack of employee buy-in and appropriate leadership<br>5. Direct Repair Programs (DRP): "Be Careful What You Wish For"<br>6. Use appropriate industry metrics to accurately track performance<br>7. Most of new business growth was due to Lean process |
| | | |

| Case Study | Codes from Each Case Study | Prominent Themes |
|---|---|---|
| Case Study #1 | • Experienced layoffs during Lean implementation<br>• The right staff needs to be hired to implement Lean<br>• 100% of growth due to Lean<br>• Did not track employee turn-over<br>• Lean reduces stress | |
| Case Study #2 | • Vice President of Operations is in charge of Lean implementation and original responsibilities<br>• MVP Training is intense/ overwhelming<br>• Training Workshops needed to help apply Lean training<br>• Hire employees that want to work in a Lean environment<br>• Use vehicle touch-time for performance metric<br>• Fired employees whom did not buy-in to Lean during implementation<br>• Insurance DRP's affect Lean performance/ maintaining Lean culture<br>• Eliminate DRP's from business model<br>• Do not allow your employees to go back to old methods<br>• 85% of growth due to Lean<br>• Phase 4 is the most difficult to reach and maintain/easy to regress<br>• Did not track employee turn-over<br>• Lean improves work-life balance for employees | |

| Case Study | Codes from Each Case Study | Prominent Themes |
|---|---|---|
| Case Study #3 | • MVP Training is intense<br>• MVP Consultant training Workshops are critical to Lean implementation<br>• Vice President of Operations is in charge of Lean implementation and original responsibilities<br>• Phase 3 and 4 are the most difficult to reach and maintain/easy to regress<br>• Hire trustworthy employees<br>• Employees must fit the Lean culture<br>• Lean reduces stress, decreases employee workload<br>• Fired employees whom did not buy-in to Lean during implementation<br>• Involve employees in hands-on training<br>• Insurance DRP's can affect Lean progression and sustainment<br>• Did not track employee turnover<br>• 100% of growth due to Lean<br>• Lean makes employees more money<br>• Lean improves work-life balance for leadership and employees | |

**Phase Two Analysis**

Phase Two of data analysis provided evidence to answer Research Question 4 and corresponding Hypotheses 1a, 1b, 1c, and 1d.

**Research Question 4**

To answer Research Question 4: *How has the Lean-for-Collision Training and Development Initiative and progression to Phase 4 of the Six Sigma Framework for SMEs impacted the automotive collision repair centers?* The researcher conducted a review of artifacts, including financial statements, spreadsheets, and performance dashboards, to compare the efficiency and quality of each automotive collision repair center prior to the implementation of the Lean-for-Collision Training and Development Initiative and their current status post-training and development. The results, as illustrated in Table 7, confirmed that all three automotive collision repair centers evaluated in this study were able to reduce their vehicle cycle-time and an increase their vehicle touch-time. These performance metrics were then used to conduct a Return-on-Investment Analysis, providing a positive Return-on-Investment of their Lean-for-Collision Training and Development Initiative.

**Table 2**
*Performance Metrics by Case Study*

| | Vehicle Cycle Time | | Touch-Time Rate | | Annual Turnover Rate | |
|---|---|---|---|---|---|---|
| | Prior to training | After training | Prior to training | After training | Prior to training | After training |
| Case Study #1 | 14.7 days | 8.4 days | 1.6 hours | 2.7 hours | N/A | N/A |
| Case Study #2 | 14 days | 14 days | 1.5 hours | 3.5 hours | N/A | N/A |
| Case Study #3 | 15.7 days | 9.7 days | 1.4 hours | 3.1 hours | N/A | N/A |

**Hypothesis $1_a$**

Results for Hypothesis $1_a$: *Automotive collision repair centers experience a lower than industry average "key-to-key" vehicle cycle time rate of 12.5 days.,* indicated that Case Study #1 and Case Study #3 reduced their average vehicle cycle-time to a number below the industry average vehicle cycle time rate of 12.5 days. While at the time of the interview, Case Study #2 was operating with an average vehicle cycle time of 14 days (exceeding the industry average), it was considered unusually high due to their re-tooling efforts from ending their Direct Repair Program (DRP) contract with a major insurance company. Therefore, Hypothesis $1_a$ was not supported.

**Hypothesis $1_b$**

Results for Hypothesis $1_b$: *Automotive collision repair centers experience a higher than industry average collision repair touch-time rate of 2 hours per day, per vehicle*., indicated that all three case studies increased their vehicle touch-time rate to one that exceeded the industry average of 2 hours per day per vehicle. These findings support $H1_{b.}$

**Hypothesis $1_c$**

Results for Hypothesis $1_c$: *Automotive collision repair centers experience a lower than industry average automotive repair technician annual turnover rate of 14.5%*, were not calculated because none of the case studies formally track repair technician turnover rates.

**Return-On-Investment Analysis**

To calculate each collision center's Return-on-Investment (ROI) percentage from their Lean-for-Collision Training and Development Initiative, the investigator compiled both the total costs associated with the training and development, and each automotive collision repair center's annual revenues posted during and after Lean-for-Collision implementation.

It is important to note that the estimation of ROI is not necessarily an exact science. Utilizing the perspective of the subjects within this study in terms of training and development investment cost and achieved fiscal year revenues, one must determine if revenues increased over time from the investments. ROI can include any benefit from the training and development program. It was also imperative to the accuracy of the ROI percentage to control for additional investments, environmental factors, etc. that were not part of the Lean-for-Collision Training and Development Initiative that may have affected the annual revenues. For this study, ROI was calculated using the following equation:

Sum of Revenue Increases for each fiscal year after Lean implementation/Training Program Investment = ROI x 100 = Return-on-Investment Percentage

*Total Cost of Lean-for-Collision Training and Development Initiative (Case Study #1)*

Considering the training program costs associated with the Analysis, Design, and Development ($3,000.00), Delivery of Training Off-Site ($22,100.00), and Delivery of Training On-Site ($117,000.00), the total cost for the Lean-for-Collision Training and Implementation Initiative was $142,100.00. Table 8 illustrates an itemized list of the training costs incurred.

**Table 3**
*Case Study #1: Lean-for-Collision Training and Development Initiative Costs*

| | |
|---|---|
| Analysis, Design, and Development | |
| (Vice President of Operations /Owner) as Training & Development Department | |
| Independent Research (Travel to Collision Centers) | $3,000.00 |
| Books/ Resource Materials (Free) | 0.00 |
| Subtotal | $3,000.00 |
| Delivery of Training (Off-Site) Minneapolis, MN | |
| Lean-for-Collision Green Belt Training Tuition for (Vice President of Operations) ($1,500 x 1) | $1,500.00 |
| Lean-for-Collision Green Belt Training Tuition for Employees ($1,500 x 6 Employees) | $9,000.00 |
| Airfare ($800 x 7 Employees) | $5,600.00 |
| Hotel ($714 x7 Employees) | $5,000.00 |
| Food ($142 x 7 Employees) | $1,000.00 |
| Subtotal | $22,100.00 |
| Delivery of Training (On-Site) | |
| Vice President of Operations/ Owner Compensation (Annual Salary and Benefits) | $85,000.00 |
| White Belt/ Repair Planning Workshop Combo | $2,000.00 |
| Paint Shop Optimization Pilot Program | $4,000.00 |
| Production Downtime for Lean Implementation (2 days x $12,000) | $24,000.00 |
| Equipment for Implementation<br>(Floor Tape: $1,200)<br>(Tables: 1 for X-ray and 1 for Parts: $500)<br>(Laminated Signs: $300) | $2,000.00 |
| Subtotal | $117,000.00 |

| Grand Totals | |
|---|---|
| Analysis, Design, and Development of Training | $3,000.00 |
| Delivery of Training (Off-Site) | $22,100.00 |
| Delivery of Training (On-Site) | $117,000.00 |
| Total Training Costs | $142,100.00 |

*Return-On-Investment Analysis for Case Study #1*

Utilizing the total costs associated with Case Study #3's Lean-for-Collision Training and Development Initiative and the annual revenues earned during the Lean implementation period (see Table 9), the Return-on-Investment percentage was calculated.

**Table 4**
*Case Study #1: Annual Revenues for Lean Implementation Period*

| Fiscal Year | Annual Revenue Amount |
|---|---|
| 2017 | $2,950,000.00 |
| 2018 (Training and Implementation) | $2,700.000.00 |
| 2019 | $3,600,000.00 |

Since previous revenues were $2,950,000.00 (2017), and training and implementation occurred in 2018, the sum of the change in revenue -$250,000 (2018 Revenue Decrease) + $900,000 (2019 Revenue Increase) = $650,000.00. The researcher divided the revenue increase by the total cost of Lean-for-Collision Training and Development Initiative ($142,100.00) and multiplied by 100. The result is 457% ROI.

*Total Cost of Lean-for-Collision Training and Development Initiative (Case Study #2)*

At Case Study #2, the training program costs associated with the Analysis, Design, and Development were estimated at $1,000.00, Delivery of Training Off-Site were $37,000.00, and Delivery of Training On-Site reached $71,887.20. The total cost for the Lean-for-Collision Training and Implementation Initiative was $109,887.20. Table 10 illustrates an itemized list of the training costs incurred.

**Table 5**
*Case Study #2: Lean-for-Collision Training and Development Initiative Costs*

| | |
|---|---|
| Analysis, Design, and Development | |
| (Vice President of Operations /Owner) as Training & Development Department | |
| Independent Research (Travel to Collision Centers) | $1,000.00 |
| Books/ Resource Materials (Free) | 0.00 |
| Subtotal | $1,000.00 |
| Delivery of Training (Off-Site) Minneapolis, MN | |
| Lean-for-Collision Green Belt Training Tuition for (Vice President of Operations) ($2,500 x 1) | $2,500.00 |
| Lean-for-Collision Green Belt Training Tuition for Employees ($2,500 x 10 Employees) | $25,000.00 |
| Airfare ($500 x 10 Employees) | $5,000.00 |
| Hotel ($100 x 5 Rooms x 5 Nights) | $2,500.00 |
| Delivery of Training (Off-Site) Minneapolis, MN (Continued) | |
| Food ($200 x 10 Employees) | $2,000.00 |
| Subtotal | $37,000.00 |
| Delivery of Training (On-Site) | |
| Lean Consultant: (6 Kaizen Workshop Events) (6 Workshops x $5,000) | $30,000.00 |
| Employee Training Time: (96 Hours x $414.45 Per Hour) | $39,787.20 |
| Equipment for Implementation<br>(Floor Tape: $500)<br>(Band-aids: $100)<br>(Tables: 1 for X-ray and 1 for Parts: $500)<br>(Laminated Signs: $500) | $2,100.00 |
| Subtotal | $71,887.20 |
| Grand Totals | |
| Analysis, Design, and Development of Training | $1,000.00 |
| Delivery of Training (Off-Site) | $37,000.00 |
| Delivery of Training (On-Site) | $71,887.20 |
| Total Training Costs | $109,887.20 |

*Return-On-Investment Analysis for Case Study #2*

Utilizing the total costs associated with the Lean-for-Collision Training and Development Initiative and the annual revenues earned during the Lean implementation period (see Table 11), the Return-on-Investment percentage was calculated.

**Table 6**
*Case Study #2: Annual Revenues for Lean Implementation Period*

| Fiscal Year | Annual Revenue Amount |
|---|---|
| 2007 | $2,400,000.00 |
| 2008 (Training Year) | $2,900,000.00 |
| 2009 | $2,800,000.00 |
| 2010 (Signed DRP Agreement Mid-Year) | $3,900,000.00 - $500,000.00 =$3,400,000.00 |
| 2011 (Under DRP Agreement) | $4,600,000.00 - $500,000.00 =$4,100,000.00 |

Unlike, Case Study #1, Case Study #2 needed three years to reach full implementation (Phase 4) of Lean-For-Collision. Therefore, the years 2007-2011 were utilized to calculate ROI. Previous revenues were $2,400,000.00 (2007), and training and implementation occurred in 2008. The sum of the change in revenue was -$100,000 (2009 Revenue Decrease) + $1,100,000 (2010 Revenue Increase) + $700,000 (2011 Revenue Increase). As discussed earlier, in order to ensure the accuracy of the ROI percentage, any additional factors that could impact the revenue for each fiscal year not related to the Lean-for-Collision Training and Development Initiative, must be included in the calculation. For Case Study #2, a Direct Repair Program (DRP) agreement was signed with a major automotive insurance provider in the middle of 2011 essentially guaranteeing an additional $1,000,000 in annual revenue. This additional revenue stream had nothing to do with the implementation of Lean-for-Collision; therefore, cannot be used in the calculation of ROI. Consequently, to determine Case Study #2's ROI on their Lean-for-Collision Training and Development Initiative, $500,000 was removed from fiscal year 2009 and $500,000 from fiscal year 2010. From these changes, the ROI equation included the sum of the change in revenues of -$100,000 (2009 Revenue Decrease) + $600,000 (2010 Revenue Increase) + $700,000 (2011 Revenue Increase) =$1,200,000.00. The researcher divided the revenue increase by the total cost of Lean-for-Collision Training and Development Initiative ($109,887.20) and multiplied by 100. The result was 1,092% ROI.

*Total Cost of Lean-for-Collision Training and Development Initiative (Remington's Custom Auto Body LLC)*

At Case Study #3, the training program costs associated with the Analysis, Design, and Development were estimated at $1,725.00, Delivery of Training Off-Site were $26,400.00, and Delivery of Training On-Site reached $60,275.00. The total cost for the Lean-for-Collision Training and Implementation Initiative was $88,400.00. Table 12 illustrates an itemized list of the training costs incurred.

**Table 7**
*Case Study #3: Lean-for-Collision Training and Development Initiative Costs*

| Analysis, Design, and Development | |
|---|---|
| (Vice President of Operations /Owner) as Training & Development Department | |
| Independent Research (Travel to Collision Centers) | $1,725.00 |
| Books/ Resource Materials (Free) | 0.00 |
| Subtotal | $1,725.00 |

| Delivery of Training (Off-Site) Minneapolis, MN | |
|---|---|
| Lean-for-Collision Green Belt Training Tuition for (Vice President of Operations) ($2,500 x 1) Louisville, KY | $2,500.00 |
| Lean-for-Collision Green Belt Training Tuition for Employees ($2,500 x 10 Employees) | $12,500.00 |
| Airfare ($175 x 5 Employees) | $875.00 |
| Hotel ($100 x 41 Rooms for all Trips) | $7,175.00 |
| Food (Total for all Trips) | $3,350.00 |
| Subtotal | $26,400.00 |
| Delivery of Training (On-Site) | |
| Workshops (WS): (Lean Consultant WS, 2/ 1-Day White Belt WS, 3 Black Belt WS, Admin WS, 3 X-Ray Repair Planning WS) | $24,885.00 |
| Employee Training Time | $31,725.00 |

| | |
|---|---|
| Equipment for Implementation<br>(Floor Tape: $1,250)<br>(Baggies: $540.00)<br>(Tables: 2 for X-ray and 1 for Parts: $900)<br>(Laminated Signs: $300)<br>(Miscellaneous Equipment: Jack stands, Jump box, etc.: $675.00) | $3,665.00 |
| Subtotal | $60,275.00 |
| Grand Totals | |
| Analysis, Design, and Development of Training | $1,725.00 |
| Delivery of Training (Off-Site) | $26,400.00 |
| Delivery of Training (On-Site) | $60,275.00 |
| Total Training Costs | $88,400.00 |

*Return-On-Investment Analysis for Case Study #3*

Utilizing the total costs associated with Case Study #3's Lean-for-Collision Training and Development Initiative and the annual revenues earned during the Lean implementation period (see Table 13), the Return-on-Investment was calculated.

**Table 8***Case Study #3:*
*Annual Revenues for Lean Implementation Period*

| Fiscal Year | Annual Revenue Amount |
|---|---|
| 2012 | $2,752,026.00 |
| 2013 (Training Year) | $2,829.645.00 |
| 2014 | $3,054,403.00 |
| 2015 | $3,007,014.00 |
| 2016 | $3,231,941.00 |
| 2017 | $3,429,169.00 |

Similar to Case Study #2, Case Study #3 needed multiple years (five) to reach full implementation (Phase 4) of Lean-for-Collision. Therefore, the years 2012-2017 were utilized to calculate ROI. Previous revenues were $2,752,026.00 (2012) and training and implementation occurred in years 2012-2017. The sum of the change in revenue was + $ 77,619 (2013 Revenue Increase) + $224,758 (2014 Revenue Increase) -$47,389 (2015 Revenue Decrease) + 224,927 (2016 Revenue Increase) + $197,228 (2017 Revenue Increase) = $677,143.00.

The researcher divided the revenue increase by the total cost of Lean-for-Collision Training and Development Initiative ($88,400.00) and multiplied by 100. The result is 766% ROI.

**Hypothesis $1_d$**

Results for Hypothesis $1_d$: *Automotive collision centers who have implemented Lean Six Sigma methods and have progressed to Phase 4 of the Six Sigma Framework for SMEs model, experience a positive Return-on-Investment (ROI) on their Lean-for-Collision Training and Development Initiative.,* indicated that all three case studies realized a positive Return-On-Investment (ROI) from their Lean-for-Collision Training and Development Initiative (see Table 14). These findings support Hypothesis $1_d$.

**Table 9**

*Summary of ROI Percentages*

| Case Study | Return-On-Investment Percentage |
|---|---|
| Case Study #1 (O'Fallon Autobody) | 457% ROI |
| Case Study #2 (Winston and Sons Collision and Auto Repair) | 1,092% ROI |
| Case Study #3 (Remington's Custom Auto Body LLC) | 766% ROI |

# Impacts of Automation: Manufacturing Jobs in the United States

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## Abstract

As industry continues to embrace the Fourth Industrial Revolution, automation becomes more integral to manufacturing. As a result, the risk to jobs in the manufacturing field increases. This increase in risk affects counties within each U.S. state differently based on workforce distribution. Therefore, an examination of the risk-adjusted for employment is needed to understand the true risk per county. This need increases as the prevalence of automation in the manufacturing industry increases. This study explored, described, and analyzed the risk of manufacturing jobs being replaced by automation on a per county level across the entire United States (US). An adjusted risk value per county per United States region was calculated based on the Bureau of Labor Statistics (BLS) and previously published literature. Results of this study provide an evaluation of the risk per county relative to the manufacturing sector. Furthermore, recommendations are provided for how workers in high-risk areas should respond to potential risks.

## Introduction

In the United States, the manufacturing field employs roughly 11.7 million people making it the fifth largest employer of workers in the United States (The United States Census Bureau, 2020). Manufacturing also accounted for 11.39% of the total gross domestic product (GDP) for the United States in 2018. However, with the progression into the Fourth Industrial Revolution (i.e., Industry 4.0), this may begin to change as we move away from industry that is reliant on human presence to function. By implementing further automation to process and complete system interconnection and communication, all processes are able to communicate with each other (Desoutter Industrial Tools, 2017). This transition could have a large effect on the current job market in the manufacturing sector. A study performed by Manyika et al. (2017), found that by 2030 up to 800 million jobs worldwide could be displaced to automation. The largest effects of automation would be seen in developed countries such as the United States, Japan, and Germany, with the United States experiencing up to a 31% decrease in employment in the manufacturing field.

The purpose of this study was to examine the risk to manufacturing jobs as a result of automation per county across the United States. Risk to manufacturing jobs was quantified in two ways using two research questions,

- What is the percentage of manufacturing jobs at risk per county?
- What is the overall impact automation will have on manufacturing jobs per county?

The results of this study offer workers in the manufacturing field insight into possible future job outlooks while also providing recommendations for how best to respond to this risk.

## Literature Review

The Devaraj et al. (2017) study, *How Vulnerable are American Communities to Automation, Trade, & Urbanization?* analyzed each county's risk of automation and offshoring. Devaraj et al. (2017) took the approach of evaluating automation risk based on a simplified county structure breakdown of employment that was evaluated using the risk values per occupation, as defined by Frey and Osborne (2017). This provided a statistic from which an overall risk could be calculated. Devaraj et al. (2017) took a broad approach to a county's risk, looking at the risk as a whole which lacked the precision necessary to evaluate the risk to manufacturing jobs on a county-by-county level.

The study, *Industry 4.0 digitization and opportunities for sustainability* (Ghobakhloo, 2020) looked at

Industry 4.0, what it is, and how moving forward it was going to create changes within industry through the revision of the current workplace. This evaluation of the forward progression of Industry 4.0 provided insight into how every area of manufacturing could be affected. It also examined the benefits of Industry 4.0 as well as the drawbacks. The Ghobakhloo (2020) study is focused in whole on what exactly these changes entail, how these changes will occur, and what are the positive or negative implications without directly considering any of the direct employment numbers or risk values. The Ghobakhloo (2020) study falls short in that it does not provide for an examination of the risk to jobs as a result of these implications discovered.

Arntz et al. (2017) conducted a study evaluating the risk of automation across different positions within multiple work environments based on the skill required to perform varying tasks as a means of establishing a better understanding of how risk is related to the extent by which each employee is used across their job fields. By exploring the risk to manufacturing jobs on a job-by-job specific approach provided a more focused determination of the risk to jobs. These jobs at risk were determined by readjusting existing values to better estimate the risk present to different jobs across many sectors. However, the Arntz et al. (2017) study only looked at these jobs in a generic sense and not on a county-by-county level and how these factors would affect these jobs.

## Methods and Materials

*Research Design*

This study was a direct comparison study designed to compare and adjust values to help determine the risk to counties within each U.S. state around their manufacturing field. Quantitative data was collected to examine the percentage of risk each county has around manufacturing and to determine the potential number of jobs at risk per county across the United States. The Devaraj et al. (2017) study provided the sorting and regional method through its use of the census breakdown. The breakdown of census regions was defined using the United States Census Division standards. An image of the census division map can be seen in Figure 1. The census regions focus was done for two main reasons. The first was that the census region approach allowed for a region by region look at how automation risk affected each county's manufacturing sector. The second reasoning was that both the Devaraj et al. (2017) study and the Bureau of Labor Statistics (BLS) use the same sorting method making it more efficient to sort into tables to provide for a side-by-side comparison of the data.

The Devaraj et al. (2017) study provides a percentage of potential automation risk based on the make-up employment fields within each county within the United States. The BLS data was retrieved in April 2021 from the U.S. Bureau of Labor Statistics' web site (U.S. Bureau of Labor Statistics., n.d.), and included September 2020 data for the following categories *Year*, *Quarter*, *Employment Totals*, and *Manufacturing Employment Total*.

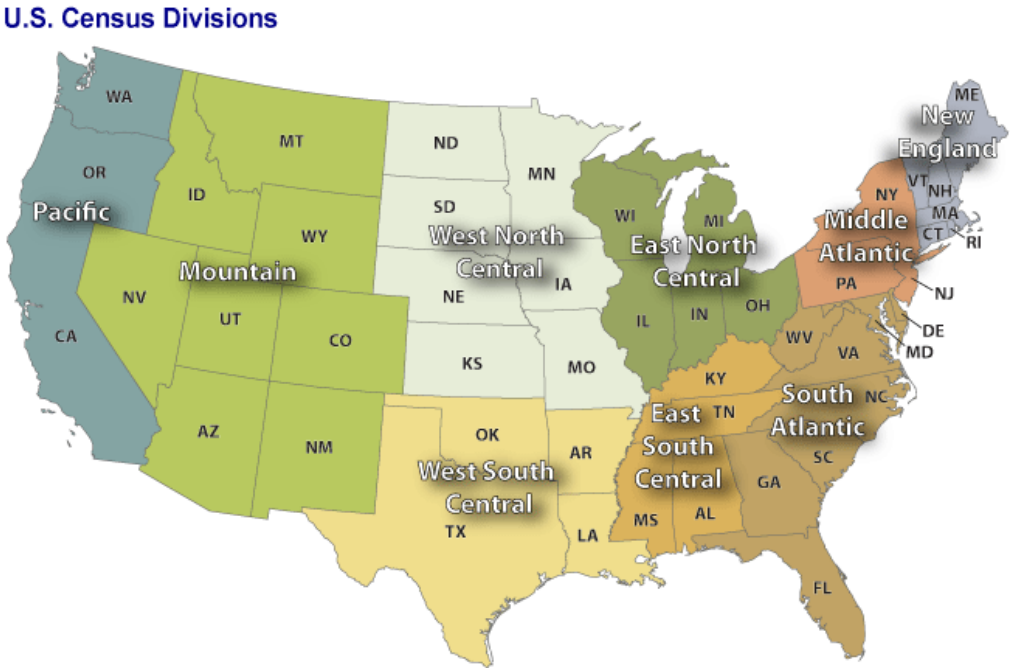


*Figure 1*. Map Depicting the Census Divisions of the United States (National Oceanic and Atmospheric Administration, n.d.)

*Experimental Focus*

For the scope of this research, automation was defined as "the creation and application of technology to monitor and control the production and delivery of products and services." (International Society of Automation, n.d.). Manufacturing was defined by the BLS as "establishments engaged in the mechanical, physical, or chemical transformation of materials, substances, or components into new products." (U.S. Bureau of Labor Statistics, n.d., P. Manufacturing: NAICS 31-33). The BLS employment data that was collected by the BLS using "workers covered by State unemployment insurance (UI) laws and Federal workers covered by the Unemployment Compensation for Federal Employees (UCFE) program" (U.S. Bureau of Labor Statistics, n.d., P. QCEW Overview). Furthermore, this research used Gilchrist's (2016) definition of Industry 4.0 as an environment of "interconnected computers, smart materials, and intelligent machines communicate with one

another, interact with the environment, and eventually make decisions with minimal human involvement" (as cited in Ghobakhloo, 2020, p. 2)

*Measures*

This study evaluated the risk to counties by calculating the percentage of risk each county has around manufacturing and the potential number of jobs at risk per county across the United States. To calculate the percentage automation risk for manufacturing per county the percentage of the workforce that was employed by the manufacturing field per county was calculated. The percentage of the workforce that was employed by the manufacturing field per county (*PM*) was calculated to the nearest one hundredth using Equation 1,

$$PM = \left(\frac{MT}{ET}\right) x100 \quad (1)$$

where *MT* is the September 2020 manufacturing employment total for each county, and *ET* is the September 2020 employment total. An adjusted automation risk to manufacturing (*AR*) was calculated per county to the nearest one-hundredth of a percent using Equation 2,

$$AR = \left(\left(\frac{PA}{100}\right) x \left(\frac{PM}{100}\right)\right) x100 \quad (2)$$

where *PA* is the unadjusted percent automation risk that each county within the United States faces based on the workforce field representation calculated by Devaraj et al. (2017), and *PM* is the percent of the workforce that was employed by the manufacturing field. The potential number of jobs at risk per county (*JA*) was calculated to the nearest full job using Equation 3,

$$JA = \frac{MTxAR}{100} \quad (3)$$

where *MT* is the September 2020 manufacturing employment total for each county, and *AR* is the adjusted automation risk value for manufacturing per county from Equation 2.

## Results and Discussion

*Descriptive Results*

To quantify the percentage of the county's total employment base that is employed by manufacturing, this study collected and examined the current number of employees per county that are employed by the manufacturing field. From the collection of the total employment and manufacturing employment data from the United States and using Equation 1, it was found that the percentage of employment per county ranged from 0.22% in Lexington City, Virginia to 90.25% in Aleutians East Borough, Alaska. The range data was collected from the raw unfiltered data set to assure that no counties were overlooked.

To quantify how a county's automation risk level will affect manufacturing this study calculated the number of manufacturing jobs that are at risk in each county per Equation 3. This data showed what could end up being the number of jobs lost per county across the United States. The county seeing the highest possible number of jobs lost is Elkhart County, Indiana which has a potential job loss risk of 22,006 jobs even though it only has an adjusted risk of automation of 34.64% and an overall automation risk of 62.01%. Lexington City, Virginia showed the lowest potential number of job loss at 0.01 jobs even though it has an adjusted risk of automation of 0.14% and an overall automation risk of 61.13%. This data was collected from the complete data set for this study.


*Figure 2.* Five highest and lowest counties at rick or automation across the U.S. census regions (italicized numbers are the unadjusted automation risk values, bold numbers are the adjusted automation risk values).

*Discussion*

To provide insight into the possible impacts to a county as focused on manufacturing, the county's risk was adjusted from their overall risk to the risk-focused solely on the manufacturing segment of each community's total workforce base. This adjustment allows for a reexamination and reranking of each county so that a county-by-county effect due to manufacturing can be examined. The existing data allowed for an adjustment to be made to each county's risk so that graphs could be made examining the overall top five and lower five counties at risk within each of the nine regions presented in this study. An example of these regional breakdowns of the upper and lower five counties can be seen in Figure 2.

The nine census regions shown in Figure 1 provided a breakdown that allows for a closer examination of how automation will have differing effects across the United States. These differences in effects are illustrated in Figure 2, especially for the East North Central Region where we can see that the above-mentioned county Elkhart County, Indiana with the highest number of potential jobs at risk at 22,006. When the scope is expanded further it can be seen that even though Elkhart County, Indiana's total number of jobs at risk is high, its adjusted automation risk value of 34.64% is not close to the highest adjusted automation risk. The United States county with the highest adjusted automation risk was Aleutians East Borough, Alaska (Pacific Region) with an adjusted automation risk of 60.46%. These differences are a result of the changes that occur within regions. To further explore these differences, the Middle Atlantic Region, shown in Figure 3, was examined more closely as it exhibited some of the largest and smallest variations in automation risk out of all of the regions in the United States.

As is illustrated in Figure 3, the relationship between the highest overall risk to automation does not always hold across the examination after being adjusted to be focused on manufacturing solely. It is seen that for the most part, the highest at-risk overall counties do tend to be located still very close to the top of the manufacturing-focused automation risk. However, the ranking of these counties does tend to be rearranged within this ranking. Sometimes only small changes are made in other occurrences and this ranking changes drastically. An example of small changes can be seen in Figure 3 where Elk County, Pennsylvania had the highest overall risk out of the entire data set but for manufacturing risk, it ranked third. The largest change in Figure 3 can be seen in Bronx County, New York which had a higher risk than some of the top five at risk for manufacturing automation was relocated to the highest at-risk out of the lowest five due to the overall low

density of manufacturing located within the county in comparison to other counties found within this region. This is seen throughout all the graphs of the upper and lower five counties at risk for automation across the nine regions that the risk is heavily affected by the overall manufacturing density present within the counties and as such, there is a relation to the overall risk that was calculated by the Devaraj et al. (2017) study which factored in the jobs present in these counties to determine a county's overall risk for automation.

As such many of the highest-ranking at-risk counties in manufacturing are also ranked highest in the overall ranking as well. The counties that saw the greatest changes in their rankings were the ones that had high automation risk due to automation factors that were outside of the manufacturing field scope and as such saw their risk to their county drastically drop as a result. An example of this is Bronx County, New York in Figure 3 which saw the largest swing in ranking from seventh highest at risk to the fifth lowest at risk of manufacturing risk due to an overall automation risk of 60.39% to an adjusted automation risk to manufacturing value of 1.24%.

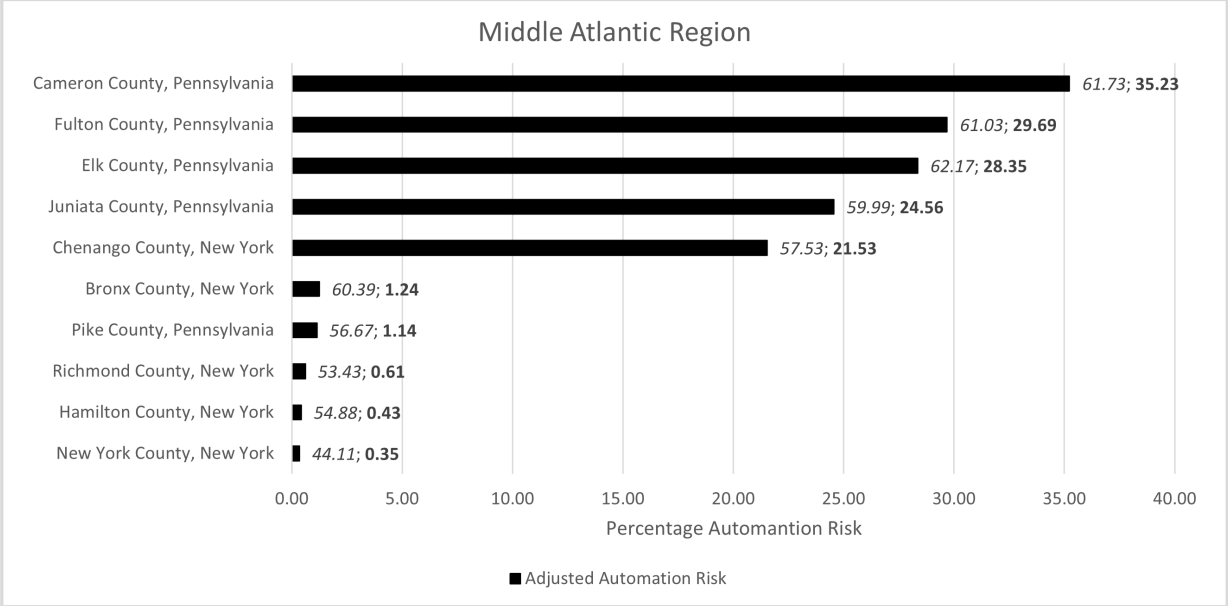


*Figure 3*. Graph of adjusted automation risk for the Middle Atlantic Region (italicized numbers are the unadjusted automation risk values, bold numbers are the adjusted automation risk values).

The risk to manufacturing jobs as a result of automation per county across the United States. was examined using two research questions. First, what is the percentage of manufacturing jobs at risk per county? The results of this study showed that a county's ranking for automation risk was tied very closely to the percentage of a county's workforce was employed by manufacturing. The best example of this being seen in Bronx County, New

York which went from seventh highest to fifth lowest. Second, what is the overall impact automation will have on manufacturing jobs per county? The results showed this was very closely tied to two factors: The percentage of the workforce employed by manufacturing and the actual number of people employed by manufacturing. This can be seen in Elkhart County, Indiana which had an adjusted automation risk of 34.64% but had the highest number of jobs at risk with 22,006 jobs.

*Implications*

The results of this study shed light on how automation could play a large role in counties that are heavily made up of manufacturing jobs. Counties that have low manufacturing employment, but a high overall risk fall significantly down the rankings of risk in each region examined. This may bring many workers in these counties to pause and consider the longevity of their positions within these fields moving forward. Furthermore, this data does provide an insight into the vulnerabilities each county has across these nine regions regarding manufacturing automation, however it does not provide a clear picture of when these changes may occur or to the full extent by which each county may experience automation risk because of every changing condition within the field of manufacturing.

*Limitations*

With this study, there were a few limitations. The first of these is that not every county reported total employment data to the BLS. A second limitation was that not every county reported manufacturing employment data to the BLS. A limitation was that counties reported their total employment as zero or their manufacturing data as zero. The reporting of county total numbers as zero seems to be an error in the collection of data by the BLS. Manufacturing totals being reported as zero may be true, but there is no way of verifying these numbers regarding the examined time frame of this study. One final limitation of this study was a limitation experienced by the Devaraj et al. (2017) study which we agree with their statement that "We wish to reiterate that these are not predictions of job losses, but rather representations of the relative risk due to automation … that may occur in the coming years" (Devaraj et al., 2017, p.7).

## Conclusion

The purpose of this study was to gain an understanding of the risk present to a county in terms of its manufacturing density. By using the BLS employment data to adjust the risk values of the Devaraj et al. (2017) study on automation risk, it was concluded that a county's risk based around manufacturing was greatly determined around the overall proportion of the county's manufacturing employment. It was observed that the most at risk for overall automation risk normally remained relatively close to their original ranking even after the automation risk was adjusted to focus on automation. The greatest variation to this was found in counties that had a high overall automation risk, but the county's employment was made up of very few manufacturing jobs.

### Recommendations

From this, we recommend that workers located in these high-risk counties should respond to these potential risks in one of the following ways. The first avenue is to seek out their state's opportunities for upskilling. The extent to which this opportunity is present through the state varies greatly from state to state. For example, in Ohio, the state provides reimbursement to employees up to $2,000 per credential (Ohio Department of Education, n.d.). Whereas in Pennsylvania, the state provides lump grants to specific counties around particular needs and lays out specific requirements to receive money from these grants as a means to help improve worker's skill base and job retention (Pennsylvania Department of Labor and Industry, n.d.). A second avenue is to reach out to one's company of employment directly to determine whether they provide upskill opportunities within their company. This also varies greatly from company to company. A third avenue is the pursuit of self-upskill in which one seek out additional education as a means of preparing yourself to stay a viable employee. The drawback to this approach is the financial burden that is placed on the individual worker. A fourth avenue is to express interest in assisting with an automation process, providing suggestions, volunteering to find and participate in the necessary training to become acquainted with the new automation. This serves as a way of taking an active role in order to keep yourself involved in the automation process so that one may continue to be a viable part of the process. As for future recommendations, further research needs to be done to determine the breakout of the types of manufacturing jobs present in this study to better provide a more accurate estimate of the risk to each county by their manufacturing segment. In addition to continue to create a more wholistic understanding of this topic an examination of the economic and workforce opportunities that will arise out of automation should be performed. However, this extends beyond the scope of this paper's focus.

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# Manufacturing Engineering Certificate and MS Degree for the Working Professional

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**Abstract**

The Manufacturing Engineering MS degree encompasses the building blocks of advanced manufacturing such as; smart manufacturing, modeling, simulation, sustainability, additive manufacturing, and advanced materials. This 30-credit degree is designed for the traditional student or working professional to align course projects to applications in their place of work. Courses will be offered in a variety of formats to suit the learner. The courses can be satisfied online or in person, and application projects will be performed on campus or at an employee's workplace. This degree is designed to be a flexible degree program, attracting people who work in industry, and who may come from a wide range of undergraduate backgrounds (e.g. manufacturing engineering, mechanical engineering, electrical or computer engineering, materials science and engineering, manufacturing engineering technology, mechanical engineering technology, etc.). The degree has 16 credits of required courses in topics of: statistics, safety, leadership, tolerance analysis, industry 4.0, and communications. The remaining credits are electives from emphasis areas in Additive Manufacturing, Manufacturing Systems and Operations, Product Tooling and Assembly Engineering, Quality Engineering, Manufacturing Sustainability, Advanced Materials and Manufacturing Processes, Cyberphysical Systems, or others to be determined by the graduate degree advisor. A nine-credit online certificate in Manufacturing Engineering is one method of getting started on this MS degree. This certificate includes two required courses that are part of the 16 required course credits in the MS degree. These two courses prepare students to manage and/or provide leadership for teams to successfully implement manufacturing processes, (Manufacturing Competitiveness Building Block), and communicate effectively utilizing the fundamental concepts of Geometric Dimensioning and Tolerances (GD&T) necessary in the manufacturing sector, (Product Tooling and Assembly Engineering Building Block). One additional course is chosen to develop skills for industry 4.0 concepts, or design for additive manufacturing.

## Introduction

The Manufacturing Engineering Online certificate and MS degree at Michigan Technological University (Michigan Tech), are designed to be flexible programs, attracting people who work in industry, and who may come from a wide range of undergraduate backgrounds (e.g. manufacturing engineering, mechanical engineering, electrical or computer engineering, materials science and engineering, manufacturing engineering technology, mechanical engineering technology, etc.). The initial target audience for this degree are recent graduates from the Mechanical Engineering Technology (MET) program at Michigan Tech.

## Background

In the Department of Manufacturing and Mechanical Engineering Technology (MMET), the MET degree enrollment has grown from 75 to approximately 160 students since 2010 (see Figure 1).

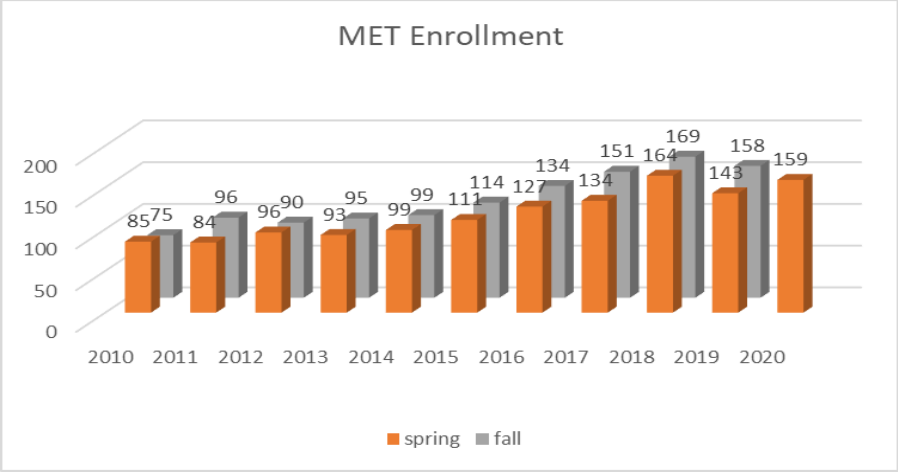



**Figure 1 – MET Enrollment 2010-2020**

The MMET department was formed as a new department in the College of Engineering in fall of 2019 as part of the University restructuring. The MMET department administers the BS MET program and the Minor in Manufacturing Systems. There are eight faculty members associated with the department and three staff. The MMET department manages a machine shop which is used for several manufacturing courses, enterprise project fabrication, and for developing undergraduate, graduate, and faculty research projects.

The MET degree has a Manufacturing focus that offers three technical elective courses to provide students with an understanding of "how things are made and work" in response to the ASME Vision 2030 Recommendations for Mechanical Engineering Education (Kirkpatrick et al., 2012). In addition, there are manufacturing courses in the Computer Aided Engineering focus area, such as Computer Aided Manufactur-

ing, and Industrial Systems Simulation. All MET graduates complete courses in Fundamentals of Machining, Manufacturing Processes, and Quality Control Methods, among others. With the manufacturing emphasis in the degree, many employers hire MET students as Manufacturing Engineers, Process Engineers, Production Engineers, and Quality Engineers.

The MMET department also supports the interdisciplinary BS and MS in Mechatronics degrees. There are five Mechatronics related graduate courses that are delivered by the MMET department. All MMET faculty have manufacturing industry experience, and most conduct research in manufacturing areas. Specifically, MMET faculty research expertise include: quality techniques, leader development, solid mechanics, vibration analysis, micro manufacturing, additive manufacturing, learning innovations, heat transfer, HVAC, heat exchangers, two-phase flow, and energy efficiency. All the tenure-track faculty have terminal degrees, and one of the lecturers is a licensed Professional Engineer. Two faculty are active Society of Manufacturing Engineers (SME) members.

## Methodology

The process of establishing the MS in Manufacturing started in early 2020 with the formation of a Manufacturing Degree Taskforce. Four MMET faculty volunteered to serve on the taskforce along with the department chair. The taskforce met frequently throughout the fall 2020 semester to share data, and develop two proposals. The University Senate proposal template was used for both the Online certificate and the MS degree. This template requires learning objectives, rationale, related programs, projected enrollment, scheduling plans, curriculum design, new course descriptions, resources, faculty resumes, needed equipment, program costs, and space requirements. The department chair delegated tasks to the taskforce members to research the main areas of: related programs, projected enrollment including a marketing plan, curriculum design, and new course descriptions. After this research was shared in taskforce meetings, it was developed into draft proposal documents.

The Online certificate and MS proposal draft versions were reviewed and revised by the MMET faculty, the College of Engineering Dean, and Associate Dean, before being presented to the Engineering Council (College of Engineering department chairs) for discussion and vote. After approval of the Engineering Council, the proposals were routed to the Graduate School for review and revision before being presented and voted on by the Graduate Faculty Council. In the University Senate, the process requires a curriculum and

finance sub-committees review prior to being introduced and voted for adoption.

The Online certificate was the first to complete this process in spring semester 2021. The Online certificate was then posted on the college and department websites, and advertised to MET alumni. The Higher Learning Commission (HLC) approved the Online certificate in August, 2021. It was decided to postpone the introduction of the MS degree to the University Senate until fall 2022. The MS degree is pending approvals at the Winter (January 2022) Michigan Association of State Universities (MASU) meeting, and the December, 2021 University Board of Trustees meeting.

During the summer 2020, all faculty in the department became certified to teach online by taking training that enables them to design and teach a quality online course. The training focused on the foundations of online teaching, instructional design principles, and backwards design techniques. The training was aligned with Quality Matters principles, to show how to craft good learning objectives, then align assessments, activities, content, and technology to them, and to make them all easy to navigate and accessible (Quality Matters Program, 2015).

## Results

This MS degree encompasses the building blocks of advanced manufacturing such as; smart manufacturing, modeling, simulation, sustainability, additive manufacturing, and advanced materials (see Figure 2). This 30-credit degree is designed for the traditional student or working professional to align course projects to applications in their place of work. Courses are offered in a variety of formats to suit the learner. The courses can be satisfied online or in person, and application projects can be performed on campus or at an employee's workplace.

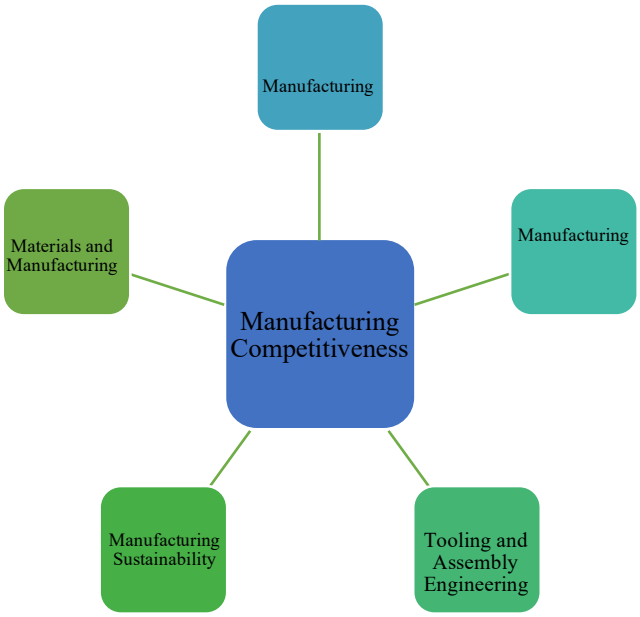



**Figure 2 - MS Manufacturing Engineering Building Blocks**

The Four Pillars of Manufacturing Knowledge (2011) is the structure used to inspire the curriculum developed for this MS in Manufacturing Engineering. The graphic representation of the Four Pillars is depicted as a structure including foundation, and the supporting pillars (see Figure 3). This degree has 16 required credits, including topics mostly listed in the "Manufacturing Competitiveness" category of the Four Pillars. Additional credits in the emphasis areas align with the other categories described in the Four Pillars model, with the option to conduct research in any emphasis area. The 16 credits of required courses are:

- Statistical Methods (3)
- Key Factors of Holistic Safety (1)
- Organizational Leadership (3)
- Tolerance Analysis with Geometric Dimensioning & Tolerancing (3)
- Industry 4.0 Concepts (3)
- Professional Engineering Communication (3) Or Engineering Research Communication (3)


**Figure 3 - SME Four Pillars**

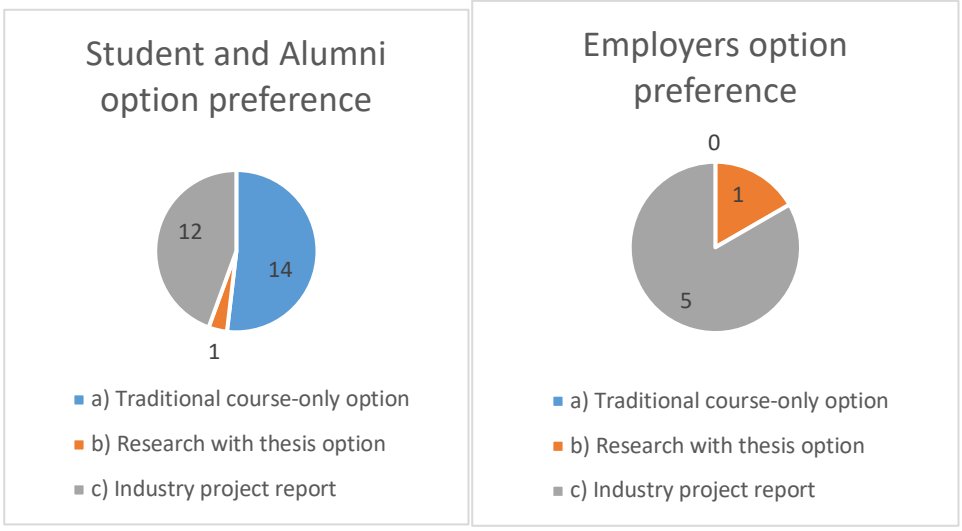
The remaining courses are subject to advisor approval, from the emphasis areas including: Additive Manufacturing, Manufacturing Systems and Operations, Product Tooling and Assembly Engineering, Quality Engineering, Manufacturing Sustainability, Advanced Materials and Manufacturing Processes, and Cyber-physical Systems.

Nationwide benchmarking revealed that there are numerous accredited manufacturing degree programs at the undergraduate level, including (26) ABET EAC Manufacturing Engineering degrees and (27) ABET ETAC Manufacturing Engineering Technology degrees. In addition, there are two ABET ETAC Manufacturing and Mechanical Engineering Technology degrees. Typically, these degree options are offered as on-campus, or online options.

Most often, however, a graduate degree in manufacturing engineering is achieved through a master's in Mechanical Engineering, with a focus in manufacturing. The obvious advantage to this proposed degree is the name recognition having "manufacturing" in the degree title. Moreover, a wider range of elective courses in various disciplines are available. Students with undergraduate degrees in biomedical, electrical, chemical, robotics or material science may desire some basic knowledge and skills in GD&T, CAD modeling software, and manufacturing processes.

The Manufacturing Taskforce developed and disseminated a local survey to assess the interest in the MS in Manufacturing Engineering degree by employers, as well as current MET students and alumni. Additional questions in the survey were to assess the most popular methods of delivery for the program. The survey was distributed by email to two groups. Group 1 were employers, using the 10 individuals on the MMET Industrial Advisory Board. Group 2 were current students, and alumni using the MMET student email group list and emails from 2019-20 MET graduates. The responses yielded a typical 20-30% return for the student and alumni, n=27. For the employer survey there is representation from companies such as Pettibone, Cummins, Greenheck, and Honda Manufacturing, n=6. The vast majority, 25 (93%), of the students answered "yes" to the question "Would you be interested in course lab assignments being satisfied by completing in-plant projects in the workplace?" and 100% of the employees also answered "yes".

The response to the first question, "Would you consider the opportunity to obtain a MS in Manufacturing Engineering requiring 30 credits after completing your MET degree?" was 23 (85%) yes. For employers, the same question was answered 6 (100%) yes. Students and alumni were approximately evenly split between preferring the course only option, and industry project report option, and employers were 5 out of 6 (83%) interested in the industry-based project report option (see Figure 4 & 5).




**Figures 4 & 5 - MS Degree option preference – Student and Alumni & Employers**

The survey indicates that there is interest in all the emphasis areas that are in this proposal (see Figure 6). The current students were mostly interested in Manufacturing Systems and Operations, where the employers were evenly split between Advanced Materials and Manufacturing Processes and Additive Manufacturing.

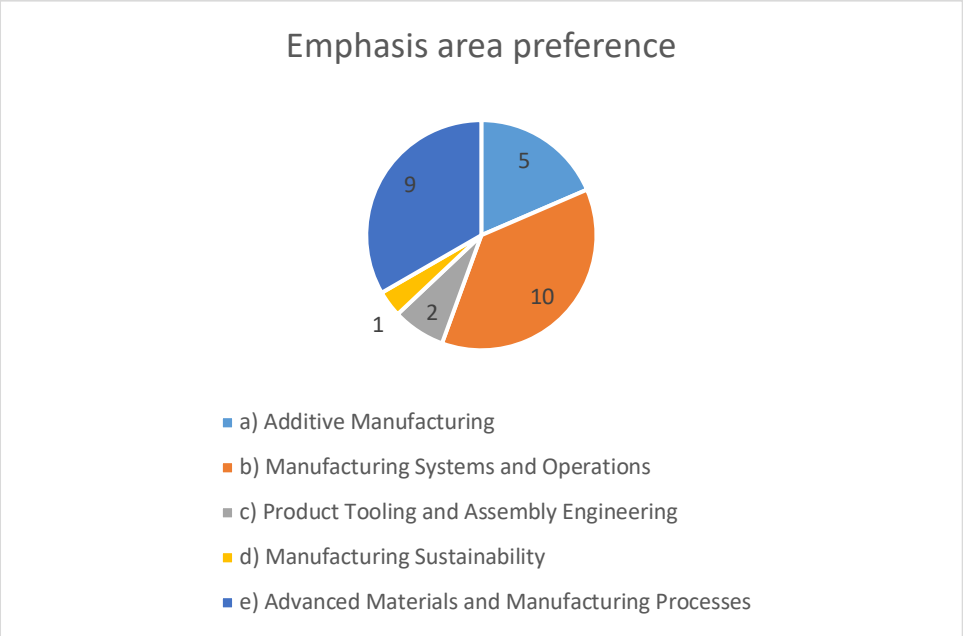



**Figure 6 - Emphasis area preference – Current Students**

The need for the degree is reinforced by the 6 (100%) employers that responded "yes" to the question "Would you consider hiring an applicant with this MS in Manufacturing Engineering?" This is also reinforced with the U.S. Bureau of Labor Statistics, Occupation Outlook Handbook (n.d.), indicating that Occupational Employment and Wages, May 2018 for 11-3051 "Industrial Production Managers". This role is defined by the BLS as "Plan, direct, or coordinate the work activities and resources necessary for manufacturing products in accordance with cost, quality, and quantity specifications." Michigan has the highest concentration of jobs with this title (see Table 1). The Location Quotient (LQ) compares the concentration of an industry within a specific area, to the concentration of that industry nationwide. An LQ greater than 1 indicates an industry with a greater share of the local area employment than is the case nationwide, which Michigan is the highest of the top 5 states. The employment estimate and mean wage estimates for this occupation (see Table 2). The Relative Standard Error (RSE) of the employment estimate is a measure of the reliability or precision of the employment estimate. The relative standard error is defined as the ratio of the standard error to the survey estimate. The reported annual wage for Industrial Production Managers of $113,370 is higher than the mean

annual salary for MET majors of $99,310 as reported by National Occupational Employment and Wage Estimates, United States Department of Labor. This increased salary is an incentive for MET alumni to pursue this certificate and further their education.

**Table 1 -** Top five States with the highest concentration of jobs and location quotients for Industrial Production Managers

| State | Employment | Employment per thousand jobs | Location quotient | Hourly mean wage | Annual mean wage |
|---|---|---|---|---|---|
| Michigan | 13,110 | 3.04 | 2.42 | $57.10 | $118,760 |
| Wisconsin | 6,580 | 2.31 | 1.84 | $53.01 | $110,250 |
| Iowa | 3,490 | 2.27 | 1.81 | $47.14 | $98,040 |
| Ohio | 11,380 | 2.10 | 1.68 | $52.50 | $109,190 |
| Kentucky | 3,800 | 2.01 | 1.60 | $46.80 | $97,340 |

**Table 2 -** Nationwide employment estimate and mean wage estimates for Industrial Production Managers

| Employment | Employment RSE | Mean hourly wage | Mean annual wage | Wage RSE |
|---|---|---|---|---|
| 181,310 | 0.7 % | $54.51 | $113,370 | 0.3 % |

## Discussion

The rollout of new graduate courses in a department with eight faculty with high teaching load is challenging. Typically, the model for course load in the department is two courses per semester for tenure track faculty, and four courses per semester for non-tenure-track lecturers and professors of practice. This model varies to accommodate courses ranging from 1-4 credits, and some courses with multiple lab sections. Regardless, it is not possible to add five new courses to the existing course load all at once with no extra resources. So, the rollout plan calls for one new graduate course to be developed each semester until all the courses can be offered in alternating semesters. This plan will allow a student to complete a course only MS degree option in three to four semesters, or an Online certificate in two semesters (see Table 3).

**Table 3.** Course Only Option

| **Year 1- fall semester: 9 credits** | **Year 1- spring semester: 9 credits** |
|---|---|
| MFGE 5000 - Organizational Leadership (3) | Emphasis Area Course (3) |
| MA 5701 - Statistical Methods (3) | MFGE 5200 - Industry 4.0 Concepts (3) |
| MFGE 5100 – Tolerance Analysis with Geometric Dimensioning & Tolerancing (3) | MEEM 5010 - Professional Engineering Communication (3) |
| | |
| **Year 2- fall semester: 9 credits** | **Year 2- spring semester: 4 credits** |
| Emphasis Area Course (3) | Emphasis Area Course (3) |
| Emphasis Area Course (3) | MET 5400 – Key Factors of Holistic Safety (1) |
| Emphasis Area Course (3) | |

Many manufacturing engineers find themselves in leadership roles in the first few years of employment without having adequate preparation. According to Bennet and Milliam (2013), few engineering leaders have gone through the process of assessing their skills,

personalities and potential. The first course to be offered for the Online certificate is the MFGE 5000 Organizational Leadership, which is designed to take the students through this process of self-assessment. Students are encouraged to look at themselves and their respective leadership in the mirror to make an assessment. During each course section, a leadership perspective is considered, these can be theories, models, or approaches to leadership. Then, the students are asked to complete an assessment using a field-tested, professional grade leadership instrument. For example, in the section dedicated to Leader-Member Exchange (LMX), the class finishes the week by assessing their leadership perspective using as the self-assessment tool LMX-7. From this exercise, the students can learn their LMX result, and by analyzing their responses to the instrument the students can begin to see what they can do to improve.

These individual LMX responses are a great way to gain a personal understanding of each perspective, but that's not really the goal. We want the students to gain a better understanding of not only leadership, but also of their leadership potential and course of action to improve. To achieve this, the students develop a leadership plan. After analyzing each leadership perspective and completing the assessment, they begin to have a clearer picture of who they are as leaders. And more importantly, what they can do about it in the future. In the end, the LMX document will contain a detailed self-evaluation followed by action items the students can complete to improve their leadership skills.

The next topic that is of great importance to manufacturing and automation is the fourth industrial revolution. The need for manufacturing engineers and engineering managers is evident from regional studies from Wisconsin and Michigan. The NEW (Northeast Wisconsin) Manufacturing Alliance Needs, Skills, & Talent Survey (2019) collected responses from over 100 manufacturers. One primary outcome from this report is that curriculum and training programs that develop process engineers and data analysts are in high demand. The report also indicates that IT, Engineering, Production, and Research & Development functions/departments will be most heavily impacted by the integration of Industry 4.0.

The next course for the Online certificate is MFGE 5200 Industry 4.0 Concepts. In this course, students will examine Industry 4.0 as it relates to manufacturing. The fourth industrial revolution has begun with the introduction of machine intelligence and cyber physical systems that can communicate over the internet. This is a result of hardware being much more affordable, readily available software that can perform complex tasks, inexpensive computational storage, and a widespread internet. All of which connects machines, devices, sensors, data, and people.

As it relates to manufacturing, students will explore topics such as smart factories, cyber physical systems, proactive maintenance, computer simulation, horizontal and vertical integration, and barriers to implementation will be explored. As an example, connected sensors will integrate an Internet of Things (IoT) network on the factory floor collecting data that will be stored in the cloud and be processed with cloud computing. The large amount of collected data, i.e. Big Data; will enable the use of computing methods including artificial intelligence to study system energy efficiency, tool wear, preventive maintenance, and product quality management. The connected factory floor, in conjunction with the use of smart human machine interfaces (HMI's), also enables the use of real-time data in automation, system integration, and supervisory control to minimize down-time. Furthermore, the collected data will enable the development of process emulators to simulate the steps of a process before the actual production begins to increase efficiency through intelligent routing.

Additive manufacturing (3D printing) is a process that creates three dimensional objects by depositing layers of materials, which is an integral part of Industry 4.0 technologies. Given the growth of additive manufacturing, it has been included as an optional course in the Online certificate. According to Wackler, Copan, & Molnar (2018) in the "Strategy for American Leadership in Advanced Manufacturing", a core component for

developing and transitioning new manufacturing technologies, includes smart manufacturing. To achieve this, small and medium manufacturers must have the knowledge to upgrade their operations. An example of the smart manufacturing technologies referred to in this study is additive manufacturing.

The final course developed for the Manufacturing Engineering MS degree is MFGE 5100 Tolerance Analysis with Geometric Dimensioning & Tolerancing (GD&T). The universal manufacturing language that this course focuses on is ASME Y14.5-2018 standard, which are the concepts of GD&T needed to communicate effectively in the manufacturing sector. The course includes: assembly tolerance stack-up, applying and interpreting geometric symbols, datum reference frames, and calculating position and profile tolerance.

## Conclusion

In the short time since the Online certificate has been published it has received a fairly good response, but many students are waiting to apply until the MS degree is fully approved. At this time there are eight students accepted into the graduate certificate program. The marketing to MET alumni has been through email and social media. The College of Engineering has hired a marketing firm to develop a platform to disseminate information for all the department Online graduate certificates and degrees in the near future.

Allowing prospective graduate students flexibility to combine graduate certificates from different disciplines is being investigated. For instance, the Manufacturing Engineering certificate, combined with a certificate in Quality Engineering, or Fundamentals of Materials Engineering would allow students to obtain a MS degree that is customized to their needs.

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# Improving the quality of welding training with the help of mixed reality along with the cost reduction and enhancing safety

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## Abstract

Welding is widely used in all industries and its demand is drastically increasing. Today, all sectors of engineering need quality welders to meet their standards. Welders need years of experience and knowledge to meet those standards. They require lots of training, equipment, tools and safety standards to master the welding skill. The cost of training is very expensive, as they will be practicing every day with different materials. The purpose of this project is to train them in a new merged up environment of virtual and real world. As a result, this method would reduce training costs and enhance the safety of the users. This method is a medium that helps users to have a better understanding of welding operation and gives them the confidence to perform proficiently in reality along with the elimination of risk, liability, and injury.

*Keywords:* welding training, mixed reality, cost reduction, safety

Welding is an ancient technique, and since man first learned to remove and refine iron, it has been studied. The method of welding was the same as that used in Roman times until around the turn of this century, and is still used today in the blacksmith's forge. In order to squeeze out slag and oxide and permit the surfaces to fuse together, the two pieces of metal to be joined are heated and then pounded or pressed together (Lancaster, 1984). The growth of welding has an amazingly long past, perhaps beginning with the hammer welding of gold. Though several elements of welding are entirely experimental, there is no question that considerable advances have been made to qualify the subject as a partial science (Metallurgy, 2020).

In the automotive manufacturing area, welding is commonly used. As a result, relative to the past, there is a strong demand for welders in today's world. Welding is one of the industry's main and widely used technologies and its applications vary from the food industry to aerospace and from precision instruments to ship building. There is a rapid development of this skill due to humans' competition in nuclear sciences which must target only at peace. Welding is one of the dangerous careers, and many risks are exposed to the related employees. In their health and making their environment healthy, the detention and refusal of these threats play a significant role. Welding, on the one hand, is a risky laborious, and dangerous occupational operation. In welding operations, using heat or pressure or both, metal pieces are connected. In other hands, with the aid of welding filler metal and heat or pressure, welding is the attachment of metal parts. (Zamanian et al., 2015). Welding, which presents possible physical and chemical health risks, is one of the main components of many industrial sectors. Welding gases consist of a wide number of fragments of complex metal oxide that can be accumulated in all parts of the respiratory tract. Mostly from the electrode wire, the welding aerosol is not homogeneous ad produced. Different gases (metal oxides, CO2, CO, O3, NO2, hydrocarbons) and welding fumes can be created by welding processes (Chadha & Singh, 2013).

Training in computer-based virtual reality (VR) has generated excitement because it has the potential to reduce the expense of training and also boost the quality of mastering the hand skill. Cost reductions, though, are only effective if a professional welder who is qualified in a timely manner is the outcome. Any study has shown that the use of VR technologies contributes to a decrease in learning time and skill transfer. Even, in training, the use of VR technology does not vary substantially from real-world training. The purpose of training for a long time is to get qualified after the welding test. A qualified welding inspector conducts the test to assess if the welder can create a sound quality weld up to the code or welding technique necessary by a business or a relevant industry standard. After the welding process, the components use in this testing cannot be reused. This test costs a lot of money and materials. Therefore, the goal of implementing the computer-based testing environment is to minimize the cost of the devices and to make consumers aware of the safety precautions in order to deter any injuries when operating in actual jobs. Research indicates that "Virtual reality technology has arisen as a modeling technology with a great potential to help construction and training practices.

This computer-based training is one of the newer welding training aids, such as virtual reality. The field of virtual reality has arisen as a modeling technology with tremendous potential to benefit the practices of architecture and training. The use of virtual reality for virtual prototyping in the near future, would play an important role in the automotive and probably in other industries" (Mavrikios et al., 2006, p. 294).

Studies have shown that the use of VR technologies contributes to a decrease in learning time and skill transfer. Even, in training, the use of VR technology does not vary substantially from real-world training. Various tools, such as SolidWorks, 3ds Max, Unity, and Visual Studio, were used in this training to create a simulated welding scenario. This simulated scenario is then merged with the actual world, known as Mixed Reality (MR), which involves both actual and computer-generated objects. This realism helps the welder to communicate with the correct directions and direction within the virtual reality to perform the welding process. Moreover, the gun's angle and arc gap between the work piece and the nozzle of the gun can be tracked down that helps to keep the hand steady and on doing so the hand skill can be improved. MR thus helps welders to work towards better preparation in a new world (a mixture of simulated and actual worlds) and to get them fit for real work.

## Literature Review

The use of virtual reality (VR) based methods to support human integrated simulation for manual welding processes. Under this framework a prototype demonstrator was developed, named 'the virtual welding environment', which provides functionality inside a virtual environment for immersive and interactive process execution. This environment's simulation features allow the user to configure, conduct, and verify the results of a welding operation. This environment shows promising potential to support process design and manual welding-related training procedures. Its aim was to support process experimentation concerning factors, which cannot be analytically described and therefore do not predeterminedly affect the process. Consequently, the focus was on the verification of subjective or random aspects of human involvement in relation to the welding process, the product and the working environment. In terms of potential use, the virtual welding demonstrator incorporates features to help the design and testing of welding processes: the environment allows the user to conduct the welding process set-up procedures, the process is conducted digitally in an immersive and interactive manner and the system is currently operating on a Silicon Graphics ONYX2 Workstation with an Infinite Reality 2 Graphics Pipeline. The VR peripherals, which are used to enable immersive and interactive process execution within the virtual assembly environment include an FS5 Virtual Research helmet, a Cyber Glove with Cyber Touch and Gesture Plus Virtual Technologies 18 sensor, a 3D Mouse Section, and a Polhemus Fastrack tracking device. With the use of Pro/Engineer V.20.verification of process characteristics the virtual welding system was modelled. A number of specific functions were also introduced to support the activities of the interactive user in the virtual welding environment, including

input evaluation functions, assembly function, process evaluation functions, welding seam creation function, and results' representation functions. This paper identified the idea and the functionality of a prototype demonstrator, the virtual welding demonstrator, which can be used for welding processes as a design verification and training tool. Based on simulation techniques for virtual reality, this environment allows for immersive and interactive performance in the process. Within the virtual welding demonstrator, the user can set up and conduct a welding MIG/MAG process, providing quantitative environment input in real time that provides support and overview of the process performed (Mavrikios et al., 2006).

A crucial and sometimes expensive endeavor is training in the welding industry; this research explores the training capacity, team learning, use of resources, and expense consequences of the use of advanced virtual reality technologies as a significant part of welder training. In this study, one of two different approaches (traditional training (TT) and virtual reality interactive training (VRI)) was used to train 22 participants. The findings found that students trained with 50 percent virtual reality had testing outcomes that matched those of typically trained students with four distinctive welding qualifications (1G, 2F, 3G, 3F). In addition, slightly higher levels of team engagement were shown by the VRI community, which contributed to improve team-based learning. Finally, the VRI group's material cost effect was slightly smaller than that of the TT group, while both schools served for a full two weeks period. The authors hypothesized that VR integrated training would lead to better training outcomes relative to conventional approaches, that the use of a state-of-the-art VR system would lead to improve levels of team engagement and understanding, and that welding training performed using VR integrated technology would be substantially less expensive than training conducted by us before conducting this study. In all, there were 22 participants (21 males and 1 female). One of the two classes was randomly allocated to the participants. Group one (VRI) subjects were trained using 50 percent VR + 50 percent conventional training, while group two (TT) subjects were trained using only the traditional method of training. In this experiment, the primary independent variable was training style at two stages, reflecting the type of interface tested: Traditional Weld Training (TT) and Virtual Reality Training (VRI) at 50 percent. The results of this research specifically demonstrate the direct advantages of using integrated training for virtual reality in the welding domain. Compared to their traditional educated peers, the VRI group students demonstrated substantially superior outcomes in training. The significantly higher rate of team learning and engagement among VRI students and the significantly higher number of welds done by VRI students in the VR setting are the factors correlated with the finding (Stone et al., 2011).

Since the first use of the word "Virtual Reality" (VR) back in the 60s, VR has developed in numerous ways, becoming closer to the physical world. It is possible to distinguish two distinct kinds of VR: non-immersive and immersive. The former is a computer-based setting that can replicate locations in actual or imaginary worlds; by giving the illusion of being physically present in the non-physical universe, the latter takes the notion much further. Although non-immersive VR can be based on a normal machine, as the requisite technologies are becoming more user-friendly and economically

available, immersive VR is still emerging. The use of equipment such as a helmet and goggles has been a big challenge in the past, although modern devices are now being built to increase accessibility for the customer. By making learning more inspiring and interactive, VR, which is based on three core principles: immersion, engagement, and user participation with the world and story, provides a very high education opportunity. Due to high product costs and their restricted accessibility, the use of immersive-VR in educational games has been limited until now. Today, in many educational contexts, new technologies such as the commercial "HTC Vive" make it easier to access immersive-VR. A research literature survey on the benefits and feasibility of using interactive Virtual Reality in Education in the last two years (2013-14) is stated in this article. It explains how VR in general and interactive VR in particular have been used mainly in specific circumstances for adult training or for university students. It then reflects on the potential benefits and disadvantages of its use in education with regard to various consumer groups such as children and some form of cognitive disorders (particularly with regard to Down syndrome). It continues by outlining methods for verifying certain concepts that could be carried out (Freina & Ott, 2015)

The application of dexterity to demonstrate the possible success of original welders in the selection of applicants for welding training programs. Successful welding training programs are imperative with strong demand for welders, but can be time consuming. The time taken to train skilled welders is one of the obstacles that training programs face. Before welcoming them to a training program, numerous vocational fields have tried to predict the possible success of a pupil by assessing their dexterous ability. The full Minnesota Dexterity Test (CMDT) was used in this research to investigate the dexterity of participants during a welding exercise program. Participants completed weld tests at the conclusion of the training program, supervised by a qualified welding instructor (CWI) who visually inspected each weld. When measuring participant dexterity on the first day of training, it can be observed that with the positioning and turning assessments, 78.3 percent of the participants have poor dexterous ability. However, 34.8 percent of the participants exuded a very high degree of dexterity during the displacement test on the first day of training. For the two-week training plans, participant independence was isolated. In all three types of tests conducted in the 50/50 simulated and traditional type of study, a general increase in dexterous ability can be observed. For basic shielded metal arc welds (SMAW), all three dexterity measures demonstrated statistically significant similarities to the visual pass/fail scores of the participants. It can be inferred that dexterity can predict the starting welders that complete simple SMAW welds for future production (Preston Byrd et al., 2019).

In various scenarios, experts have investigated the advantages and uses of virtual reality (VR). VR has a great deal of promise, and its application to education has recently see a great deal of research activity. However, there is currently no comprehensive study on how academics have used immersive VR for higher education purposes, which considers the use of both high-end and budget head-mounted displays (HMDs). Therefore, to classify design features in current

research committed to the use of VR in higher education, we recommend using systematic mapping. By collecting key information from documents indexed in four scientific digital repositories, which were manually filtered using exclusion, inclusion, semi-automatic, and manual processes, the checked papers were acquired. The mapping was carried out between application domains and content for learning and between elements of architecture and content for learning. Our research has found many deficiencies in the adoption of VR in higher education. For example, learning hypotheses have not always been considered in the development of VR applications to support and direct learning outcomes. In comparison, the assessment of educational VR applications concentrated mainly on the usability of VR applications instead of learning results, and interactive VR was often part of theoretical and growth work rather than being routinely extended to practical instruction. Nevertheless, since this research recognizes 18 application domains, VR seems to be a promising area, suggesting a stronger reception of this technology in many disciplines (Radianti et al., 2020).

**Problem Description**

As far as the Iron Age and the Bronze Age are concerned, welding is known to occur in some manner. There is evidence that the Egyptians learnt to weld iron together, and have discovered tiny gold boxes that were welded with lap joint pressure form 2,000 years ago. However, the style of welding then widespread and discovered in the Middle Ages was a very primitive method of welding that typically involved merely hammering two pieces of metal under heat together before they fused together. As early as 1800, some of the first inroads into conventional welding came about. After that, welding techniques progressed very quickly. Since the 19th century, people have been developing more and more efficient techniques for precise, quick, and effective welding (Reed, B., 2019). One of the best work prospects worldwide is manual welding. Several banks, building agencies, and factories employ welders. So, they're not unfairly hiring those employers. Each company has its own specifications and system relating to the welding process. The welding skills must then be learned by welders to suit into the curriculum. The talent would not arrive in a single day. It needs lots of experience, effort and time. The element that helps to learn the welding potential is only by practice and practice. To perform welding, trainers have to cover the expenses for the tools, machinery, and instruments etc.

Welding is one of the dangerous professions and the resulting workers are prone to several hazards. Inside their wellbeing and healthy climate, the containment and rejection of these risks plays an important part. In the one hand, with the aid of welding metal filler and heat or strain, welding is the linkage of metal sections. The welding process, in other words, is risky, laborious and harmful to the profession (Zamanian et al., 2015). The majority of welders work in manufacturing. They work both indoors and outdoors, depending on the exact industry or welding project. To get qualified for job, the welders need to be skilled depending upon the industry needs. The basic important part of being qualified is the hand skill. The journey to be certified welder is the knowledge and practice, which is not easy and economical. The enactment process consumes abundant amount of materials, tools, and equipment along with the preparation time. In

addition, electricity will be used while welding procedures are carried out. If uses who use, touch or supervise the use of these processes do not fully understand that their unsafe use by poisoning, fire, explosion or electric shock may result in loss of life and property. Whenever the output is on, the electrode and operating circuit are electrically alive. When power is on, the input power circuit and computer internal circuits are still alive. Carelessness in these terms can lead to injuries or serious injury.

The study primarily focused to reduce the training cost and master the quality of hand skill during welding training. In the education sector, mixed-reality systems are used to both develop the ability of students to learn and to obtain information. With this technology the virtual scenario of the welding can be created and make available to different areas where welding is performed for training process. Students can communicate with and manipulate simulated objects using 3D projections and simulations in order to analyze them in a way that is important to themselves and their learning. In the next section of this paper, the proposed methodology and the step-by-step process of the system will be defined.

## Method

This paper's suggested model is to train welders in a hybrid reality that is the result of integrating the physical and digital realms. The next step in interaction with humans, robots and the universe is mixed reality, which examines possibilities that were historically limited to our imaginations. This is made possible by advances in computer vision, graphics processing power, display technology, and input devices. It also requires feedback from the atmosphere, spatial tone, and position. For the past few decades, the relation between human and machine feedback has been well studied. It also has a highly studied specialty known as human interface computers, or HCI. Human input takes place by a range of methods, including keyboards, cursor, touch, pen, speech, and even skeletal tracking for Kinect. Environment feedback measurements such as person's place in the world (e.g. head tracking), structures and borders (e.g. spatial imaging and scene perception), ambient illumination, sound from the environment, identification of objects, and location. Today, the capacity to create true perceptions of mixed reality is embedded into all three: data modeling, human input, and ambient feedback. In the real world, device experiences in the interactive realm, such as game play, can be influenced by boundaries. Without environmental feedback, which is presented in Fig. 1, knowledge does not blend between tangible and digital realities (BrandonBray).

Achieving high welding standards is a difficult job because welders need to be highly qualified and trained. It is only from years of experience that these criteria can be met. The key point of incorporating the mixed reality, however, is to have confidence and a deeper understanding of welding. There are several strategies that need to be observed to use virtual reality to train the welders. A step by step procedure, including diagrams, used to create this new model can be seen in the next section.

The suggested approach begins with the first step, i.e. to research in depth the configuration of the welding workshop that would be generated in a simulated environment so that welders can experience the actual workshop during training. Materials, equipment and instruments needed for the welding process are included in the setup. For better experience, all the tools, supplies, instruments, and protective wear that are available in the actual workspace need to be established in the virtual scenario. The next step is to find the necessary materials for the Computer-Aided Design (CAD) model. These models are downloaded from grabcab.com, an online website where various CAD models are available, or build the appropriate CAD model with the aid of software known as SolidWorks. It is the program that makes it possible for designers to transform new designs into great products. With advanced analytical software and automation architecture, SolidWorks is a highly powerful 3D CAD creation framework that helps refine physical behaviors such as kinematics, friction, tension, deflection, vibration, temperature or fluid flow to match all design types. These CAD templates are then exported to 3ds Max, another program used for mesh optimization and editing. 3ds Max is a program for computer graphics intended for the creation of 3D models, animations and digital images. It is one of the most popular programs in the computer graphics industry and is well-known for providing a versatile range of resources for 3D artists. When it comes to modeling, it is well known for its unmatched speed and simplicity. The file is then converted to the Filmbox (FBX) file format so that it can be imported into Unity, where all the CAD files are grouped together to create an animation workshop.

Unity is the key software for optimizing game play. Unity is used to build high-quality 3D and 2D games and deploy them around the desktop, VR, console. It is a cross-platform gaming engine that is used mostly for computer and tablet video games and simulations. Unity provides built-in support for writing Visual Studio Code scripts as an alternative script writer for various operating device applications. These scripts lead to the interactive workshop being run. The trainers may also be helped with the aid of voice or visual instructions during the preparation, which is possible because of the unity program. The last step to complete the model is to merge the animated workshop with the real world to train the welders proficiently. In this case, device name HTC Vive Pro come handy, a virtual reality technology developed by HTC and Valve. The headset uses “room scale” tracking technology, allowing the user to navigate in 3D space and to communicate with the world using motion-tracked handheld controls. This training scenario main motive is to improve the hand on performance and also to improve the knowledge of the welders. Along with the HTC Vive Pro, the combination of Noitom Hi5 VR glove and the Tracker produces a remarkably convincing feedback experience that offers Vive interactions with finger-level fidelity. One advantage off the Noitom Hi5 is the quick setup time, which lead to a remarkably persuasive feedback experience on the Vive that feels more immersive than the simple Vive controllers for some use-cases. With the help of the controller, the vibration is also included to have the real feeling of welding as the real welding gun is triggered. In this scenario, the welders need to perform welding tests; plate welding and pipe welding for certification. When the

welder starts the program, the in-built instruction will guide the welder to perform welding. Once the test is done, the welding inspector will review the performance and will review the welder.

**Illustrative Example**

In this section, an illustrative example of this process can be seen. Making the environment feasible with the aid of the software specified in the procedure. First of all, to build a virtual welding station, the real model is analyzed in depth. Then, with the use of SolidWorks, the necessary CAD models are made or downloaded from grabcad.com. SolidWorks also come with lot of features, which allow to cut any CAD model in different plane and can attach different component with the mate feature. With the help of this feature, the upper section of gun is used to create a support that enable to attach with the controller of HTC Vive Pro as illustrated in Fig. 4. PhotoView 360 is a SolidWorks add-in that creates SolidWorks models with photo-realistic renderings. The picture made contains the appearances, lighting, scenario and decals that are included with the model.

After that, in 3ds Max, these CAD Models are subjected to optimize the product along with the mesh edition. Later, since it is used to provide interoperability between digital content creation applications, the model is exported to the FBX file format. This FBX file is imported in order to build the welding station which is seen in Fig. 5.

Once everything is imported in Unity, the only task needs to be done is to make these CAD file work. Unity has built-in support, such as Visual Studio Code, which requires the script to be written such that it is possible to execute multiple functions. With the use of coding, these CAD model start functioning which they are made for. The correct form of coding is must and need to understand the way it works. The script used to activate the vibration and fire the sparkle of welding is achieved with the coding, which is depicted in Fig. 6.

With the assistance of equipment such as HTC Vive Pro, the welders can sense the environment of the virtual scenario. The overall devices required to work on the mixed scenario of welding is shown in Fig. 7. In this figure, the CAD model of upper part of welding gun with support is 3D printed so that the user has the feeling of holding a real gun. Within the practicing, such as grabbing and triggering the welding gun as per the instruction provided to welders, the trackers help to manipulate as illustrated in Fig. 8. The primary purpose of this training program is to prepare and qualify the welders by encouraging them to perform the test. With everything working, the user will put on the Vive headset and VR glove. Then, the user will hear the voice which will guide throughout the welding process. The user can see his/her hand inside the scenario which will help to grab and lift the necessary equipment. The trigger of the controller is programmed in such a way that when it is pressed, it enables vibration and welding sparks giving the feeling of real welding gun. Coding further add-in immediate feedback on work angle and nozzle-to-plate distance, which main motive is to mastering hand skill. With the execution of the welding task, the overall performance is reviewed and can repeat the task as many times as the user want. This save the preparation time as well as there is no more wastage of materials. Welding certifications are usual-

ly a hands-on welder training examination conducted by a qualified welding inspector who decides whether, according to the code or welding technique necessary for a job site or industry standard, the individual or machine can generate sound quality welding.

One of my colleagues contributed her time for testing the scenario. Once she is ready to perform the test, a voice instructor will guide her to start virtual welding. As per the instruction, she moves around the scenario and start performing the welding task. After she starts welding, features such as timer, gun's angle, arc gap and overall score comes to action. The test was conducted for five consecutive times and respective data was collected to see the progress. The data is presented in Table 1 with respect to time and score.

**Limitations and Complications**

There are some limitations in this training though the training costs less and prevents the users from hazardous gases and fumes. The filler material increased the strength of welding which is a limitation in mixed reality because the chemical composition of the filler material cannot be tested. The complications of this welding environment are it cannot replicate the real welding operation. Although it allows welders to practice and perfect their skills as a companion to hands-on. The welders may experience certain health issues such as nausea, anxiety, and eye strain.

**Results and Conclusion**

The performance of the user in virtual reality training is examined and the outcome came pretty fascinating. At first, the user performance was below average. But with consecutive training the outcomes were far better than the very first time. So, the result itself shows the overall training improvement along with the frequent time practicing. Thus, the quality of welding is improved with conserving the resources as well as enhancing the safety.

The development of the welding training scenario in mixed reality thus allows the user to omit the restriction of movement and grabbing. This study enable users to exploit within the virtual world with the help of trackers and cameras. Therefore, the welder can take the plate and position it in the welding table according to the welder's versatility. Furthermore, the welder can also walk along with the welding gun to another welding table to perform different operation like pipe welding. With this feature available, welder's performance is enhanced dramatically. This training scenario also includes voice instruction and visual instruction is also possible with the help of panel inside the scenario. So, it displays warning message every time the welder performs out of instruction. In this way, the welder know the error and perform well in the future. This method is much more convenient and less expensive than the traditional training. Also, when working in mixed reality, gasses, smoke, dust, and exposure to UV light and electric shock are absent. Thus, the safety of the welder is not compromised and is fully protected from the hazardous factors mentioned in problem description. Also, this approach is environmental friendly. Future research activities will include the test to find the occurrence of welding defects in mixed reality. It can be also used in different fields by implementing the standards of respective fields.

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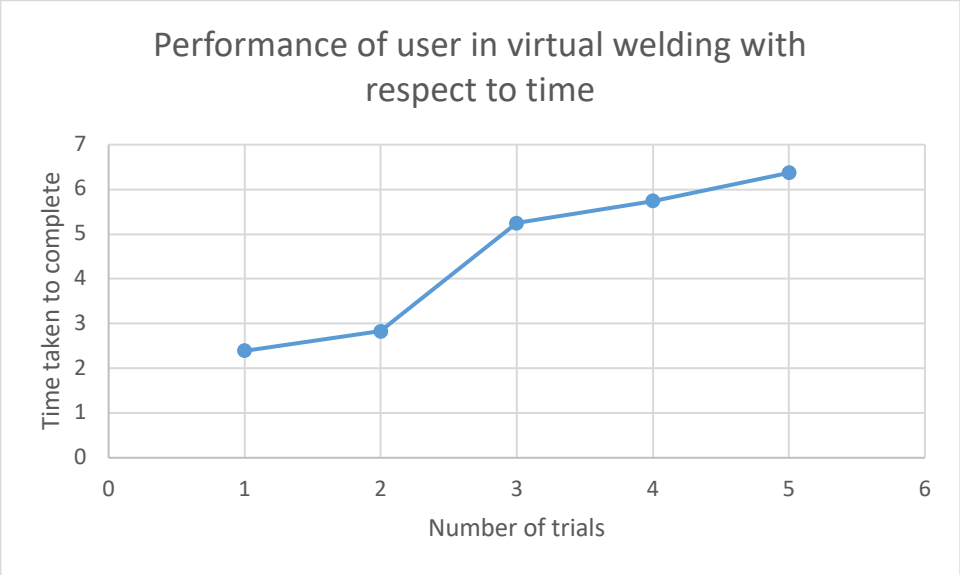
**Table 1.** Performance of user in virtual welding for 5 consecutive trials.

| Number of Trials | Score | Time taken |
|---|---|---|
| 1 | 36 | 2.39 |
| 2 | 94 | 2.83 |
| 3 | 91 | 5.25 |
| 4 | 88 | 5.74 |
| 5 | 94 | 6.37 |

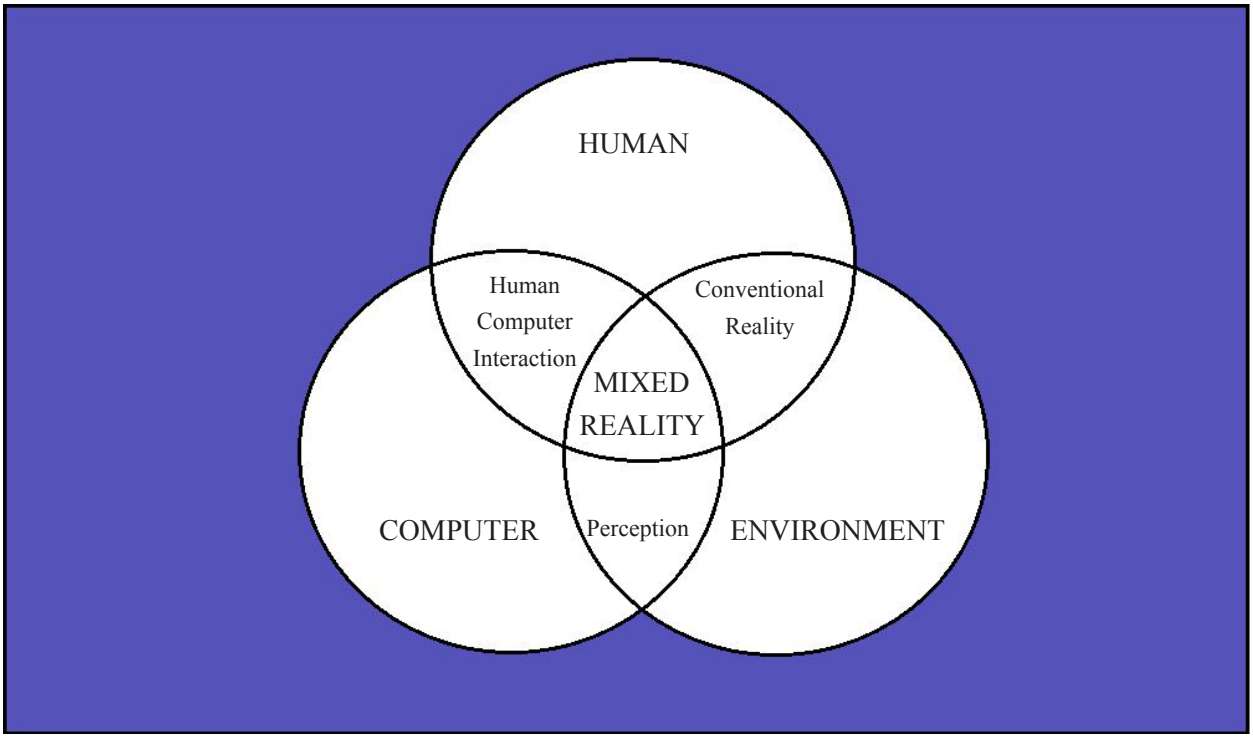
Note. The above data are recorded while performing welding in totally immersed virtual welding scenario. The welding is done for 5 consecutive times to check the performance of the user in virtual welding environment.

**Figure 1.** X Y Scatter plot of Table 1.




**Note.** Based on data recorded in table 1, the graph is plotted

**Figure 3.** The interference between computers, humans and environments.

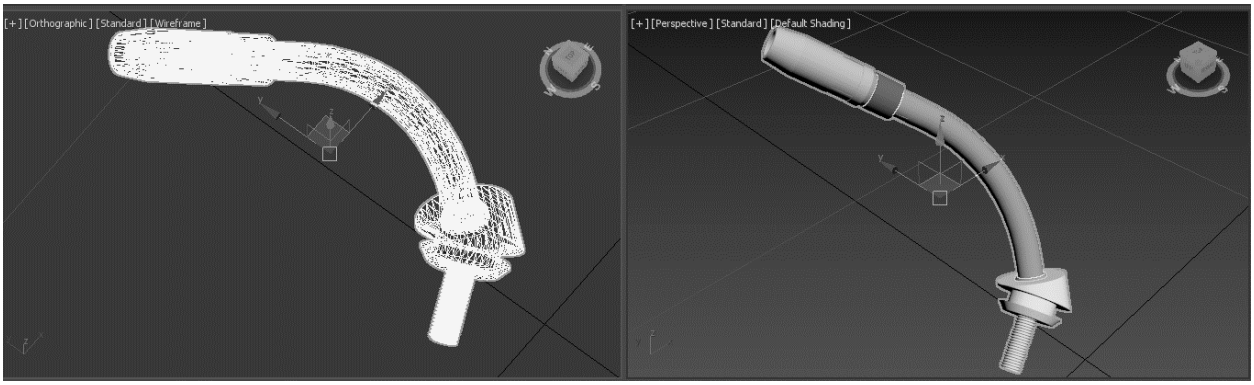



Note. It shows how Human, Computer and Environment relate to each other in mixed reality.

**Figure 4.** Rendering in SolidWorks

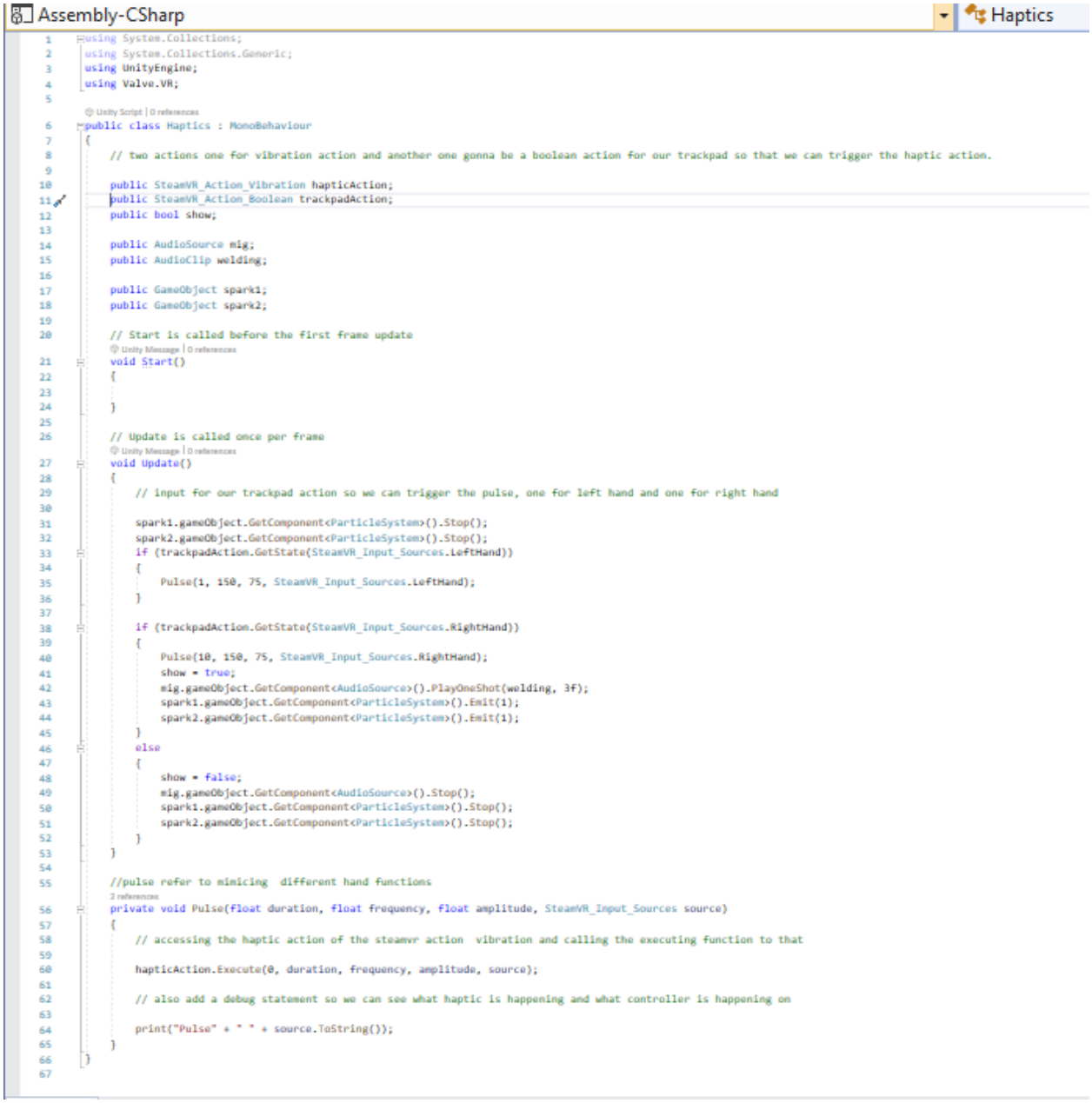
Note. SolidWorks is the base for designing the 3D CAD model and with its integrated analytical tools and design automation help to stimulate the physical behavior. In the above figure, the support is designed so that the upper part of the MIG Gun fits well with the HTC Vive Controller without covering its sensors.

**Figure 5.** Optimizing and editing the mesh of CAD model in 3ds Max.




Note. The uses of proOptimizer and Mesh Edit in 3ds Max enable us to reduce the number of vertices in an object while preserving the object's appearance and provide variety of tools for editing all sub-object levels of the selected object respectively. Left picture is presented in wireframe to visualize the vertices whereas right picture is presented in default shading.

**Figure 6.** C# Sharp script for triggering the welding gun.



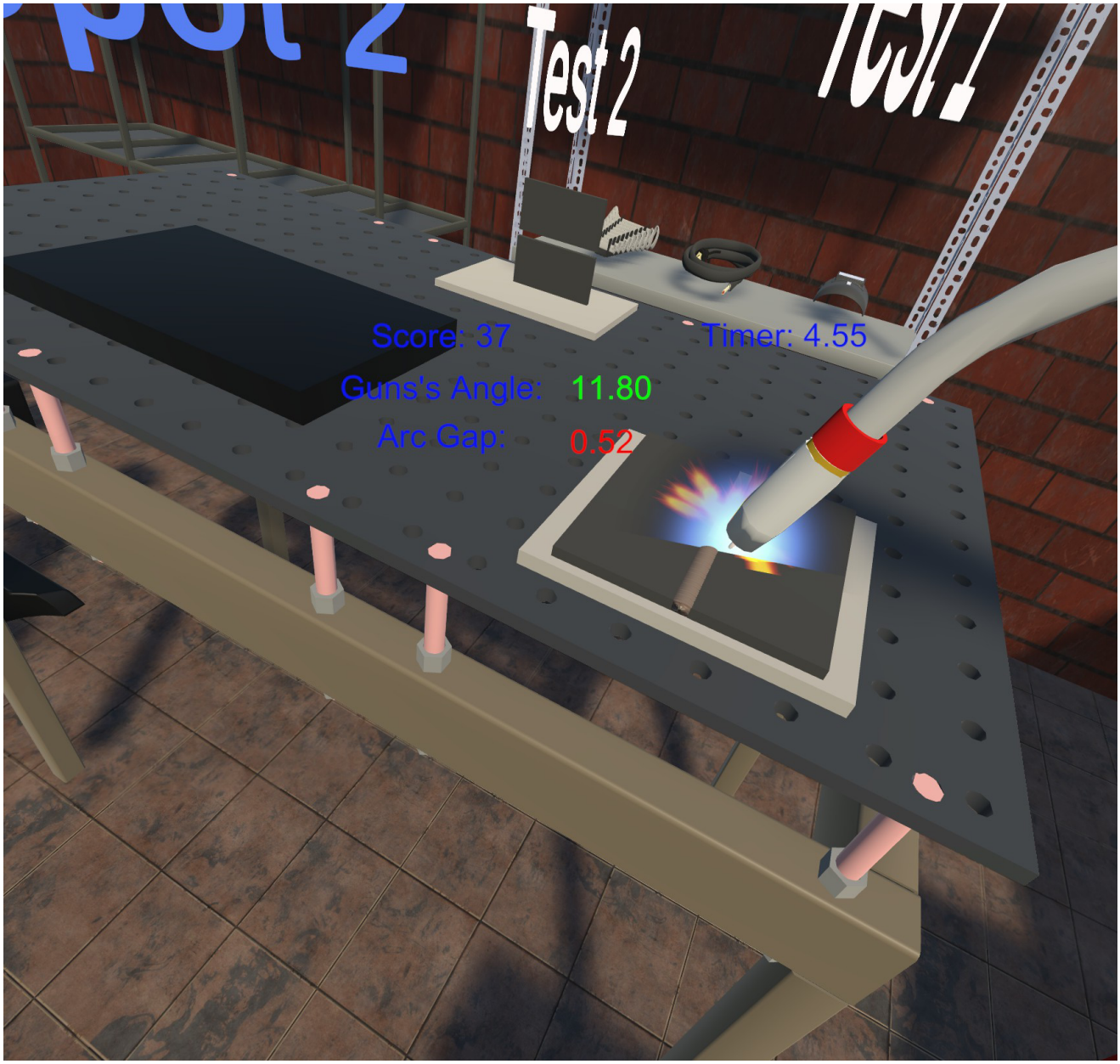

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using Valve.VR;

Unity Script | 0 references
public class Haptics : MonoBehaviour
{
    // two actions one for vibration action and another one gonna be a booleam action for our trackpad so that we can trigger the haptic action.

    public SteamVR_Action_Vibration hapticAction;
    public SteamVR_Action_Boolean trackpadAction;
    public bool show;

    public AudioSource mig;
    public AudioClip welding;

    public GameObject spark1;
    public GameObject spark2;

    // Start is called before the first frame update
    Unity Message | 0 references
    void Start()
    {

    }

    // Update is called once per frame
    Unity Message | 0 references
    void Update()
    {
        // input for our trackpad action so we can trigger the pulse, one for left hand and one for right hand

        spark1.gameObject.GetComponent<ParticleSystem>().Stop();
        spark2.gameObject.GetComponent<ParticleSystem>().Stop();
        if (trackpadAction.GetState(SteamVR_Input_Sources.LeftHand))
        {
            Pulse(1, 150, 75, SteamVR_Input_Sources.LeftHand);
        }

        if (trackpadAction.GetState(SteamVR_Input_Sources.RightHand))
        {
            Pulse(10, 150, 75, SteamVR_Input_Sources.RightHand);
            show = true;
            mig.gameObject.GetComponent<AudioSource>().PlayOneShot(welding, 3f);
            spark1.gameObject.GetComponent<ParticleSystem>().Emit(1);
            spark2.gameObject.GetComponent<ParticleSystem>().Emit(1);
        }
        else
        {
            show = false;
            mig.gameObject.GetComponent<AudioSource>().Stop();
            spark1.gameObject.GetComponent<ParticleSystem>().Stop();
            spark2.gameObject.GetComponent<ParticleSystem>().Stop();
        }
    }

    //pulse refer to mimicing  different hand functions
    2 references
    private void Pulse(float duration, float frequency, float amplitude, SteamVR_Input_Sources source)
    {
        // accessing the haptic action of the steamvr action  vibration and calling the executing function to that

        hapticAction.Execute(0, duration, frequency, amplitude, source);

        // also add a debug statement so we can see what haptic is happening and what controller is happening on

        print("Pulse" + " " + source.ToString());
    }
}
```

Note. The above picture of script enable the triggering of the MIG Gun along with vibration and welding sparks when the trigger of actual controller is pressed. And also enable the welding sound when the user put on the HTC Vive Headset. This allow user to have immersive welding experience in virtual welding scenario.

**Figure 7.** HTC Vive Pro and Noitiom Hi5 VR glove along with 3D printed MIG Gun.


Note. These devices are used to perform welding in virtual world. The above figure includes HTC Vive Headset, two controllers, and two Noitom Hi5 VR gloves along with the attached two trackers. The CAD model of MIG Gun along with support is 3D printed to attach with the right controller is clearly mentioned.

**Figure 8.** Welding the flat plate in virtual scenario.




Note. The welding of the flat plate along with the display of gun's angle, score, timer and nozzle-to-plate distance to allow user for improving the hand skill. The devices that are shown in Fig. 6 play an important role to make this welding possible. With the continuous practice, the user will master the hand skill and improve the welding quality.

# Study of Biofouling using Femtosecond Laser Induced Breakdown Spectroscopy.

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## Abstract

Marine biofouling accounts for around 60 Billion USD in loss every year according to US Naval sources. Biofouling refers to the undesirable growth and adhesion of marine organisms such as barnacles and algae. These marine organisms attach to a ship hull and glue themselves to the surface and create a calciferous bottom plate, building up walls around their soft body. Apart from protection, the shells also create surface turbulence. For a ship of any size that will increase the fuel costs dramatically, lower the speed, increase costs regarding maintenance and thereby reduce efficiency, both in financial as well as safety terms.

The study of biofouling composition is critical to developing anti fouling technologies. In this study, a method of Laser Induced Breakdown Spectroscopy (LIBS) is introduced to determine the elemental composition of biofouling by analyzing the spectral emission from the sample. The laser used is a 1 MHz femtosecond laser from Clark MXR. Samples of biofilm are collected by suspending Stainless Steel grade 316 plates at a depth of 1m in Pascagoula Bay for 5,10,15 and 20 days. This study will help in understanding the elemental composition of biofouling and facilitate in the formulation of novel antifouling coatings.

*Keywords*: Biofouling, Biofilm, LIBS, Femtosecond, Laser Induced Breakdown Spectroscopy.

## Introduction

Biofouling has been a cause of concern for marine structures for centuries. It is a phenomenon in which marine organisms attach to the ship hull and colonize to build huge masses of marine organisms, thus resulting in increased fuel costs, maintenance costs and decreased overall efficiency. Biofouling is also time consuming due to the necessity of dry docking to get rid of the growth on fouled hull. Biofouling is a complex process that begins with the production of biofilm and can be broadly classified into slime fouling, algal fouling and animal fouling. In the proposed study a LIBS (Laser Induced Breakdown Spectroscopy) technique is utilized for determining the elemental composition of biofouling. The elemental composition of biofouling can aid in formulating suitable antifouling coatings to suppress biofouling formation.

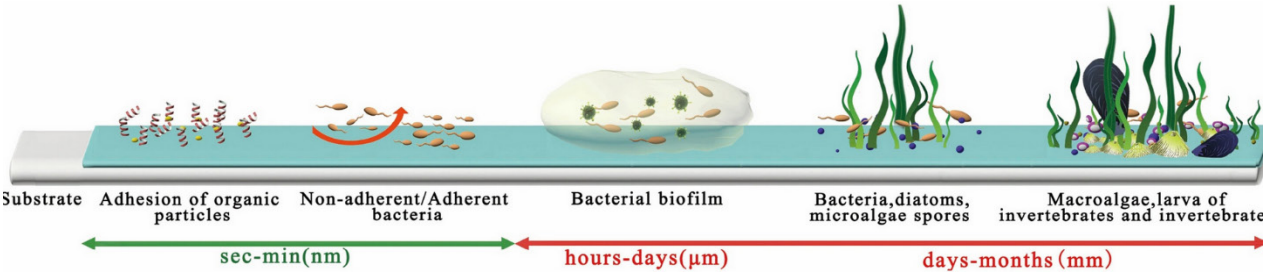


Figure 1. Schematic illustration of the development processes of marine fouling (Han et al., 2021)

## Literature Review

There are many ways to prevent marine biological fouling. According to anti-fouling technology the principle used can be divided into physical antifouling method, chemical antifouling method and biological anti-fouling method (Huang & Peng, 2004).

### Physical Antifouling Method

The physical anti-fouling method refers to the removal and inhibition of biological attachment, so as to achieve the purpose of preventing biological fouling. The main methods of physical antifouling are mechanical removal method, cavitation water jet decontamination method, low surface energy coating anti-fouling method, ultrasonic antifouling method, heating method and Ultraviolet antifouling method (Xu et al., 2012). Most traditional antifouling and decontamination methods belong to the physical anti-fouling method, and this method is also the earliest applied and mature method. Of the above physical antifouling methods, mechanical removal method is time-consuming and requires a lot of labor; cavitation water jet decontamina-

tion, the equipment used in the method is complex and costly; the heating method consumes a lot of energy; ultrasonic waves and ultraviolet antifouling not only affects the antifouling effect of the coatings, but also causes genetic variation of foreign organisms; and the low surface energy antifouling paint can reduce the adhesion of marine fouling organisms or make It less firmly attached. This has no impact on the environment and has good antifouling effect. It has attracted widespread attention and has become a research hotspot in recent years.

**Chemical antifouling method**

The chemical antifouling method uses chemical substances to prevent biological attachment and poisoning. Kill the attached organisms, so as to achieve the purpose of preventing biological fouling. The chemical antifouling method can be divided into direct addition method, electrolytic sea water method and chemical antifouling coating method. Directly addition method (Xu et al., 2012) is to directly add chemical substances with antifouling effect into seawater medium, inhibit or kill fouling organisms; this method is compared with other anti-fouling methods in terms of economic efficiency, it has a greater impact on the ecological environment, so its applications are greatly reduced. Li et al. (1996) introduced the electrolysis seawater method in which electrolysis is produced to achieve anti-fouling effect. It is mostly used in closed or semi-closed systems and it is difficult to use in the anti-fouling treatment of underwater hulls. Li et al. (1996) doped antifouling agents (such as: $Cu_2O$, ZnO and organic Biocides, etc.), that continue to permeate to inhibit fouling attachment and growth of objects. This chemical antifouling paint method can be divided into base dissolving antifouling paint and base-insoluble antifouling paint. Chemical antifouling coating method has good antifouling effect and is currently the most widely used antifouling method. But as awareness of environmental protection continues to increase and regulatory requirements get high, its application is subject to certain restrictions and it must move towards low toxicity, non-toxic.

**Biological antifouling method**

The biological antifouling method uses biologically active substances as antifouling agents to inhibit the attachment, reproduction and destruction of biological membranes, so as to achieve anti-fouling target material. Antifouling biologically active substances include enzymes Classes, organic acids, inorganic acids, lactones, terpenes, phenols, sterols and indole Class and other natural compounds (Perez et al., 2014). Currently, researchers working on marine organisms (such as Red algae, sponge, coral, pepper, white wood, thorny

cloud) extract the biologically active substance from the resin, add it directly to the resin or treat it. However, in most animals and plants, the content of active substances is low, and the extraction is more difficult. Also, the external environment has an impact on the activity of active substances (such as enzymes), resulting in a short active life. So, the biological antifouling method is not practical.

It has been widely used but needs to be studied and further improved. In addition, the researchers also studied the antifouling mechanism of natural antifouling agents. When chemically synthesized it can produce functional groups with antifouling function, and design low-toxic or non-toxic anti-fouling stain agent. Pérez et al. (2014) synthesized sorbates and discussed their antifouling mechanism, the experimental results of the real sea hanging board showed excellent anti-fouling performance, it is a potential antifouling agent. Zheng (2007) synthesized an isoniazid, the oxazolidinone compound has been found to have a strong ability to kill barnacle larvae. It is mixed into marine antifouling paint, and the results show excellent antifouling performance.

## Ship antifouling paint

Marine biological fouling has been affecting the performance of ships and marine structures. The current antifouling coating is the most effective and broad-spectrum method, and it is also the most mature technology evolved to date.

### The development history of antifouling coatings

As early as 2000 years ago, people realized that marine creatures play a role in ships fouling. The earliest antifouling method is to put asphalt, wax, tar Etc. Yebra et al. (2004) painted on the immersed ship's hull, sulfur and Arsenic are also used. Coatings containing Cu and Pb are also documented. During 13th to 15th century, asphalt is widely used in ship antifouling. Many times, asphalt is reduced to Oil, resin, or a mixture of tallow oil; at the beginning of the 17th century, the hulls were mostly Wood, Pb-containing coatings are widely used; in the middle of the 18th century, CuO, As and Hg containing coatings began to appear (Yebra et al., 2004). Late 18th century to the beginning of the 19th century, Cu, As and Hg were widely used in ship antifouling. As the hull material changed from wood to iron, Cu-containing coatings were restricted because copper promotes iron corrosion (Young et al., 1945). During mid-19th century a series of new antifouling coatings had been developed which can precipitate toxic antifouling agents. Polymer paints containing Cu, As and Hg antifouling agents for chemical compounds had become mainstream products; in the course of use, people found this kind of antifouling agent has a short antifouling validity period, difficult to cure, and

coating problems such as too long time. In the middle of the 20th century, coatings containing tributyl organotin (TBT), a highly toxic antifouling paint came out. TBT has a broad spectrum of Bacterial killing effect and a long validity period. By the late 20th century, people realized that TBT coatings would seriously affect the growth and reproduction of marine organisms and even enter the human body through food chain, so countries began to gradually restrict or prohibit the use of organotin antifouling coatings (Evans et al.,1995). In, 1999 the International Maritime Organization decided to ban the use of organic tin antifouling paint. In recent years, antifouling coatings have become non-toxic and are widely used because of the spectral efficient development. Fouling releasing non-toxic antifouling paint and bio-reducible non-toxic antifouling agents for detoxification have received more and more attention.

**New antifouling paint**

Fouling release type antifouling paint is the use of low surface energy and other properties of the paint surface to make marine creatures difficult to attach or not firmly attached. Using their own weight and the impact of the water flow during sailing or special cleaning equipment can easily remove the attached organisms (Zhang et al., 2010). Research has found that the surface energy of the coatings, Elastic modulus, thickness, surface morphology, etc. have great influence on the antifouling performance. For most marine organisms, the surface energy of the coating determines the strength and number of marine organisms attached to its surface, and the surface energy, the lower the value, the less likely it is to adhere to the surface, and the surface energy of the coating when it is less than 25 mN/m, that is, the contact angle between the coating and the liquid is greater than 98°, has anti-fouling effect (Zhang et al., 2008); while certain marine organisms (such as diatoms and mussels) adhere more firmly on low surface energy coatings (Zhang et al., 2010). Currently applied antifouling coatings mainly include (1) silicone (~22 mN/m), (2) organic fluorine (~10~18 mN/m) and (3) fluorosilicone resin (Zhang et al., 2008).

**Organic silicon modified fouling release type antifouling paint.** Silicone refers to organopolysiloxane, according to its molar mass and the difference in structure can be divided into silicone oil, silicone resin and silicone rubber (Vesco et al., 2019). Silicone resin has good antifouling performance, but is more expensive, has poor mechanical properties, poor recoat ability and other shortcomings, and it cannot be used as a film forming alone substance. Hydroxyl groups on the polysiloxane chain react with other polymers on the hy-

droxy group, carboxyl group, isocyanate group, etc. to combine to become an antifouling paint with excellent performance (Sommer et al., 2010). Research has found that polydimethylsiloxane-based siloxane-polyurethane antifouling paint has a low surface energy (~22 mN/m) and is a potential defense dirt paint. Waterborne polyurethane-silane resin synthesized by Rahman et al. (2013) also showed good anti-fouling performance and mechanical properties.

**Organic fluorine modified fouling release type antifouling paint.** Although fluoropolymers have excellent durability and chemical resistance, it's expensive, and it is very limited in practical application. Dimitriou et al. (2011) synthesized a Fluorine-containing triblock polymer, and found that the coating has a better antifouling effect on Ulva spores. Wang et al. (2011) studied the amphiphilic perfluoropolyether/polyethylene glycol network structure on anti-fouling performance, and its influence on Diatoms, barnacle larvae, and Ulva spores have better antifouling effects than polydimethylsiloxane.

**Fluorosilicone resin fouling release type antifouling paint.** This paint has poor mechanical properties and is not resistant to organic solvents, but it is flexible; excellent performance of fluororesin, fluorine-containing side groups can improve the material solvent resistance and improved surface performance, but it is expensive. Therefore, researchers have developed a new type of anti-corrosion and anti-fouling coating that has the advantages of both in order to obtain a more excellent performance of fluorosilicone resin coating (Martinelli et al., 2011). Martinelli et al. (2011) synthesized a fluorine-containing silicon amphiphilic resin Coating, the coating is hydrophobic and oleophobic, and has a high release rate to Ulva Less than 80%, showing a good antifouling effect.

Nanocomposite coatings are also documented to show anti-biofouling properties. Slippery hybrid coatings (SHCs) fabricated from tetraethyl orthosilicate (TEOS), methylriethoxysilane (MTES), N-Octyltriethoxysilane (OTES) have shown to significantly inhibit biofilm formation (Wei et al. 2016). Zn wetted CeO2 (Zn/CeO2) composite galvanic zinc coating has shown to impair the cellular respiration and results in bacterial death, thus exhibiting antibiofouling properties (Sreelekshmy et al., 2019). Several approaches of biomimetic antifouling are researched such as bioinspired polymeric antifouling coatings, biomimetic surface microtopographies but many restrictions such as expensive and complex manufacturing processes along with insufficient durability and longevity in marine surroundings limit the industrialized production of these coatings. Although an effective combination of biomimetic antifouling strategies may contribute to the development of new anti-

fouling techniques with exceptional repellency and stability (Chen et al., 2021). A Laser Induced Breakdown Spectroscopy technique is utilized for determining the elemental composition of biofouling. The elemental composition of biofouling can aid in formulating suitable antifouling coatings to suppress biofouling formation.

**How can ATMAE faculty benefit from this Research?**

This research can be utilized in developing a class for undergraduate students in Industrial Technology. One of the emerging concentrations nowadays is Paints and Packaging, and a class on corrosion and coatings in this concentration would make students aware of the latest technological advancements in the field. Also, undergraduate students can actively participate in conducting research in corrosion and paint technology to further their interests.

**Experimental work**

A diode pumped mode locked system capable of producing pulse energies >10 μJ, with a wavelength of 800nm and pulse duration of 35fs is used as an excitation source. The spectra was collected with a broadband spectrometer (Andor Mechelle ME5000, 200-975 nm spectral range). The samples were collected on Stainless steel grade 316 plates that were immersed at a depth of 1m in the Gulf of Mexico for a period of 5,10,15 and 20 days.

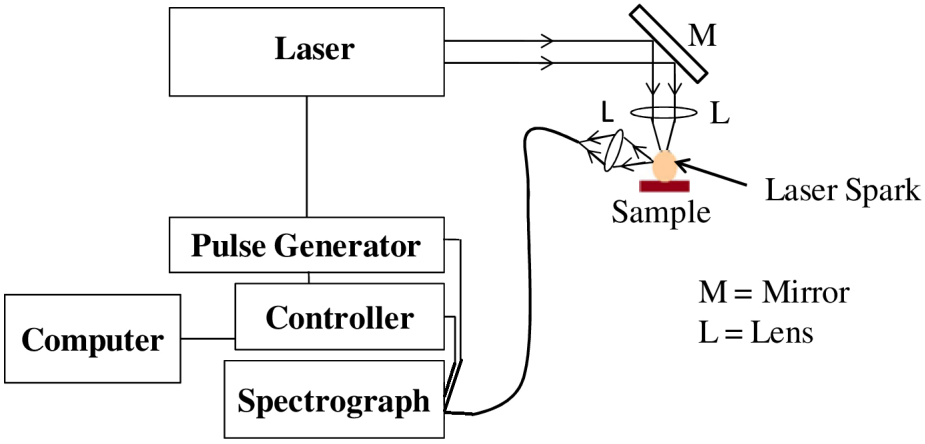


Figure 2. LIBS Schematic

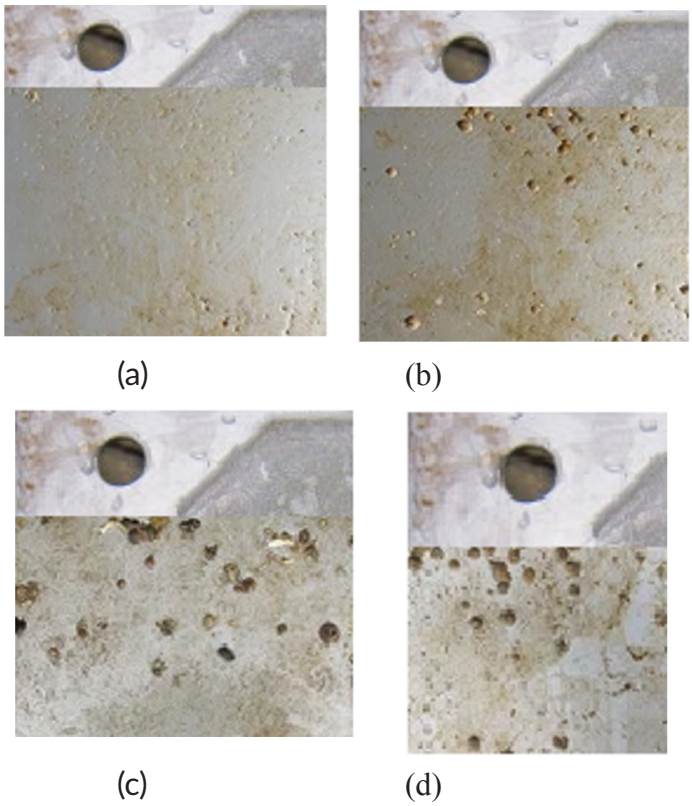


Figure 3. Biofouling of Stainless steel grade 316 plates. (a) 5 days (b) 10 days (c) 15 days (d) 20 days.

## Results and Discussion

From the spectra that was generated from the LIBS analysis of biofouling sample that was immersed in the Gulf of Mexico for 20 days, it was evident that elements Mg, Al, Ca, Si, Ba, Br, Fe, N, S, Na were observed.

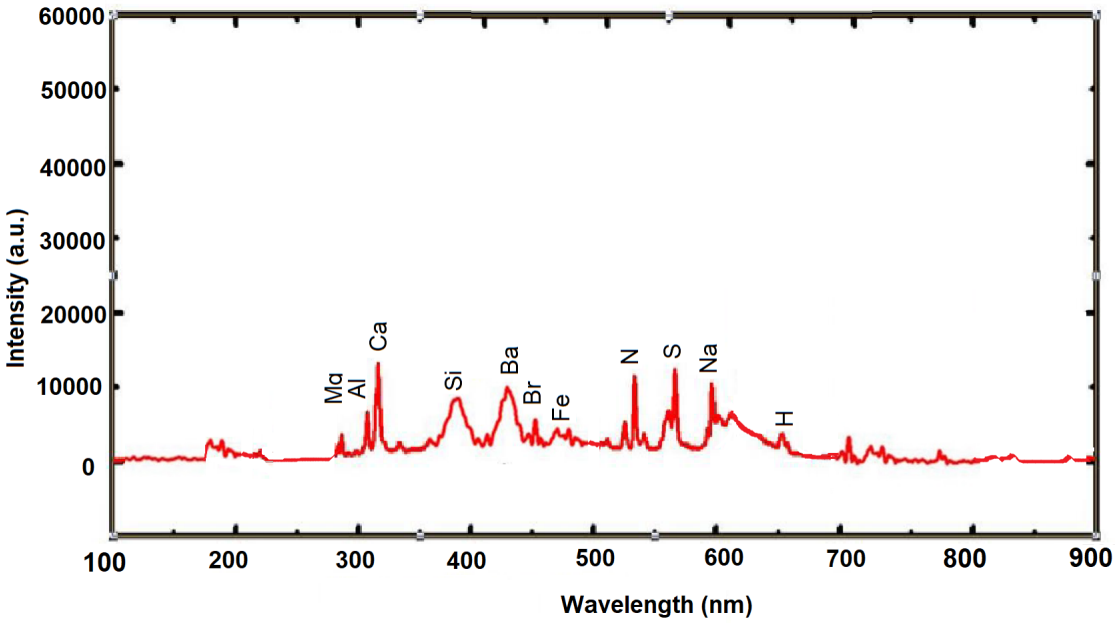


Figure 4. LIBS elemental analysis of biofouling samples.

In this study, it was possible to determine the elemental composition of biofouling samples that were immersed in the Gulf of Mexico through LIBS technique. The elemental composition of biofouling could facilitate in the formulation of novel antifouling coatings.

## Conclusion

Biofouling has a tremendous impact on the marine structures and it costs billions of dollars for prevention and maintenance. In this study we have determined the elemental composition of biofouling samples from the Stainless Steel grade 316 plates that were suspended in the Gulf of Mexico for 5,10,15,20 days. The prominent elements visible in the LIBS spectra are Mg, Al, Ca, Si, Ba, Br, Fe, N, S, Na etc. Further, a detailed review is documented on the development of antifouling technologies over the years. This review helps us in understanding the different antifouling technologies discovered so far and looking at the elemental composition of LIBS spectra of the biofouling samples it will enables us to discover the best antifouling technologies. These technologies are bound to develop in the direction of low toxicity, environmental protection, broad-spectrum and high-efficiency, and use bionic technology. Fouling release antifouling coatings that combine technology and nanotechnology are the future of antifouling coatings.

Further research will be conducted to understand how the elemental composition of biofouling matter can be used to formulate the nanotechnology based antifouling paint.

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# Risk Factors of Non-Hodgkin's Lymphoma Cancer ad Exposure to Glyphosate: A Systematic Review

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## Abstract

Studies investigating the health effects of pesticide exposures started in late 1980s and 1990s as the use of such chemicals became wide spread. Most studies covered a range of the pesticides and cancer types and general consensus among experts has been that exposure to Glyphosate can be carcinogenic. The goal of this article was to conduct a systematic review to specifically investigate the association between exposure to glyphosate and Non-Hodgkin's Lymphoma.

A critical appraisal was conducted twice after a thorough review of peer-reviewed studies published after 2000. A summary of potential factors and health outcomes were provided. The results showed deficiencies and shortcomings in different aspects of epidemiological studies included in this review such as subject selection, data analysis methods and quality of observation. Overall, there were signs indicating potential association between glyphosate exposure and Non-Hodgkin's Lymphoma but overall the findings of this systematic review were inconclusive and cannot be generalized.

*Keywords:* Glyphosate, Non-Hodgkin's Lymphoma, NHL, Systematic Review, Critical Appraisal, Pesticide, Epidemiology, Roundup

**Review**

Over the past few decades, the use of pesticides has drastically increased worldwide to approximately 5.2 billion pounds annually (Mahmood et al., 2016). The term pesticides in general includes insecticides, herbicides, defoliants, desiccants, fungicides, nematicides, avicides, and rodenticides, which are not easily degraded. They persist in soil, leach to surface and groundwater and contaminate the environment and subsequently influence human health. Among them, herbicides are substances widely used in large scale agriculture to inhibit the growth and reproduction of unwanted plants and vegetation (Vats, 2015). A major subset of herbicides that are commonly used is Glyphosate, also known as N-(phosphonomethyl) glycine. It is an organophosphate compound that acts by inhibiting the enzyme 5-enolpyruvylshikimate-3-phosphate synthase, which is essential for the formation of aromatic amino acids in plants. (Gervais et al., 2010; Klaassen and Watkins III, 2015). It was marketed for agricultural use in 1974 under the trade name Roundup.

Initially after revising the toxicological data on glyphosate, the U.S Environmental Protection Agency (U.S. EPA, 1993) and the World Health Organization (WHO, 1994) concluded that glyphosate is not mutagenic or carcinogenic (De Roos et al., 2005). However, more than two decades later in 2015, the International Agency for Research on Cancer (IARC) classified glyphosate as "probably carcinogenic to humans", due to strong mechanistic evidence and positive associations for Non-Hodgkin's Lymphoma (NHL) in some epidemiological studies (Andreotti et al., 2018).

There have been conflicting results from research conducted to determine if glyphosates causes cancers. Preliminary studies indicated no relationship (De Roos et al., 2005, Orsi et al., 2009); while other studies indicate a relationship between glyphosate and NHL (Williams et al., 2000; Hardell et al., 2002). Use of herbicides such as glyphosate have contributed substantially to improve the quality and quantity of agricultural products around the world, and meanwhile prevalence of cancers increased in the same countries where they were used (Zhang et al., 2019).

Exposure to glyphosate can cause a wide range of clinical symptoms in humans such as eye, skin and throat irritation, headache, numbness, nausea, hypo- or hypertension, and heart palpitations or even death. (Cox, 1998; Mahendrakar et al., 2016) and route of entry can be an important factor. Epidemiological studies have reported mixed results about the risk of developing NHL among people exposed to glyphosate (Hardell et al., 2002; Orsi et al., 2009).

Because none of the previous studies tried to focus specifically on the association between glyphosate and NHL, this systematic review was conducted on epidemiological studies published after 2000 in order to evaluate such association by using Epidemiological Appraisal Instrument (EAI) (Genaidy and LeMasters, 2005; Genaidy et al., 2007).

## Methodology

Search Strategy and Inclusion Criteria: This review primarily focused on epidemiological studies about exposure to glyphosate and its potential association with Non-Hodgkin's Lymphoma (NHL) which were published in English in any, but not limited to, occupational health and safety, medical, toxicological, business, industrial hygiene, and agricultural journals in which researchers examined the potential health effects of pesticides on human health.

An electronic and bibliography search from identified articles was carried out on EBSCOhost, ScienceDirect, ProQuest, PubMed, Web of Science, Directory of Open Access Journals (DOAJ). The keywords used in this search were: glyphosate, Non-Hodgkin's Lymphoma, NHL, Roundup.

Inclusion criteria were: *i.* articles published between January 2000 and September 2019 (when the search was completed), *ii.* articles published in English, *iii.* epidemiological studies with human subjects. Articles that studied other types of pesticides and/or other types of cancers in addition to glyphosate and NHL were also included in the review. Articles published in languages other than English were excluded due to difficulties and limitations in translation.

Critical Appraisal: The quality of all accepted articles was blindly assess by one of the authors (JE) twice using Epidemiological Appraisal Instrument (EAI) version 3.1 (Genaidy et al., 2007). Both appraisals were four weeks apart. EAI is composed of 43 questions and factors considered for appraisal includes: study design, objectives, sample and population size, methodology, statistical analysis, reliability and validity of measurements, input variables or exposures, covariates and confounders, outcomes and adjustments. EAI scales range from '0' to '2'. Two points were given for each question if the information was available, one point, if it was partially available and zero points, if the answer was not available. At the end, in order to show the agreement between both rounds of critical appraisal processes, a Kappa test was performed to calculate the intra-rater reliability score.

## Results

Identification of Studies: the search resulted in 359 studies related to this topic and they were filtered and narrowed further down to 12 articles based on their topics and abstract. After implementing the inclusion criteria only six articles were eligible for the systematic review. Figure 1 details the search strategy and its results.

Description of Evidence: A detailed description and summary of all the studies included in this review is presented in table 1. Among all the studies two were cohort studies (De Roose et al., 2005, Andreotti et al., 2018) and four were case-control (McDuffie et al., 2001, Hardell et al., 2002, De Roose et al., 2003, Eriksson et al., 2008) and among the case-control studies, Hardell et al. (2002) and De Roose et al. (2003) combined the data of two and three separate studies into one large case-control study respectively. Hardell et al. (2002) had the

smallest sample size with 1656 subjects and De Roose et al. (2005) had the largest sample with 57,311 participants. The studies listed in table 1 covered a range of pesticides and cancer types and all of them had glyphosate and NHL in common.

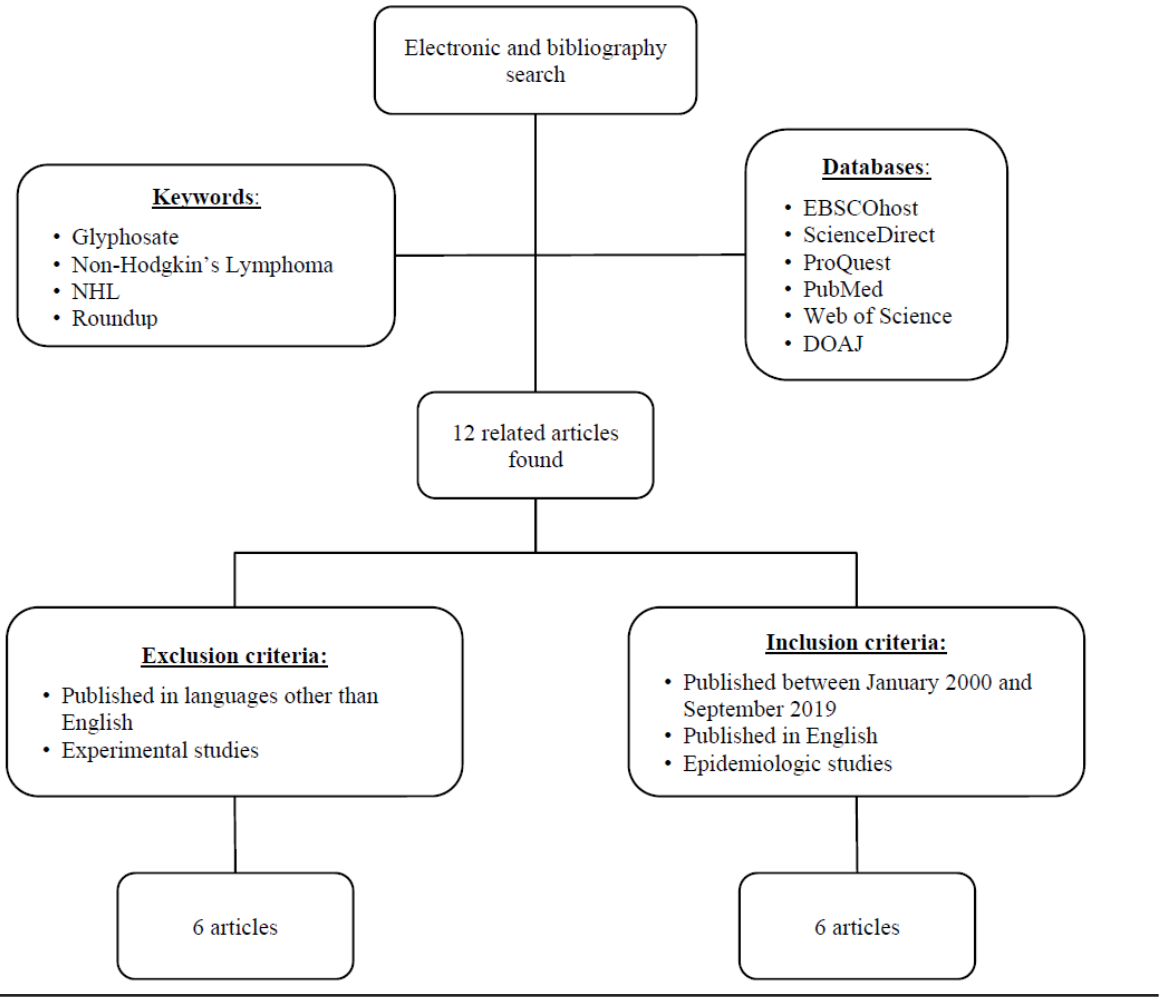


**Figure 1** – Literature search strategy

Risk Factors: All six accepted articles were subjected to blind critical appraisal twice. The critical appraisals were conducted four weeks apart and the overall intra-rater reliability score (Kappa test coefficient) was 0.83.

**Table 1** – Description of evidence

| Reference | Study design | Sample size | Independent variables | Dependent Variables | Results |
|---|---|---|---|---|---|
| McDuffie et al. (2001) | Case-Control | • n=2023, (517 cases, 1506 controls), 19 years or older<br>• All men from six provinces in Canada<br>• Cases recruited from Cancer Registries in each province - in Quebec from hospital records | A survey questionnaire - Demographics, smoking and medical history, exposure to pesticides | NHL diagnosis | Found correlation between NHL and…<br>• 2,4-D , OR=1.32 & 95% CI=1.01-1.73<br>• Mecoprop, OR=2.33 & 95% CI=1.58-3.44<br>• Dicamba, OR=1.88 & 95% CI=1.32-2.68<br>• Carbaryl, OR=2.11 & 95% CI=1.21-3.69<br>• Lindane, OR=2.06 & 95% CI=1.01-4.22<br>• Aldrin, OR=4.19 & 95% CI=1.48-11.96<br>• DDT, OR=1.73 & 95% CI=1.08-2.76<br>• Malathion, OR=1.83 & 95% CI=1.31-2.55<br>• Captan, OR=2.51 & 95% CI=1.32-4.76<br>• Sulphur Comp., OR=2.80 & 95% CI=1.41-5.57 |
| Hardell et al. (2002) | Case-Control<br><br>Two studies pooled in one | • n=1656, (515 cases, 1141 controls), 25 years or older<br>• All men from four northern counties in Sweden and three mid-Sweden counties<br>• Cases recruited from regional Cancer Registries | A survey questionnaire - Demographics, working history, exposure to pesticides | • In one study the independent variable was NHL diagnosis<br>• In second study the independent variable was Hairy Cell Leukemia (HCL) diagnosis | Found higher risk for NHL and HCL among people exposed to…<br>• Herbicides, OR=1.75 & 95% CI=1.26-2.42<br>• Insecticides, OR=1.43 & 95% CI=1.08-1.87<br>• Fungicides, OR=3.11 & 95% CI=1.56-6.27<br>• Impregnating agents, OR=1.48 & 95% CI=1.11-1.96<br>Among herbicides, significant associations were found for…<br>• Glyphosate, OR=3.04 & 95% CI=1.08-8.52<br>• MCPA, OR=2.62 & 95% CI=1.40- 4.88 |

a**Table 1** – Description of evidence (continued)

| Reference | Study design | Sample size | Independent variables | Dependent Variables | Results |
|---|---|---|---|---|---|
| De Roos et al. (2003) | Case-Control<br><br>Three studies pooled in one | • n=3417<br>• Study 1 - all white male, 21 years or older from Nebraska<br>• Study 2 - all white male, 30 years or older from Iowa & Minnesota<br>• Study 3 - all white male, 21 years or older from Kansas<br>• Cases recruited from state health registries and hospital records | Interviews - Demographics, life style, exposure to pesticides | NHL diagnosis | Found correlation between NHL and…<br>• Coumaphos, OR=2.4 & 95% CI=1.0-5.8<br>• Diazinon, OR=1.9 & 95% CI=1.1-3.6<br>• Atrazine, OR=1.6 & 95% CI=1.1-2.5<br>• Glyphosate, OR=2.1 & 95% CI=1.1-4.0<br>• Sodium chlorate, OR=4.1 & 95% CI=1.3-13.6<br>also combination of…<br>• Diazinon+Altrazine, OR=3.9 & 95% CI=1.7-8.8<br>• Alachlor+Altrazine, OR=2.1 & 95% CI=1.1-3.9<br>• Altrazine+Dicamba, OR=2.1 & 95% CI=1.0-4.7 |

| | | | | | |
|---|---|---|---|---|---|
| De Roos et al. (2005) | Cohort | • n=57,311 (97.5% male)<br>• Licensed pesticide applicators in Iowa and North Carolina<br>• Subject recruited from Agricultural Health Study (AHS) and cancer registries in Iowa and North Carolina | A survey questionnaire - Demographics, working and medical history, smoking and alcohol consumption, exposure to glyphosate | Different cancer types (i.e. Lung, Colon, Rectum, Pancreas, Kidney, Bladder, Prostate, Melanoma, all Lymphohematopietic cancers, Non-Hodgkin's Lymphoma, Leukemia, Multiple myeloma) | The researchers only found higher risk for Melanoma cancer after adjusting for age RR=1.8, 95% CI=1.0-3.4 |

**Table 1** – Description of evidence (continued)

| Reference | Study design | Sample size | Independent variables | Dependent Variables | Results |
|---|---|---|---|---|---|
| Eriksson et al. (2008) | Case-Control | • n=1926 (910 cases, 1016 controls), 18-74 years old<br>• Cases recruited from records of four different hospitals in Sweden | Interview and survey questionnaire - Demographics, life style and medical history, exposure to pesticides | NHL and eight other lymphoma diagnoses | Found correlation between NHL and other types of Lymphoma and…<br>• Herbicides, OR=1.72 & 95% CI=1.18-2.51<br>• MCPA, OR=2.81 % 95% CI=1.27-6.22<br>• Glyphosate, OR=2.02 & 95% CI=1.10-3.71<br>• Impregnating agents, OR=1.57 & 95% CI=1.07-2.30 |
| Andreotti et al. (2018) | Cohort | • n=54,251 (97.3% male)<br>• Licensed pesticide applicators in Iowa and North Carolina<br>• Subject recruited from Agricultural Health Study (AHS) and cancer registries in Iowa and North Carolina | A survey questionnaire - Demographics, working and medical history, smoking and alcohol consumption, exposure to glyphosate | Different cancer types (i.e. Lung, Colon, Rectum, Pancreas, Kidney, Bladder, Prostate, Melanoma, all Lymphohematopietic cancers, Hodgkin and Non-Hodgkin's Lymphoma [different subtypes], Leukemia, Multiple myeloma, Testicular) | The researchers did not find any association between any cancer type and exposure to glyphosate. |

OR: Odds Ratio

The result of critical appraisal for all six articles is presented in figure 2. All scores are in the range of zero to two. Both Eriksson et al. (2008) and Hardell et al. (2002) had the highest overall score of 1.38 and McDuffie et al. (2001) had the lowest overall score of 1.00. The Study Design were clearly described in every article where the scores were very close (1.7 to 1.8). In regard to Subject Selection McDuffie et al. (2001) was the weakest with a score of 1.0 and Andreotti et al. (2018) was the strongest with a score of 1.9. Most studies did not provide enough information about subject loses or whether subjects in different groups were recruited during the same period of time.

All the studies scored lower than 1.0 in observation quality. The lowest score belongs to McDuffie et al. (2001) and the largest one to Hardell et al. (2003). The most common problems were validity and reliability of data because *i.* data was collected from next of kin in cases a subject was deceased at the time of data collection; *ii.* data was collected over a long period of time; and *iii.* it was not clear if the subjects and observers were blinded to the study design and

methodology. Most of the studies provided a list of potential covariates and/or confounders such as gender, consumption of alcohol and tobacco, level of education, but not all the studies included them in the analysis. Hardell et al. (2002) scored the lowest in data analysis mainly because it did not provide analysis for different groups of subjects and it did not even mentioned anything about the covariates and confounders. Despite the size of the sample, all studies scored very low in generalization because the samples were not representing the entire population and they were biased in certain directions, such as gender or race/ethnicity.

## Discussion

The goal of this systematic review was to investigate the possible association between exposure to glyphosate and developing NHL. Epidemiological studies focusing specifically on this herbicide and NHL are rare and most of the available research articles covered a range of pesticides and cancer types. Most of the articles, even those published in 2000s and later had used data from 1980-90s. The regulations and standards about pesticides have changed during this time. Some of the chemicals are no longer produced or used and at the same time new substances have been developed. Such continuous changes can affect the research in this topic. This systematic review tried to focus on research that have been published recently.

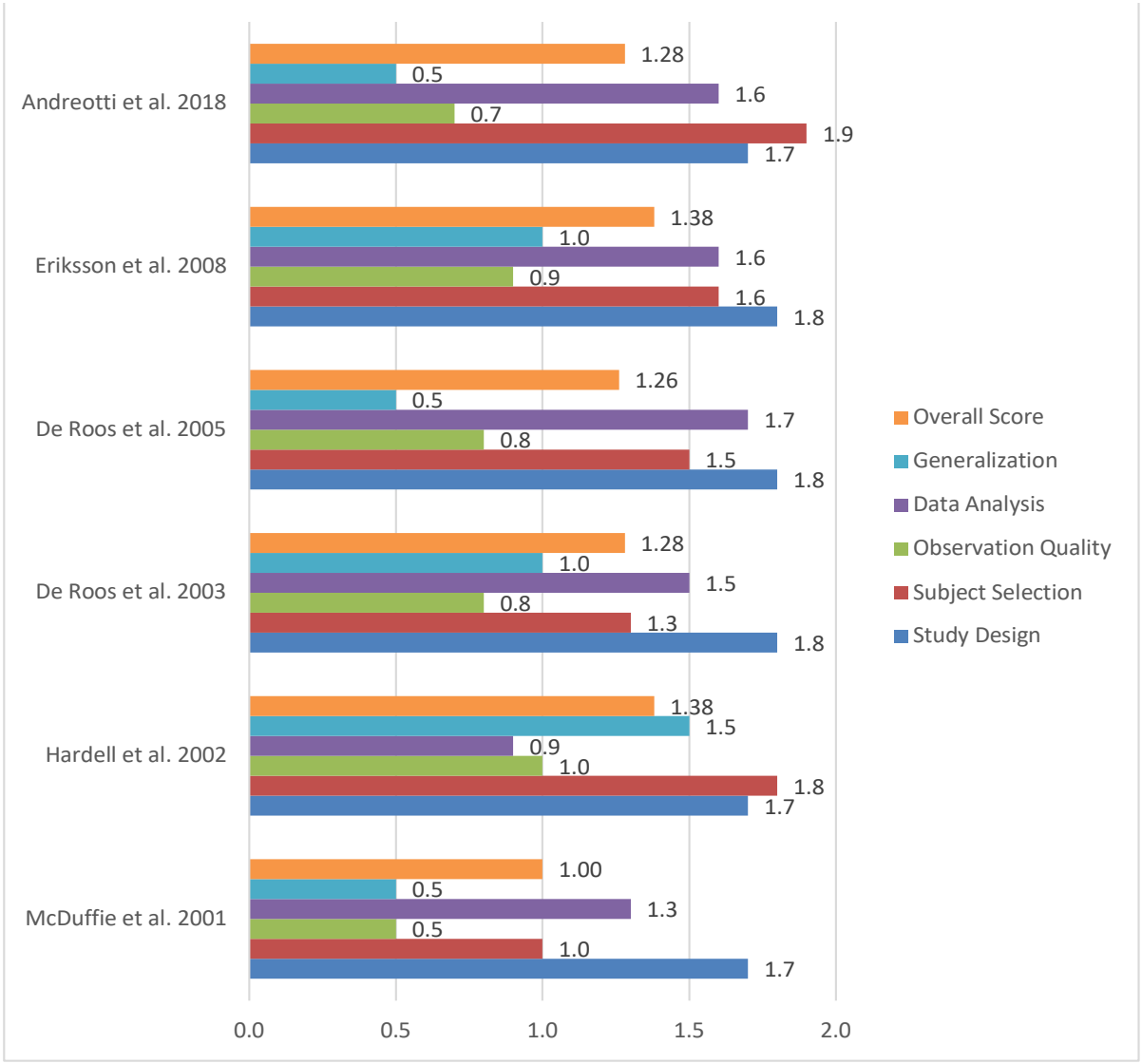


**Figure 2** – Critical appraisal ratings for all included articles

McDuffie et al. (2001) was the only study in this review that was conducted in Canada and they showed correlation between NHL and exposure to certain pesticide but glyphosate was not among them. The results of this study cannot be generalized because the authors did not provide explanation about i. the time-line ii. whether the subjects or observers were blinded to their groups, and iii. what type of occupations were included in the study. In addition, confounders/covariates were not included in analysis.

The study conducted by Hardell et al. (2002) was a pooled case-control study from two separate studies in Sweden. One of the studies was to investigate the correlation between exposure to pesticides and NHL and the second one Hairy Cell Leukemia (HCL), a sub-type of NHL. The results showed there were higher risk of developing NHL and HCL (OR=3.04, 95% CI=1.08-8.52) among those who were exposed to glyphosate. Although a larger sample size was considered an advantage, the findings cannot be generalized for the same reasons mentioned above.

In another study from Sweden conducted by Eriksson et al (2008), the correlation between several pesticides (including glyphosate) and NHL as well as eight other lymphomas were examined. The researchers failed to explain if subjects and observers were blinded to group assignments, or how valid or reliable the observations were considering that some of the subjects had experienced exposures decades ago. The analysis did not include the effects of confounders and covariates. Their findings were consistent with Hardell et al. (2002) and concluded that the risk of developing NHL among subjects exposed to glyphosate is high (OR=2.02, 95% CI=1.10-3.71).

De Roos et al. (2003) was a pooled case-control study in which researchers combined data from three different studies conducted in different states; i.e. Nebraska, Iowa/Minnesota, and Kansas. The subjects in case group were selected from different timeframes (In Nebraska 1983-1986, in Iowa 1981-1983, in Minnesota 1980-1982, and in Kansas 1979-1981). A 7 years of difference between the earliest and latest diagnosis among subject can raise questions about the quality of observation and subject/record selection. At the end, the researchers reported higher risk of NHL diagnosis for subjects who were exposed to glyphosate (OR=2.1, 95% CI=1.1-4.0).

De Roos et al. (2005) conducted another study specifically about potential association between glyphosate exposure and different types of cancers. In this cohort study case subjects were recruited from Agricultural Health Study (AHS) and cancer registries in Iowa and North Carolina and it included licensed

pesticide applicators between 1993 and 1997. The average follow-up time was 6.7 years. The findings of this article cannot be generalized mainly because it did not explain if subject and observers were blinded to their measurement and group assignments. Also the analysis by level of exposure was conducted in tertiles which divided the sample into three relatively equal sub-groups while the exposure levels were divided into three unequal intervals. Some potential covariates/confounders (e.g. age, lifestyle factors and other exposures) were included in the results. Overall, the researchers did not find any statistically significant correlation between exposure to glyphosate and NHL.

Andreotti et al. (2018) was another cohort study using a survey questionnaire between to follow up subject between 1999 and 2005. This study also scored relative low in observation quality and generalization mostly for the same reasons mentioned above. The researchers used an unusual method in their subject and record selection (a mathematical method) to estimate values for missing data (Andreotti et al., 2018, Heltshe et al., 2012). They also divided the sample to tertiles and quartiles which created sub-groups of relatively equal sizes but the exposure levels were divided into three or four unequal intervals. At the end the researchers did not find any correlation between exposure to glyphosate and any type of cancer.

Tables 2 and 3 show all the pesticides and cancers covered by articles in this systematic review. It is clear that not enough research has been done specifically about the correlation between exposure to glyphosate and NHL in recent years and some of the studies included in this systematic review covered different pesticides and different types of cancers. Determining the possible relationship between exposure to glyphosate and NHL is complicated for different reasons; i.e. *i.* subjects are usually exposed to a variety of pesticides some of which are not mutagenic, teratogenic, or carcinogenic when tested individually and some of them are known immunotoxic substances; *ii.* routes of possible exposure (ingestion, dermal, inhalation, and ocular) can be an important factor in developing NHL; *iii.* simultaneous exposure to multiple chemicals can create additive, synergistic or antagonistic effect (McDuffie et al., 2001, Hardell et al., 2002).

It should be emphasized that rarely an individual is exposed to all these pesticides in their lifetime. Approximately half of the farmers were exposed to only one or two pesticides, however, the risk of developing NHL increased significantly as the number of pesticides that subjects were exposed to increased to five or more (De Roos et al., 2003).

In addition to factors mentioned above, other individual and socioeconomic factors can play a role in developing NHL among people exposed to glyphosate. Table 4 provides a list of potential personal and socio-economic factors that were considered in the studies included in this systematic review. Not all articles provided analytical information about these factors which made it difficult to make a conclusive statement about the relationship between glyphosate and NHL. Some studies showed age or familial medical history were important confounders.

**Table 2** – List of all pesticides covered by articles in this systematic review

| | McDuffie et al. 2001 | Hardell et al. 2002 | De Roos et al. 2003 | De Roos et al. 2005 | Eriksson et al. 2008 | Andreotti et al. 2018 |
|---|---|---|---|---|---|---|
| **Herbicides** | | | | | | |
| 2, 4, 5-T | | ✓ | ✓ | | ✓ | |
| 2,4-D | ✓ | ✓ | ✓ | ✓ | v | |
| Alachlor | | | ✓ | | | |
| Alachlor | | | | ✓ | | |
| Atrazine | | | ✓ | ✓ | | |
| Bentazon | | | ✓ | | | |
| Bromoxynil | ✓ | | | | | |
| Butylate | | | ✓ | | | |
| Chloramben | | | ✓ | | | |
| Cyanazine | | | ✓ | | | |
| Diallate | ✓ | | | | | |
| Dicamba (Banvel or Target) | ✓ | | ✓ | | | |
| Diclofopmethyl | ✓ | | | | | |
| EPTC + protectant | | | ✓ | | | |
| Glyphosate (Round-up) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Linuron | | | ✓ | | | |
| MCPA | ✓ | ✓ | ✓ | | ✓ | |
| Mecoprop | ✓ | | | | | |
| Metolachlor | | | ✓ | ✓ | | |
| Metribuzen | | | ✓ | | | |
| Paraquat | | | ✓ | ✓ | | |
| Phenoxyacetic acids | | | | | ✓ | |
| Propachlor | | | ✓ | | | |
| Sodium chlorate | | | ✓ | | | |
| Trifluralin | ✓ | | ✓ | ✓ | | |
| **Insecticides** | | | | | | |
| Aldrin | ✓ | | ✓ | | | |
| Bufencarb | | | ✓ | | | |
| Carbaryl | ✓ | | ✓ | ✓ | | |
| Carbofuran | ✓ | | ✓ | | | |
| Chlordane | ✓ | | ✓ | | | |
| Copper acetoarsenite | | | ✓ | | | |
| Coumaphos | | | ✓ | | | |

**Table 2** – List of all pesticides … (*continued*)

| | McDuffie et al. 2001 | Hardell et al. 2002 | De Roos et al. 2003 | De Roos et al. 2005 | Eriksson et al. 2008 | Andreotti et al. 2018 |
|---|---|---|---|---|---|---|
| DDT | ✓ | ✓ | ✓ | | ✓ | |
| Diazinon | ✓ | | ✓ | ✓ | | |
| Dichlorvos | | | ✓ | | | |
| Dieldrin | | | ✓ | | | |
| Dimethoate | ✓ | | ✓ | | | |
| Ethoprop | | | ✓ | | | |
| Famphur | | | ✓ | | | |
| Fly, lice, or tick Spray | | | ✓ | | | |
| Fonofos | | | ✓ | | | |
| Heptachlor | | | ✓ | | | |
| Lead arsenate | | | ✓ | | | |
| Lindane | ✓ | | ✓ | | | |
| Malathion | ✓ | | ✓ | | | |
| Methomyl | ✓ | | | | | |
| Methoxychlor | ✓ | | ✓ | | | |
| Nicotine | | | ✓ | | | |
| Phorate | | | ✓ | | | |
| Pyrethrins | | | ✓ | | | |
| Rotenone | | | ✓ | | | |
| Terbufox | | | ✓ | | | |
| Tetrachlorvinphos | | | ✓ | | | |
| Toxaphene | | | ✓ | | | |
| **Fungicides** | | | | | | |
| Arsenic | | ✓ | | | ✓ | |
| Benomyl | | | | ✓ | | |
| Captan | ✓ | | | | | |
| Chlorophenoles | | ✓ | | | ✓ | |
| Creosote | | ✓ | | | ✓ | |
| Formaldehyde | ✓ | | | | | |
| Maneb | | | | ✓ | | |
| Mercury dust | ✓ | | | | | |
| Mercury liquid | ✓ | | | | | |
| Organic solvents | | ✓ | | | | |
| Pentachlorophenol | | ✓ | | | | |
| Pyrethrins | | ✓ | | | ✓ | |
| Sulphur Compounds | ✓ | | | | | |
| Vitavax | ✓ | | | | | |

**Table 3** – List of all cancers covered by articles in this systematic review

| Cancer Type/Region | McDuffie et al. 2001 | Hardell et al. 2002 | De Roos et al. 2003 | De Roos et al. 2005 | Eriksson et al. 2008 | Andreotti et al. 2018 |
|---|---|---|---|---|---|---|
| Acute Myeloid Leukemia | | | | | | ✓ |
| All Lymphohematopoietic Cancers | | | | ✓ | | ✓ |
| Bladder Cancer | | | | ✓ | | ✓ |
| Chronic Lymphocytic Lymphoma, Small Lymphocytic Leukemia | | | | | | ✓ |
| Chronic Myeloid Leukemia | | | | | | ✓ |
| Colon Cancer | | | | ✓ | | ✓ |
| Diffuse Large B-cell Lymphoma (DLBCL) | | | | | ✓ | ✓ |
| Follicular, grade I-III (FL) | | | | | ✓ | ✓ |
| Hairy Cell Leukemia | | ✓ | | | | |
| Hodgkin Lymphoma | | | | | | ✓ |
| Kidney Cancer | | | | ✓ | | ✓ |
| Leukemia | | | | ✓ | | |
| Lung Cancer | | | | ✓ | | |
| Lymphocytic Lymphoma/B-CLL (SLL/CLL) | | | | | ✓ | |
| Marginal-zone Lymphoma | | | | | | ✓ |
| Melanoma | | | | ✓ | | |
| Multiple Myeloma | | | | ✓ | | ✓ |
| Non-Hodgkin's Lymphoma | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Other specified B-Cell Lymphomas | | | | | ✓ | |
| Pancreas Cancer | | | | ✓ | | ✓ |
| Prostate Cancer | | | | ✓ | | ✓ |
| Rectum Cancer | | | | ✓ | | ✓ |
| T-cell Lymphomas | | | | | ✓ | ✓ |
| Testicular | | | | | | ✓ |
| Unspecified B-cell Lymphomas | | | | | ✓ | |
| Unspecified non-Hodgkin Lymphomas | | | | | v | |

The data analysis method used in some of the articles (De Roos et al., 2005 and Andreotti et al., 2018), was another factor that made the results inconclusive. By dividing the sample into tertiles and quartiles, the sample was divided into three or four sub-groups that were relatively equal in size but the exposure level was divided to unequal intervals. For example, the tertile cut points in De Roos et al. (2005) were 0.1-79.5, 79.6-337.1, and 337.2-18,241 of intensity-weighted exposure days. The number of subjects in each tertile for all cancers were 435, 436 and 438 people, while the range of exposure values were 79.4 intensity-weighted expo-

sure days for the first tertile; 257.5 and 17,903.8 for the second and third tertiles respectively. Similar problem was observed in Andreotti et al. (2018) as they divide the sample in tertiles and quartiles and none of them provided any explanation how such unequal intervals of exposure evaluation were analyzed in their research.

**Table 4** – List of all individual/socioeconomic factors covered by articles in this systematic review

| | McDuffie et al. 2001 | Hardell et al. 2002 | De Roos et al. 2003 | De Roos et al. 2005 | Eriksson et al. 2008 | Andreotti et al. 2018 |
|---|---|---|---|---|---|---|
| **Age** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Gender** | | | | ✓ | ✓ | ✓ |
| **Race** | | | | | | ✓ |
| **Location of Residency (Farm/Urban/County/State)** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Exposure to Pesticide** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **History of Tobacco Consumption** | ✓ | | | ✓ | ✓ | ✓ |
| **History of Alcohol Consumption** | | | | ✓ | | |
| **Subjects' Medical History** | ✓ | | ✓ | | ✓ | |
| **Family Medical History** | | | ✓ | ✓ | | |
| **Education** | | | ✓ | ✓ | | ✓ |
| **Type of Applicator** | | | | ✓ | | ✓ |
| **Leisure Time Activities** | | | | | ✓ | ✓ |
| **Body Mass Index** | | | | | | ✓ |

Another potential problem with Andreotti et al. (2018) research was that they used a mathematical model to estimate the values of missing information which was described by Heltshe et al. (2012). There were two major errors reported with the model, *i.* errors based on chemicals and *ii.* error based on year of exposure. This means that the estimated values for missing data can have larger errors depending on what chemicals and which year the exposure occurred.

## Conclusion

Although there are some signs that might indicate possible association between exposure to glyphosate and NHL, the overall result and findings of this systematic review was inconclusive due to limitations, shortcomings, missing or incomplete data and information, or questionable methodology. Other similar systematic reviews or meta-analysis about the health effects of pesticides and cancers (specifically glyphosate and NHL)

came to similar conclusion (Acquavella et al., 2016, Zhang et al., 2019, Chang & Delzell, 2016). In order to have a definitive result, better sample selection and data analysis should be implemented.

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# Occupational Risk Factors and Prostate Cancer in Firefighters: A Systematic Review

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**Abstract**

Despite what is known regarding firefighters' increased exposure to carcinogenic substances while on the job, there is inconsistent evidence on the association between prostate cancer and firefighting, as well as associated occupational risk factors. The goal of this study was to conduct a systematic review to investigate if there is an association between firefighting occupation and prostate cancer, and what the potential risk factors are.

A critical appraisal was conducted twice after a thorough review of peer-reviewed studies published between 2010 and 2020. A summary of potential factors and health outcomes were provided. The results showed majority of studies compared firefighters to the general population and determined an increase in prostate cancer risk, however, the demographic regions were extremely varied, and few studies were able to control for confounding variables due to lack of information available. Most of the articles included in this review did not conduct any direct measurements of exposure variables (such as physical or chemical hazards). Overall, there were signs indicating potential association between prostate cancers among firefighters but, overall, the findings of this systematic review were inconclusive and cannot be generalized.

*Keywords:* prostate cancer, firefighter, occupational risk factors, systematic review

Firefighting as an occupation has been linked to elevated prostate cancer risk (Daniels et al., 2013; Pukkala et al., 2014). Some of the occupational risk factors for firefighters include shift work, stressful work conditions, and exposure to endocrine disruptors and heavy metals (Rao et al., 2015; Fabian et al., 2010; Garg, 2016; Mannetje et al. 2016; Shaw et al., 2013; Wirth et al., 2013). In 2018, there were approximately 1,115,000 firefighters in the United States and 92% were male (Evarts & Stein, 2020). The International Association of Fire Fighters (IAFF) also cites that 65 percent of line-of-duty deaths between 2002 and 2018 were cancer-related which has been on the rise since 1980 (IAFF, 2019).

Firefighters are exposed to potentially carcinogenic substances more frequently than the general population. The introduction of new building materials (e.g. synthetic materials) has led to an exponential increase in exposure of combustion products among firefighters (Guidotti & Brandt-Rauf, 1995). Fire scenes often contain unknown materials and common bi-products of combustion including asphyxiants (*e.g.* carbon monoxide, carbon dioxide and hydrogen sulfide), irritants (*e.g.* ammonia, hydrogen chloride, particulates, nitrogen oxides, phenol and sulfur dioxide), allergens, and carcinogens (*e.g.* asbestos, benzene, styrene, polycyclic aromatic hydrocarbons and certain heavy metals) (Fabian et al., 2010). Such toxins and carcinogens can be inhaled or absorbed through the skin and it is not limited to structure fire scenes.

There has been three meta-analyses conducted on the association between firefighting and cancer during the past two decades. Le Masters et al. (2006) critically evaluated 32 studies and reported on 21 types of cancer. It concluded a probable increased risk of prostate cancer among firefighters. Similarly, Jalilian et al. (2019) investigated cancer incidence and mortality rates among firefighters and found an increased incidence of prostate cancer. However, the study by Sritharan et al. (2017) focused only on prostate cancer and found no significant risk among firefighters. Other epidemiological studies on cancer mortality and exposure-response relationships did not find an association between prostate cancer and firefighting (Ahn et al., 2012; Brice et al., 2015; Daniels et al., 2013).

Despite what is known regarding firefighters' increased exposure to carcinogenic substances while on the job, there is inconsistent evidence on the association between prostate cancer and firefighting, as well as associated occupational risk factors. Most of the published studies include a range of cancer types and very few focused on prostate cancer alone as potential outcome of occupational exposure of firefighters. A systematic review was conducted to appraise the available evidence related to prostate cancer, as well as to determine what risk factors were potentially associated with prostate cancer among firefighters.

## Methodology

Search Strategy and Inclusion Criteria: The review was focused on studies about prostate cancer among firefighters published in English from around the world in any, but not limited to, medical, occupational and/or environmental health, industrial hygiene and safety journals, in which scientists examined the prevalence of prostate cancer among firefighters as well as potential risk factors. An electronic and bibliography search from identified articles was conducted using the following online databases: Medline, PubMed, Web of Science, ProQuest, EBSCOhost, and ScienceOpen. The keywords used in the search included prostate cancer, risk factors, prevalence and firefighters.

Inclusion criteria were: *i.* articles published between January 2010 and November 2020; *ii.* articles published in English; and *iii.* epidemiological studies with human subjects. The rationale for choosing January 2010 as cut off time for inclusion was based on new safety requirements for firefighters and new developments in personal protective equipment (figure 1). The authors chose to exclude studies conducted on populations affected by the attacks on the World Trade Center mainly because the level and duration of exposure to numerous health factors and agents among first responders were extreme and unusual (Shapiro et al., 2020).

Critical Appraisal: The quality of articles were assessed by (RF) twice using the Epidemiological Appraisal Instrument (EAI) version 3.1 (Genaidy et al., 2007). Both appraisals were about 6 weeks apart. The EAI consists of 43 questions and covers different aspects of a high quality epidemiological study such as hypothesis/aim/objectives; exposure variables and/or intervention; main outcomes; study design; study population; covariates and confounders; statistical tests and analysis; results; measurement quality; reliability and validity of data; and generalization of results. Each question was scored on a scale of 0-2. Two points were given for each question if the information was available; one point, if it was partially available and zero points, if it was not available. At the end, a Kappa test was performed to calculate the intra-rater reliability score in order to show the agreement between both critical appraisal processes.

## Results

Identification of Studies: The search resulted in 246 papers, and 28 met the relevant criteria to be reviewed in more detail. One article was in a language other than English, one was an experimental study, five articles were related to World Trade Center, and eight were similar studies of the same cohort of firefighters with limited differences in study design. At the end, 13 studies were included in this review. Figure 1 details the search strategy and its results.

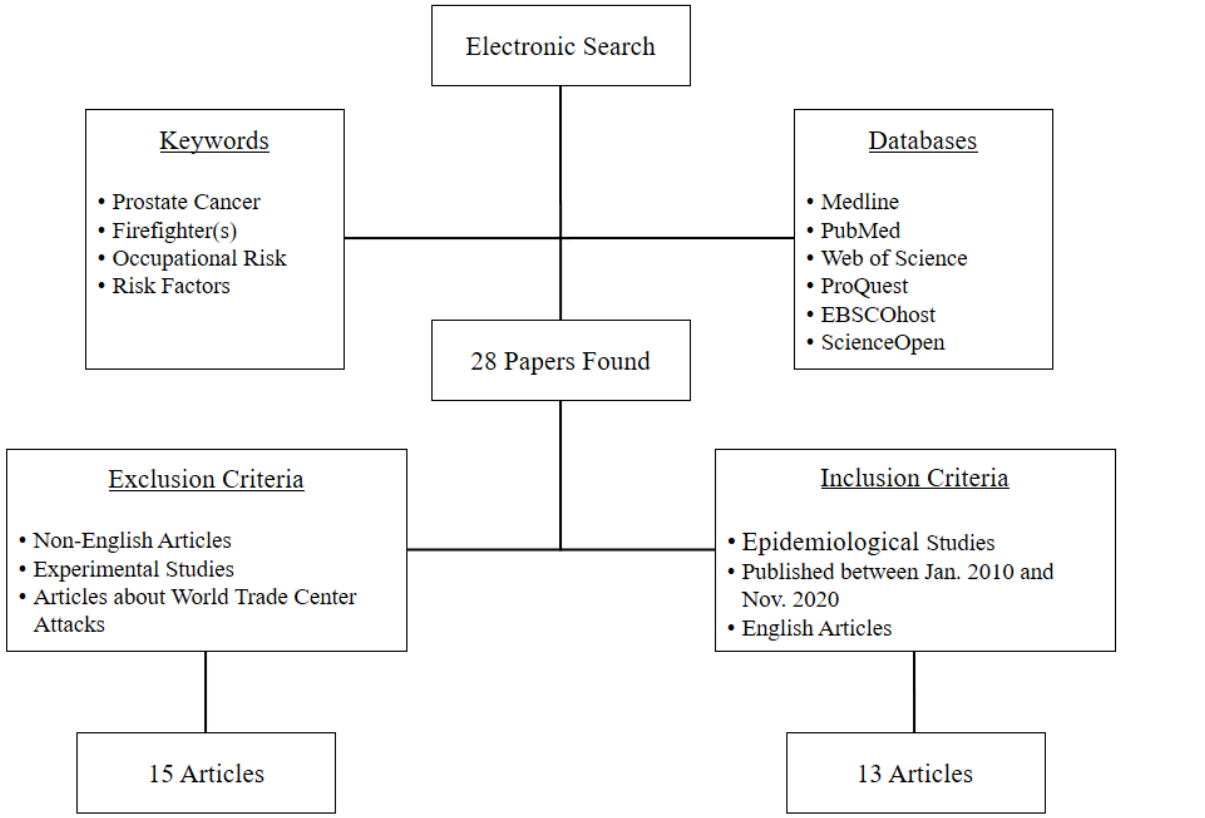


**Figure 1** – Search strategy and literature survey

Description of Evidence: A detailed description of all included studies is summarized in table 1. All of them were follow up on older cohort studies around the world except Lee et al. (2020) and Tsai et al. (2015). All the studies had large sample sizes ranging from 1080 subjects to more than one million. Among them, ten investigated the mortality rate of different types of cancers and non-cancer illnesses (Ahn et al., 2012; Brice et al., 2015; Tsai et al., 2015; Glass et al. 2016 and 2017; Kullberg et al., 2018; Petersen et al., 2018; Harris et al., 2018; Pinkerton et al., 2020; Lee et al., 2020) and only three of them exclusively studied the prostate cancer (Barry et al., 2017; Alder et al., 2019; Sritharan et al., 2019). Sample subjects in all of them were male except two (Pinkerton et al., 2020 and Lee et al., 2020). Ahn et al. (2012), Barry et al. (2017), Sritharan et al.

**Table 1 -** *Description of Evidence*

| Reference | Study design | Sample size | Exposure variables | Health outcomes | Results |
|---|---|---|---|---|---|
| Ahn et al. (2012) | Follow up on a cohort study<br>Time period was 1996 to 2007 | - N=33,416 emergency responders<br>- All male<br>- N=29,438 Firefighters (88.1% of the sample)<br>- General population in Korea was control group | - Date of birth<br>- Date of hire and termination<br>- Work history<br>- Job categories<br>- Smoking<br>- Alcohol<br>- Physical exercise | - Cancer morbidity, and mortality for all types of cancer | - Prostate cancer morbidity for all firefighters was low (SRR 0.22, 95% CI: 0.05 – 1.05)<br>- Prostate cancer incidence was not significantly increased for firefighters (SIR 1.32, 95% CI: 0.60–2.51) compared to other occupations.<br>- When compared to non-firefighters, firefighters did not show significantly increased or decreased cancer morbidity overall (SRR 0.83, 95% CI: 0.59 - 1.16). |
| Brice et al. (2015) | Follow up on a cohort study<br>Time period was 1979 to 2008 | - N=10,829 firefighters<br>- All male<br>- General population in France was control group | - Firefighter as occupation | - Vital status and causes of death, all cancer types | - Overall mortality was 20% lower compared to the general population.<br>- Observed cases of prostate cancer were lower than expected compared to the general population.<br>- Compared to the French male population, professional male firefighters exhibited significantly lower mortality from malignant prostate neoplasms (SMR 0.54; 95% CI: 0.31 – 0.86). |
| Tsai et al. (2015) | Case Control<br>Time Period = 1988 - 2007 | - N=3,966 firefighters in California<br>- All male<br>- About 90.2% white | - Firefighter as occupation<br>- Race/ethnicity | - 32 cancer types | - Used logistic regression to estimate ORs<br>- Firefighters were found to have a significantly elevated risk of prostate cancer (OR 1.5; 95% CI: 1.3 – 1.7).<br>- Firefighters of "other race/ethnicity" were found to have a significantly elevated risk for prostate cancer compared to white firefighters (OR 2.42; 95% CI: 1.53 – 3.84). |

**Table 1 -** *Description of Evidence (Continued)*

| Reference | Study design | Sample size | Exposure variables | Health outcomes | Results |
|---|---|---|---|---|---|
| Glass et al. (2016) | Follow up on a cohort study<br>Time period was 1990 to 2010 | - N=30,057 fire-fighters<br>- 17,394 full-time<br>- 12,663 part-time<br>- All male<br>- General popula-tion of Australia was control group | - Age<br>- Year of employment<br>- Employment status (part-time, full-time)<br>- No. of firefighting incidents attended per year | - All cancer types | - Prostate cancer was significantly increased for full-time (SIR 1.23; 95% CI: 1.10 – 1.37) and part-time (SIR 1.51; 95% CI: 1.28 – 1.77) fire-fighters compared to the general population.<br>- Prostate cancer was associated with longer service but only in full-time fire fighters when compared to volunteers with duration of ser-vice >3 months – 10 years: 10-12 years (RIR 1.05, 95% CI: 0.61 0 1.82); 20+ years (RIR 1.56, 95% CI: 0.98 – 2.51).<br>- Prostate cancer was associated with and increased attendance at all instances (p=0.01): Second tertile: 2.49 (1.32–4.72) and Third tertile: 2.45 (1.35–4.41) |
| Glass et al. (2017) | Follow up on a cohort study<br>Time period was 1998 to 2011 | - N=144,512 fire-fighters<br>- All male<br>- All volunteer fire-fighters<br>- General population of Australia was control group | - Duration of service<br>- Era of first service<br>- Type of incidents attended<br>- No. of incidents attended | - No. of deaths caused by cancer | - Poisson regression modeling was used to esti-mate SIR and RIR.<br>- Increased prostate cancer risk for all male volunteer firefighters (SIR 1.12, 95% CI: 1.08 – 1.16) and male volunteer firefighters who attended incidents (SIR 1.13, 95% CI: 1.08 – 1.19) compared to the general population.<br>- Prostate cancer was associated with longer service when compared to volunteers with duration of service >3 months – 10 years: 20+ years increase for all male volunteer firefight-ers (RIR 1.12, 95% CI: 1.02 – 1.23) and male volunteer firefighters who attended incidents (RIR 1.15, 95% CI: 1.01 – 1.31).<br>- There was no increase of prostate cancer with incident attendance. |

**Table 1 -** *Description of Evidence (Continued)*

| Reference | Study design | Sample size | Exposure variables | Health outcomes | Results |
|---|---|---|---|---|---|
| Barry et al. (2017) | Follow up on a cohort study<br>Time period was 1960 to 1990 | - N=1,521 public safety workers<br>- All male<br>- General population of Denmark, Finland, Iceland, Norway, and Sweden was control group | - Occupations (e.g. firefighters, police, etc.) | - Early-onset and late-onset prostate cancer diagnosis | - A total of 42 cases of prostate cancer in men aged 30 – 49 was observed.<br>- A total of 4,851 cases of prostate cancer in men aged > 50 was observed.<br>- Highest SIRs were observed for early-onset prostate cancer in public safety workers (e.g. firefighters) (SIR 1.71, 95% CI: 1.23 -2.31).<br>- The results does not show that the higher rate of prostate cancer among firefighters is different from other public safety workers. |
| Kullberg et al. (2018) | Follow up on a cohort study<br>Time period was 1958 to 2012 | - N=1,080 firefighters<br>- All male<br>- General population of Stockholm, Sweden was control group | - Firefighter as occupation,<br>- Employment duration | - All cancer diagnosis | - Firefighters had a significantly low risk for prostate cancer compared to the control group (SIR 0.68, 95% CI: 0.52 – 0.87)<br>- No trend of increasing prostate cancer incidence with increasing employment duration (p = 0.75).<br>- Firefighters 50-64 years of age had a significantly lower risk of prostate cancer (SIR 0.50, 95% CI: 0.24 – 0.92).<br>- Firefighters employed from 1960 – 1983 had a lower risk of prostate cancer (SIR 0.20, 95% CI: 0.08 – 0.47). |
| Petersen et al. (2018) | Follow up on a cohort study<br>Time period of cohort study not clear | - N=9,061 firefighters<br>- All male<br>- General population of Denmark was control group | - Firefighter as occupation<br>- Duration of employment<br>- Employment era<br>- Job function (regular, specialized) | - Vital status<br>- All cancer diagnosis | - A slight excess of prostate cancer was observed in comparison to the general population (SIR 1.10; 95% CI: 0.95 – 1.26).<br>- Regarding the selected exposure measures, no distinct pattern of risk correlation seemed present<br>- As for age at diagnosis, a significant increase in prostate cancer was seen ≥70 years while younger age groups (<50 years) had less than expected cases. |

**Table 1 -** *Description of Evidence (Continued)*

| Reference | Study design | Sample size | Exposure variables | Health outcomes | Results |
|---|---|---|---|---|---|
| Harris et al. (2018) | Follow up on a cohort study<br>Time period was 1991 to 2011 | - N=4,535 firefighters<br>- All male<br>- Total of 1,108,410 Canadian workers were in control group | - Age<br>- Occupation (police, firefighter, armed forces)<br>- Level of education<br>- Province of residence | - Death records reviewed for 25 cancer sites | - For firefighters, elevated risk was noted for prostate cancer (HR 1.18, 95% CI: 1.01-1.37). |
| Adler et al. (2019) | Case control<br>Time period was 2004 to 2012 | - N=1,713 of different occupation in Ghana<br>- All male<br>- Total of 794 in case group<br>- Total of 964 in control group | - Age<br>- Region of birth<br>- Family history of prostate cancer<br>- Occupation<br>- Ethnicity<br>- Level of education<br>- Smoking<br>- Status of medical insurance | - Prostate cancer diagnosis | - Firefighters were not studied as an individual subgroup. They were included in the Protective Service Occupations group.<br>- Prostate cancer risk was 50% lower for men employed in Protective Service Occupations (OR 0.5, 95% CI: 0.2 - 0.9) compared to control group. |
| Sritharan et al. (2019) | Follow up on a cohort study<br>Time period was 1983 to 2015 | - N=1,231,177 employees with different occupations<br>- All male from Ontario, Canada<br>- Total of 34,997 subjects with prostate cancer were in case groups. | - Occupation | - Prostate cancer diagnosis | - Prostate cancer was found in 404 firefighters of 11647 total.<br>- Elevated prostate cancer risk was observed for firefighters after adjusting for age (HR 1.62, 95% CI: 1.47-1.78). |

**Table 1 -** *Description of Evidence (Continued)*

| Reference | Study design | Sample size | Exposure variables | Health outcomes | Results |
|---|---|---|---|---|---|
| Pinkerton et al. (2020) | Follow up on a cohort study<br>Time period was 1950 to 2009 | - N=29,992 firefighters<br>- Male (97%) and female (3%)<br>- From San Francisco, Chicago, and Philadelphia<br>- General population of the US was control group | - No. of exposed days<br>- No. of fire-runs<br>- No. of hire-hours<br>- Gender<br>- Age<br>- Race/ethnicity<br>- Duration of employment | - Mortality of all cancer types | - Total of 334 cases of prostate cancer was found among male firefighters.<br>- Found no association with prostate cancer mortality and occupational exposure variables. |
| Lee et al. (2020) | Case Control<br>Time period was 1981 to 2014 | - N=73,899 firefighters<br>- Male (95.7%) and female (4.3%)<br>- From Florida<br>- Non-firefighter employees were in the control group | - Age<br>- Gender<br>- Race/ethnicity | - All cancer diagnoses | - N=1,119 observed cases of prostate cancer in male firefighters.<br>- Male firefighters were at increased risk of early-stage cancers for prostate (OR 1.13; 95% CI: 1.03 =1.23).<br>- There was an increased risk of prostate cancer among male firefighters younger than the age of 50 (OR 1.88; 95% CI: 1.49-2.36 vs 1.36; 1.26-1.47).<br>- There was an increased risk of prostate cancer among male firefighters older than the age of 50 (OR 1.36; 95% CI: 1.26-1.47) which is slightly lower than younger firefighters. |

SIR: Standardized Incident Ratio; SRR: Standardized Rate Ratio; SMR: Standardized Mortality Ratio; OR: Odds Ratio; RIR: Relative Cancer Incident Ratio; HR: Hazard Ratio;

(2019) and Alder et al. (2019) were the only studies who included subjects with occupations other than firefighters in their samples.

Risk Factors: Most of the studies acknowledged that firefighters are exposed to variety of chemicals, some of which are classified as carcinogens (Ahn et al., 2012; Tsai et al., 2015; Kullberg et al., 2018; Peterson et al., 2018; Pinkerton at al., 2020; Lee et al., 2020). However, none of the article used any direct measurement of exposures to any of such substances. Instead, some of them used other factors such as duration of employment or number of fire-runs/incidents as proxy measures of exposure to chemicals (Ahn et al., 2012; Glass et al., 2016 and 2017; Kullberg et al., 2018; Petersen et al., 2018; Pinkerton et al., 2020). Other factors that might affect the health outcome as covariate or confounder were age, gender, race/ethnicity, level of education, alcohol consumption, smoking, family medical history; and environmental (non-occupational) exposures but none of the articles conducted any form of correlation analysis (Ahn et al., 2012; Tsai et al., 2015; Glass et al., 2016; Harris et al., 2018; Alder et al., 2019; Pinkerton et al, 2020; Lee et al., 2020).

Prostate Cancer as Health Outcome: Every articles included in this review attempted to compare the prevalence of prostate cancer among firefighters to a control group, which was usually the general population of the region or other occupations. Different types of ratios were calculated by authors of each article and the findings were mixed. Ahn et al. (2012), Petersen et al. (2018) and Pinkerton et al. (2020) found no statistically significant difference compared to the control groups; and Brice et al. (2015), Kullberg et al. (2018) and Adler et al. (2019) found that the mortality and/or incident rates of prostate cancer among firefighters was lower than the control group; while Tsai et al. (2015), Glass et al. (2016 and 2017), Barry et al. (2017), Harris et al. (2018), Sritharan et al. (2019) and Lee et al. (2020) found that firefighters have significantly higher mortality and/or incident rate of prostate cancer compared to control group.

Critical Appraisal of Studies: Each of the 13 identified studies was critically appraised by (RF) twice using the EAI. The critical appraisals were conducted six weeks apart and the overall intra-rater reliability score (Kappa test coefficient) was 0.79.

Results of the critical appraisal are displayed in Figure 2. With scores between 1.28 (Barry et al., 2017) to 1.81 (Sritharan et al. 2020) on a scale of 0-2 for study description, all the studies included in the systematic review provided relatively good study descriptions. All of the studies used some kind of national registry of cancer, census data and other large databases to select subjects and as the result, the sample sizes were relatively large. They were all a follow up  on previously conducted cohort studies except three of them, which were case-control studies (Tsai et al., 2015; Adler et al., 2019; Lee et al., 2020). Most common shortcomings

among these studies were failure to report *i.* sample size calculation, *ii.* random variability estimate or parameter association, *iii.* covariates/confounders estimates, *iv.* characteristics of lost subjects.

In regards to subject selection, the scores ranged from 0.5 (Barry et al., 2017) to 1.75 (Lee et al., 2020) and the main reasons that studies scored low in this criteria were failure to report *i.* groups comparability, *ii.* participation rates, *iii,* randomization of study subjects. Researchers compared the firefighters groups to either male subgroup of general population of the country/region or to other occupations, but the characteristics of groups (such as age, race/ethnicity) were not compared.

In the category of observation quality, all of the studies considered in this review scored relatively low from 0.44 (Adler et al., 2019) to 1.05 (Petersen et al., 2018) mainl, because they did not provide information if *i.* the subjects and/or observers were blinded to the study design, *ii.* the measurement of exposure variables were reliable and/or valid, *iii.* the measurement of outcome variables were reliable and/or valid.

The scores for data analysis category varied significantly among articles. It was as low as 0.71 (Sritharan et al. 2019) and as high as 1.57 (Lee et al. 2020). The articles, which scored low in this category, did not *i.* include covariates/confounders in data analysis, *ii.* adjust the analysis for important factors (individual or environmental variables), *iii.* include prior history of diseases in the analysis.

Finally, due to the shortcomings explained above, it was not possible to generalize the findings of each study to other groups or general male population, which was the reason that all articles in this systematic review scored relatively low in generalization category from 0.5 (Barry et al., 2017) to 1.5 (Kulberg et al., 2018). The Overall score for each study was calculated by averaging the scores of all categories and it ranged from 0.78 (Barry et al., 2017) to 1.35 (Kullberg et al., 2018).

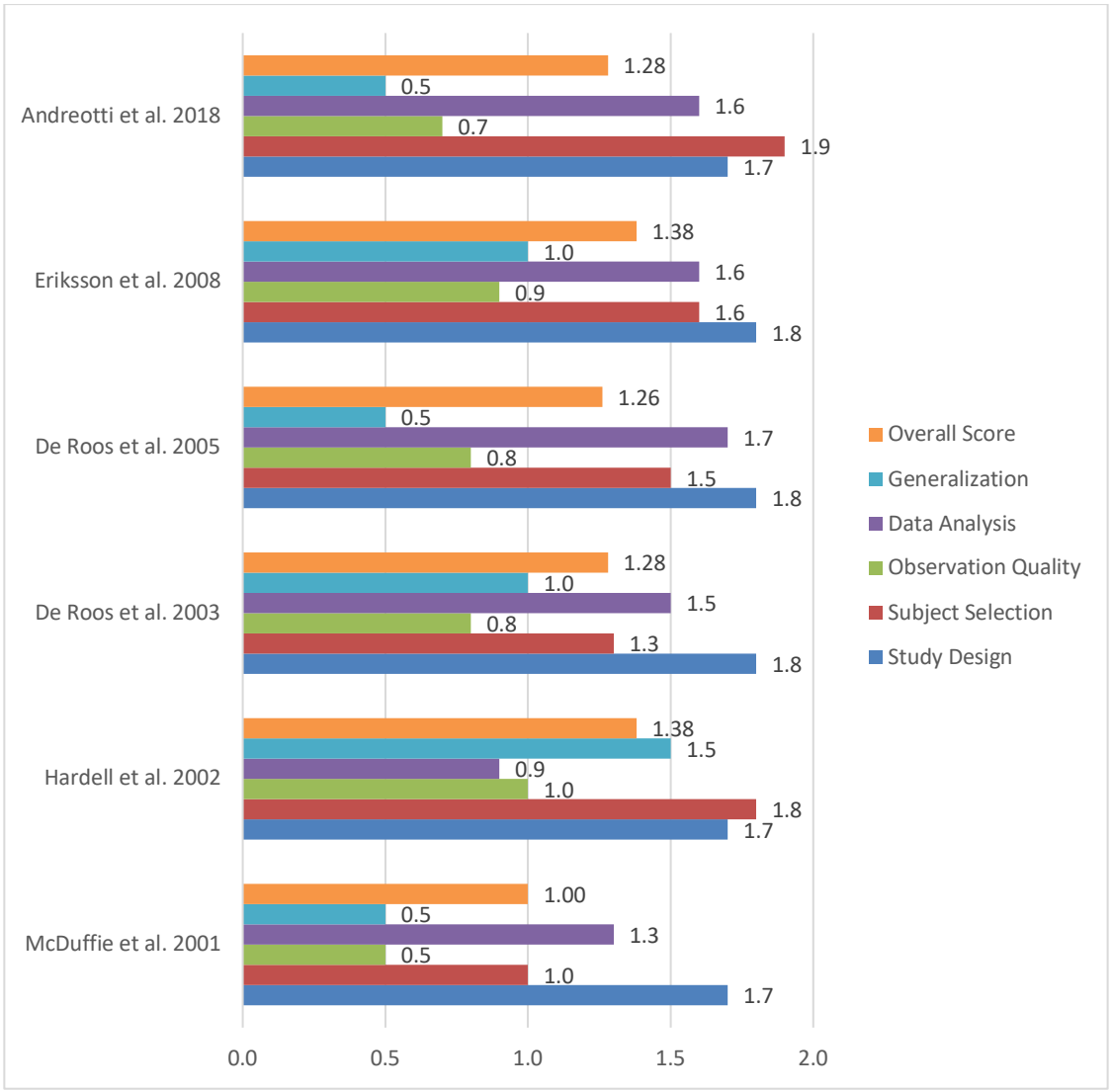


**Figure 2** – Critical appraisal ratings for all included articles

## Discussion

The purpose of this systematic review was to critically appraise the available evidence related to prostate cancer prevalence among firefighters, as well as to determine what occupational risk factors are associated with it. All the articles included here were published after 2010, but most of them analyzed data from the 1970s and 1980s. Most of the studies examined firefighting as an occupation for risk of prostate cancer and some of them reported specific occupational exposure variables such as number of fire runs and fire hours, duration of employment, and part-time vs. full-time employment status without actually conducting correlation analysis. Table 2 displays all the occupational variables and potential confounders and covariates that were reported by researchers in this systematic review.

**Table 2** – Variables discussed or considered in the analysis

| | Ahn et al. (2012) | Brice et al. (2015) | Tsai et al. (2015) | Glass et al. (2016) | Glass et al. (2017) | Barry et al. (2017) | Kullberg et al. (2018) | Petersen et al. (2018) | Harris et al. (2018) | Adler et al. (2019) | Sritharan et al. (2019) | Pinkerton et al. (2020) | Lee et al. (2020) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Exposure Variables** | | | | | | | | | | | | | |
| Work duration | ✓ | | | ✓ | ✓ | | ✓ | ✓ | | | | | |
| Era of employment | | | | | ✓ | | ✓ | ✓ | | | | | |
| Full-time vs. part-time status | | | | ✓ | ✓ | | | | | | | | |
| Incidents attended | | | | ✓ | ✓ | | | | | | | | |
| Fire runs | | | | | | | | | | | | ✓ | |
| Fire hours | | | | | | | | | | | | ✓ | |
| **Covariate/Confounders** | | | | | | | | | | | | | |
| Age | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Race and ethnicity | | | ✓ | | | | | | | | | ✓ | ✓ |
| Gender | | ✓ | | | | | | | | | | ✓ | ✓ |
| Location of residency | | | | ✓ | ✓ | ✓ | | | ✓ | | ✓ | ✓ | |
| Medical history | ✓ | | | | | | | | | | | | |
| Family history | | | | | | | | | | ✓ | | | |
| Medical insurance | | | | | | | | | | ✓ | | | |
| Education | | | | | | | | | ✓ | ✓ | | | |

General knowledge indicates that firefighters are exposed to variety of chemicals more frequently than the general population, some of which are known to be carcinogenic to humans (Guidotti & Brandt-Rauf, 1995, Fabian et al., 2010, Conlon et al., 2007; Pukkala et al., 2014; Rao, 2015). Even though some of the variables in table 2 can be used as proxy measurements of exposures to toxic substances (such as number of fire runs, or fire hours, number of incidents attended), none of them were true and valid measurements of exposure to such chemicals. None of the studies in this systematic review attempted to measure the level of exposure to such chemicals in terms of concentration, duration of exposure, or route of absorption, therefore it is not possible to establish a conclusive list of risk factors for prostate cancer among firefighters.

When investigating the prevalence of prostate cancer among firefighters, researchers used different parameters to study the level of risk compared to general population or other occupations. Standardized Incident Ratio (SIR) was used by Ahn et al. (2012), Glass et al. (2016 and 2017), Barry et al. (2017), Kullberg et al. (2018), Petersen et al. (2018); while Ahn et al. (2012) was the only study that used Standardized Rate Ratio (SRR) in their estimates. Standardized Mortality Ratio (SMR) was used by Brice et al. (2015) and Pinkerton et al. (2020). Among the 13 studies included in this review, Tsai et al. (2015), Adler et al. (2019), Lee et al. (2020) were the only ones that conducted case-control studies and used Odds Ratio (OR) in their analysis. Glass et al. (2016 and 2017) used the same datasets and studied the prevalence of prostate cancers in two different groups of firefighters (career firefighters vs. volunteer firefighters) and used Relative Cancer Incident Ratio (RIR) in addition to SIR. Finally, Harris et al. (2018) and Sritharan et al. (2019) were the only studies that used Hazard Ratio (HR) for analysis. Due to lack of detailed information, it was not possible to convert such estimates into a single ratio for comparison (Gerstman, 2003). Five of the thirteen studies included in this review either did not find that firefighters were at increased risk for prostate cancer or stated that firefighters were actually at lower risk for developing prostate cancer (Ahn et al., 2012; Brice et al., 2015; Kullberg et al., 2018; Adler et al., 2019; Pinkerton et al., 2020). One of the reasons provided by these researchers were “the healthy worker effect” which means employees go through health screening at the time of hiring and during employment due to the physical/mental job demands associated with firefighter occupation. Because of the constant care received by firefighters, they were less likely to develop prostate cancer. The problem with this argument is that even though the risk for prostate cancer was lower, some studies has shown firefighters have elevated risk of developing other types of cancer. If “the healthy worker effect” is true, it should be true for

all kinds of cancers not just prostate cancer. Table 3 presents the list of cancers commonly considered in the studies.

The samples taken by these thirteen studies were from different countries, *i.e.* Korea, France, USA (California, Illinois, Pennsylvania, Florida), Australia, Demark, Finland, Iceland, Norway, Sweden, Canada, and Ghana. It is possible that exposure to risk factors were different for each sample due to difference in building codes, fire safety standards and practices in each country. The level of exposure to risk factors can also be different based on the region a firefighter is stationed. For example, the type of chemicals and the amount of exposure to toxic substances can be different if firefighters attend a fire incident in urban, rural, or industrialized region. None of the studies stratified their samples based on the location of employment and did not include it in their analysis.

Socioeconomic factors, alcohol and tobacco consumptions, access to healthcare and medical services, as well as the quality of the medical services are among important confounders that most of the studies included in this systematic review did not consider in their analysis.

**Table 3** – List of types of cancers studied among male subjects in each article

| | Ahn et al. (2012) | Brice et al. (2015) | Tsai et al. (2015) | Glass et al. (2016) | Glass et al. (2017) | Barry et al. (2017) | Kullberg et al. (2018) | Petersen et al. (2018) | Harris et al. (2018) | Adler et al. (2019) | Sritharan et al. (2019) | Pinkerton et al. (2020) | Lee et al. (2020) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oral | | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | | | | ✓ |
| Nasal | | | | | | | | ✓ | ✓ | | | | |
| Esophagus | ✓ | ✓ | ✓* | ✓ | ✓ | | ✓ | ✓ | ✓ | | | ✓* | ✓ |
| Larynx | ✓ | ✓ | ✓* | ✓ | ✓ | | | ✓ | ✓ | | | | ✓ |
| Stomach | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓* | ✓ | ✓ | | | ✓ | ✓ |
| Colon/Intestine | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | | ✓* | ✓ |
| Rectum | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | | | ✓* | ✓ |
| Pancreas | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | | | ✓ |
| Liver | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | | | ✓ |
| Gall Bladder | ✓ | | | | | | | ✓ | | | | | |
| Bones and Joints | ✓ | | | | | | | ✓ | | | | | ✓ |
| Lung | ✓ | ✓ | ✓* | ✓ | ✓ | | ✓ | ✓ | ✓ | | | ✓* | ✓ |
| Skin | | ✓ | ✓* | ✓* | | | ✓ | ✓* | ✓* | | | ✓ | ✓* |
| Prostate | ✓ | ✓ | ✓* | ✓* | ✓* | ✓* | ✓ | ✓* | ✓* | ✓ | ✓* | ✓ | ✓* |
| Other Male Genital | | | ✓ | ✓ | ✓ | | | ✓ | ✓ | | | ✓ | ✓* |
| Bladder | ✓* | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | | | ✓ | ✓ |
| Kidney | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | | ✓* | ✓ |
| Eye and Orbit | | | | | | | | ✓ | | | | | ✓ |
| Brain | ✓ | | ✓* | ✓ | ✓ | | ✓ | ✓ | ✓ | | | ✓ | ✓ |
| Thyroid | ✓ | | ✓ | ✓ | ✓ | | | ✓ | ✓ | | | | ✓* |
| Hodgkins/Non-Hodgkins Lymphoma | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓* | | | ✓* | ✓ |
| Myeloid | | | | | | | | ✓ | | | | | ✓ |
| Leukemia | ✓ | | ✓* | ✓ | ✓ | | ✓ | ✓ | ✓ | | | ✓ | ✓ |
| Mesothelioma | | | ✓ | ✓ | ✓ | | | ✓ | ✓ | | | ✓* | ✓ |
| Other types of Cancers | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | | | ✓ | |
| Illnesses other than Cancer | | ✓ | | | | | | | | | | ✓ | ✓ |

* Higher risk for developing cancer compared to general population or other occupations

## Conclusion

Overall, the findings of this systematic review were inconclusive. While a majority of studies that compared firefighters to the general population or other occupations, determined an increase in prostate cancer risk, the demographic regions were extremely varied and few studies were able to control for confounding variables due to lack of information available. Regarding the occupational exposure variables, only two variables (work duration and era of employment) were addressed by three or more studies.

In order to determine if firefighters have higher risk of developing prostate cancer, further research is necessary and it will be important to have a direct measurement of exposures to toxic chemicals (concentration and duration) in order to examine the potential association between exposures and prostate cancer. It is also important to understand how the chemicals are absorbed. This information will be useful to develop better fire suppression methods and equipment to reduce the exposure as well as better screening methods to protect firefighters from prostate cancer, or any other types of cancers in fact.

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