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Chapter 1

Technology Education and Existential Risk

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Abstract

Recent advances in machine learning and biotechnology inspires a longer time perspective on possible technological change. One such perspective is provided by the study of existential risk, namely risks that endanger the survival of the whole of humanity. Central ideas from existential risk studies are of relevance for discussion in technology education since they include a clear indication of nuclear weapons and emerging technologies as the main short term source of existential risk and emphasize the huge ethical importance of continued human survival into the distant future. This is clearly of interest for technology education as a subject in Swedish education where the societal dimension of technology is mandated content. Due to large uncertainties surrounding existential risk, the educational implications are generally unclear. One possibility could be to teach about existential risk indirectly, for instance by placing a bigger curricular emphasis on large scale societal change brought by technology.

To begin making sense of existential risk implications in education a modest study of ethical beliefs about existential risk among 14-15 year-old lower secondary students was undertaken. A vignette question, built upon one of Parfit's (1984) thought experiments, was administered to a convenience sample of around 100 students. Half of them answered that the death of the last humans, when almost all of humanity had already died in a nuclear war, would be much worse than the nuclear war itself. It could be argued that this result indicates that the unique tragedy of human extinction is within common ethical consideration of students of this grade level. The vignette question is therefore a viable candidate for future inclusion in larger tests of ethical beliefs regarding existential risk.

***Keywords**:* Existential risk, Technology education, Swedish compulsory school

Introduction

The purpose of this paper is to introduce the research field of existential risk to the academic community of technology education, and to take the first steps in discussing and studying possible educational prerequisites and consequences. Existential risk is introduced in the first section, followed by a discussion of the implications for inclusion of existential risk in technology education in the second, and in the last section concludes with the presentation of results from a small study of ethical beliefs among lower secondary students regarding existential risk.

Existential risk

There has been writing the last few years about the social impact of technological change. Advances in machine learning have inspired ideas about a society transformed by artificial intelligence and automation technology (Brynjolfsson & McAfee, 2014; Schwab 2017). Others have discussed the huge potential for both good and bad impacts of human biotechnology (Harari, 2017). But the intellectual environment has also alluded to a much darker vision of the future where humanity goes extinct. Existential risk is a term for that kind of risk, namely risks that endanger the whole of humanity (Bostrom, 2002).

Human extinction was discussed during the height of the cold war as a possible consequence of global nuclear war raised by the massive stockpiles of nuclear weapons. While the foundation of the existential risk discipline stems from that age, for instance from Parfit (1984), the term existential risk and the associated research paradigm can be traced more recently to Bostrom (2002). In his paper Bostrom defines existential risk as "*One where an adverse outcome would either annihilate Earth originating intelligent life or permanently and drastically curtail its potential*" (p. 4). Since then a highly interdisciplinary field of existential risk studies has begun to form. *Here be Dragons* by Häggström (2016) is a contemporary introduction to the field that includes the role of emerging technology, the large uncertainties associated with it, and the potential of huge ethical importance.

Existential risks are often categorized based on whether they emanate from nature or from humans themselves (Häggström, 2016; Bostrom & Cirkovic, 2011). Risks emanating from nature include things like a large asteroid hitting earth, a gamma burst from a nearby supernova, and climate altering volcanic activity. The original case for possible existential risk from human activity is a global nuclear war. Other candidates that have been proposed are uncontrolled geoengineering (Baum, Maher, & Haqq-Misra, 2013), bioengineered pandemics (Millett & Snyder-Beattie, 2017), and artificial super-intelligence misaligned with human values (Bostrom, 2014).

To divide existential risk between naturally occurring and human driven is useful when trying to assess the probabilities involved. While the whole field is characterized by large uncertainties, the situation regarding the known naturally occurring potential risks is much better understood than for those linked to human activity. For example, geological records provide long time data on earlier super volcanic activity, as well as on large asteroid impacts. In the case of human activity however, that timespan shrinks to the 50-60 years we have had nuclear weapon stockpiles large enough for a global war. Attempting to estimate the probabilities for emerging technological possibilities that might lead to human extinction is even more difficult. For instance, a common view articulated by scholars in the field such as Häggström (2016) is that in the shorter term (the coming centuries), the probability of the naturally occurring existential risks are dwarfed by those emanating from technologically assisted human activity.

That human extinction would be tragic is a widely shared notion both in the general population and among those specializing in principled ethical reasoning. However, tragedy comes on longer scale than commonly imagined according to existential risk ethicists. That human extinction would be extremely and uniquely tragic is a central tenet in their reasoning. Specifically, this is recognition of the vast value of human existence created over a very long period of time, and which would be lost in the case of extinction. Even if humanity in the long run remained bound to planet Earth, it might still flourish for a billion years (Bostrom, 2013). In this context, and given both the huge ethical importance and the reality of technological sources for near-future existential risk, it is the position of this researcher that existential risk should be an instructional topic of great interest for technology educators.

Technology education and existential risk

Technology as a school subject is construed in different ways in different school systems. In this study, arguments about existential risk in technology education builds upon a version of technology as a school subject devoting substantial curricular priority to the societal dimensions of technology development and use. The standpoint is made from a Swedish technology subject perspective (Skolverket, 2011), but should transfer to other subject conceptions, for instance the one outlined in the *Standards for Technological Literacy (ITEA. 2007)*. It is a standpoint about a technology education reaching beyond engineer recruitment as described by Olson (2013) and leaving ample room for the curriculum emphasis described by Klasander (2010) as the democratic citizen emphasis. Some of the reasons for the societal aspects of the Swedish technology subject can be summarized as "*Teaching in technology should essentially give pupils the opportunities to develop their ability to*" … "*assess the consequences of different technological choices for the individual, society and the environment*" in the national curriculum (Skolverket 2011, p. 254). In that context existential risk represents one endpoint on the scale of potential technological impacts.

If one is to accept the scholarly view regarding the large ethical importance and that a non-negligible likelihood cannot be ruled out due to the large degree of uncertainty, it is hard to put an upper bound on the importance. This matters since our normal duties as education researchers and teachers with respect to our pupils and the surrounding society assumes normal bounds. For instance, is it realistic to expect that we can teach about all things deemed to be sufficiently important? Such intuition might not hold in extreme situations. The lack of an upper bound for the importance of existential risk implies that we do not know if it should be treated as an interesting, and possibly important phenomena worthy of curricular inclusion. Nor whether our seemingly normal situation actually is extreme and therefore how we approach existential risk is perhaps the only thing that really matters from the ethical perspective of the whole of humanity, present and future. Viewed from this perspective, it suggests that we should try to be unusually careful, and reason thoroughly, about how to think about existential risk and technology education before committing to a view or larger scale action.

The need for careful reasoning before acting is accentuated because of the potential blowback. In the case of eventual super-intelligence and associated potential risks, there is sometimes a heated debate where some positions seem to be held with much more certainty than warranted due to the lack of evidence and expert disagreement. A survey of experts in machine learning gave wide ranging estimates for when machines will outperform humans in certain complex domains (Grace et al., 2018). Still some experts hold a strong and certain view about how it is impossible, while at the same time other experts mirror their certainty in the opposite direction viewing it instead as an inevitable outcome arriving in the very near future. Baum (2018a) describes this debate as mostly intellectually honest but with a big potential for oncoming politicization due to the uncertainty and big vested interests. As it also can be argued that the general public is not the most important group to be informed (Baum, 2018b) and premature curricular decisions could therefore easily end up doing more harm than good even if existential risk worries turn out to be well founded.

So while there clearly are things that could be better understood both in the study of existential risk and in the technological fields of interest, significant uncertainty will remain for technology educators as they grapple with curricular recommendations to address this issue. As technology educators we can be mindful of these large uncertainties, but should still try to articulate what considerations and curricular options the problem of existential risk demands.

The first consideration is probably whether this problem is a problem for technology educators rather than for instance civics or philosophy educators. In order to better reason about that can we distinguish between direct and indirect teaching prompted by the problem of existential risk. Direct teaching is to be understood as teaching that directly mentions existential risk, while indirect teaching is all other teaching where the content taught is influenced by existential risk while never directly mentioning it.

In the case of using direct teaching of existential risk, the affective dimension becomes important. While technology education is not a subject with strong traditional linkage to affective outcomes, one must still mention examples such as the joy of making and especially of reaching functionality in the construction of an artefact. That is not the affect direct teaching of existential risk is most likely to evoke. Instead such teaching would probably share the affective profile of teaching about global problems like climate change described by Sinatra, Broughton, and Lombardi (2014) and would have to be planned with action competence in mind (Jensen & Schnack, 1997). This might very well mean that direct existential risk teaching is most at home in a well-functioning technology curriculum since that is where the tools for thinking about and handling technological change are taught. A pupil confronted with the possibility of existential risk outside of the context of the tools for mitigating it could reasonably be saddened or react with undue dismissal and false hope (Ojala, 2015).

Direct teaching about existential risk seems to be much more susceptible to the pitfalls of potential controversy and politicization mentioned earlier than does the indirect teaching approach. That makes relying on indirect teaching an option worthy of consideration. We can also distinguish between two types of indirect existential risk teaching, where both seem especially at home in a broad civic minded technology subject.

The first type is teaching of content that opens the mind for the possibility and deep ethical impact of technologically driven radical societal change. This type could contextualize direct existential risk teaching, or substitute for it in the case only indirect teaching. One example could be teaching about the invention of nuclear weapons and how profoundly that invention changed society by ending the world war, as well as being instrumental in preventing a new one ever since while at the same time imperiling our whole civilization. This might just require a slightly different choice of example in a curriculum like the Swedish where "*Consequences of choice of technology from ecological, economic, ethical and social perspectives, such as in questions about development and use of biofuels and munitions."* are required content (Skolverket, 2011, p. 257). Another example could be to discuss where humanity could be technologically in hundred years' time.

The second type is the teaching of content that equips the pupils with tools for participating in technological decision making at the societal level. Examples could be teaching about strategies for dealing with the inherent uncertainty of the impact of technological change such as those given by Collingridge (1980) or about examples such as how knowledge about industrial learning curves has enabled policy options to hasten the technological development of solar power.

The proper place for the eventual teaching of existential risk seems to be as an extreme among other examples of societal impact of technological change, both historical and potential. While the profound changes in the human condition depending on the Neolithic and the industrial revolution are historical facts and not open to speculation, they still bear the message of not ruling out future change of corresponding magnitude. To teach that such change is not preordained to be either good or bad would seem to be to teach that existential risk has a mirror image of things like material abundance and radically extended lifespans. This perspective seems as though it should go together with teaching how technological change works as well as large scale sociotechnical tools that might be used to try to steer it towards, rather than away, from humanity blossoming. Technological assessment and choice can be taught at different scales, from the more mundane individual level, to a distant but far-reaching societal level. If existential risk is to be taught, it should probably be as the far endpoint of that societal scale.

At the same time, it must be said that a problem in handling, and probably also teaching existential risk, is that its potential magnitude makes it *sui generis*, meaning that our evolutionary past is unlikely to provide us with emotions and institutions in correspondence to the issue at hand (Bostrom, 2002).

To sum up this attempt at reasoning about how existential risk might be viewed from the perspective of technology education, there is a combination of potentially vast ethical importance and large uncertainties that sets it apart from other phenomena. Because of the close linkage between existential risk and technological change, a special responsibility falls upon technology education. The potential ethical weight demands a response and the speculative nature of existential risk requires that response to be crafted with a firm carefulness. One way to begin to craft that response might be to differentiate between direct and indirect teaching of existential risk. Indirect teaching seems to be much less controversial and therefore less prone to blowback. This implies that less rigor would be required to recommend indirect rather than would direct existential risk teaching. A recommendation to put a larger emphasis on something already in the curriculum would be an especially clear case of this principle.

One further reason to recommend indirect existential risk teaching would be if the teachers or students in question find the ethical foundation of existential risk to be unreasonable. Specifically, meaning something broader than only personal concurrence. There might be much ethical reasoning that one finds to be reasonable without personally concurring. If on the other hand one finds some ethical reasoning to be unreasonable or unacceptable, that might prompt controversy or blowback. In order to get a first glimpse on how Swedish lower secondary students view the central ethical tenet of existential risk, that human extinction is much worse than other bad things, a small survey research study was conducted.

Ethical beliefs about existential risk among lower secondary students

Since existential risk might be an important phenomenon within the societal aspects of technology and that importance depends upon the ethical valuation of a long future for humanity, it would be good to get an indication of whether this ethical standpoint is considered reasonable for learners in the age group receiving technology education. The last stage of obligatory technology education in Sweden takes place in lower secondary (three school years roughly between 13-15 years old). Therefore, the research was design to find out how such students consider human extinction in relation to other equally tragic outcomes. To get an indication of their perceptions, a vignette question was constructed base on an elegant thought experiment made by Parfit (1984). Parfit compared the ethical loss of value going from peace to a nuclear war that killed 99% of all humanity, to the loss going from that situation with 99% already dead to total extinction. He argued that the latter loss was far bigger than the former. The constructed vignette question was then administered to students in the later part of the lower secondary.

The study was carried out in the setting of a Swedish international lower secondary school inviting an existential risk scholar to hold a lecture for multiple classes in grades 8 and 9 (14 and 15 year-old pupils). The general education of the parents of students attending the school is high, and student academic results are good. The lecture was attended by around 200 pupils. The original plan was to administer a very short two section questionnaire before and after the lecture where half of the pupils would answer the main question before the lecture while the other half would answer it afterwards. Due to unforeseen circumstances, one part of the planned study was compromised and therefore only the surviving part is reported here.

Method

Immediately before the lecture 198 unmarked and randomized envelopes, each containing one of two sets of white (before) and blue (after) questionnaires, were handed out to the pupils. The pupils were then informed of the voluntary nature of participation, the anonymity guaranteed by randomization, and clear instructions for them not to answer unless they understood and related to the question. Five minutes were given to complete the first part of the questionnaire and then the lecture commenced. After the lecture another five minutes were given to complete the second part. Due to insufficiently clear communication many pupils filled out the blue (after) part before the lecture had ended, either before or in some cases during the lecture. This compromised the possibility of comparing the before and after answers of the main question and consequently the compromised results were dropped from the study. The nature of some of the questions on the blue (after) questionnaire belonging to the white (before) main question seem to have little sensitivity to when they were answered. Therefore, pupil responses to the questions about whether the main question was easy are reported even though they might have been answered at the wrong time.

The main question was a vignette question illustrated by a diagram (Fig. 1). The options are construed so that option one (a war killing almost everyone is much worse than the subsequent death of the last remaining humans) and option two (the war and the subsequent extinction is of comparable badness) are evidence against that the pupil holds the ethical standpoint of existential risk as uniquely important. Option three (the subsequent extinction is much worse than the initial war) indicates the opposite.

Read the three scenarios and answer the question.

Scenario A **Peace**

After twenty years of tension and a fast nuclear arms race a crisis occurs. The crisis subsides and the tension between the countries of the world slowly dissolves. One thousand years later **peace** reigns and humanity flourishes like never before.

Scenario B **War – almost everyone is killed but humanity recovers**

After twenty years of tension and a fast nuclear arms race a crisis occurs. A global nuclear **war breaks out and almost everyone is killed** in the war or in the coming few years. But one thousand years later there still is humans alive and **humanity has recovered.**

Scenario C **Humanity goes extinct**

After twenty years of tension and a fast nuclear arms race a crisis occurs. A global nuclear war breaks out and almost everyone is killed in the war or in the coming few years. One thousand years later the last humans have died and **humanity goes extinct**.

Question.

Is it worse to go from **peace [A]** to **a war where almost everyone is killed [B]** or is it worse to go from a **war where almost everyone is killed** [B] to the **extinction of humanity [C]**?

Tick the option that best describes what you think.

○ **1.** It is much worse to go from **peace [A]** to **a war where almost everyone is killed [B].**

○ **2.** Neither of the both steps is much worse than the other.

○ **3.** It is much worse to go from **a war where almost everyone is killed [B]** to the **extinction of humanity [C].**

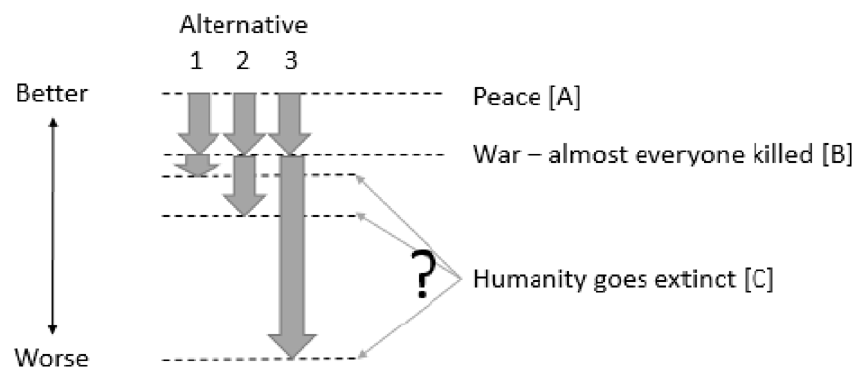

Figure 1. The vignette question.

Results

Ninety-three envelopes containing the main question as the first part were collected. Of those, six were unanswered and two had ambiguous answers where multiple options where ticked. These are reported together. Of the remaining 85 answered questionnaires, 38 respondents answered with either option one or option two, and 47 were answered with option three. The results are shown in Table 1.

Table 1. Main result.

Option 1	Option 2	Option 3	No answer	Total
15	23	47	8	93

The high proportion of option three answers is a result that is highly unlikely to have come about by coincidence as shown by comparison with the binomial distribution for at least 47 out of 93 trials with a probability of ⅓ that gives a p-value of 0,0002. The 93 envelopes also contained the blue questionnaire with background and follow up questions. The answers to one of the follow up questions are presented in Table 2.

Table 2. Answers to: “How difficult was it to understand the question on the white paper?”

Easy	Neither easy nor difficult	Difficult	No answer	Total
36	35	9	13	93

Responses regarding the difficulty of understanding the main question had a weak tendency towards more difficult among those who answered, with option three compared to those who answered with option one and two as shown by Table 3.

Table 3. Spread of answers about difficulty of understanding the main question.

	Easy	Neither easy nor difficult	Difficult	No answer	Total
Option 3	16 (34%)	22 (47%)	5 (11%)	4 (9%)	47
Option 1 and 2	18 (47%)	13 (34%)	3 (8%)	4 (11%)	38

Discussion

The question of interest is whether or not the broad notion of human extinction as something uniquely tragic is within the range of common consideration for participants of this age group. Participant responses to the main question are to be regarded as an indication of the broader range of common consideration. That would hold if we could be sure that those percentages actually meant that the pupils in question concurred with the notion of human extinction as almost uniquely tragic. Since there are only three options, should a significant number of students just tick a box at random, or misunderstand the rather abstract and complicated question, this would be very worrisome for the interpretation of results. To check the result against the binomial distribution gives some pause against these worries. It is important to note, however, that even though it seems to be highly unlikely that the entire proportion of the option three answers were driven by chance alone, that does not preclude the possibility that many of them still are. This is mitigated by the results indicating that most of pupils found the main vignette question to be understandable. As such, it is reasonable to accept the answers to the vignette question as mainly meaningful, rather than driven by coincidence. Therefore, the high proportion answering option three was interpreted as a strong indication that human extinction is something almost uniquely tragic was well within common consideration of this group of pupils.

Since results are based on a convenience sample of students and therefore not a representative sample of the broader Swedish population of lower secondary students, there is good reason to be very careful in extending interpretation to that population. A key issue is determining what proportion of the option three responses are trustworthy and therefore considered acceptable data for answering the research question. Since there seems to be no reason to expect this question to be polarized on any social dimension, a convenience sample could still be considered weakly indicative of the broader population had the results been clear enough. This was not the case here.

The failed part of the study was intended to address the stability of the pupils' opinion. Since the ethical implication of existential risk is a rather specialized subject, it might be that opinions change a great deal when one first encounters it. That would be useful information from an educational perspective.

One very clear result of the research is that the vignette question seemed to be understandable and usable by pupils in the age group. One improvement on the research design however, might be to go to five options by introducing two additional options with meaning close to option 2. That might possibly compromise the ease of understanding and make the question harder to fit on one side of a paper. A better solution would be to use more questions. This vignette question is definitively a candidate for incorporation in such a broader set of questions for measuring ethical beliefs in this area.

Conclusion

Existential risk is a phenomenon that clearly should be of interest for technology education. This research has been a first attempt at justifying the inclusion of existential risk in the technology education curriculum and determining how technology education could respond. But the recommendations for that response based on the research presented are rather weak. There seems to be reason for a slightly higher curricular emphasis on the larger scale of technologically driven social change than it would without considering existential risk. Other than on that matter the picture seems unclear in terms of practical educational consequences. The possible ethical implications create a need for addressing this issue through further discussion and study.

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Chapter 2

Environmental Impacts of Tiny Home Downsizers: A Call for Research

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Abstract

This paper is an exploration into the relationship between people who downsize to tiny homes (dwellings under 400 square feet) and their resulting environmental impacts. Issues of sustainability in the built environment are also explored, and tiny homes are introduced as a potentially viable housing solution to negate current unsustainable impacts of large homes. The review of literature indicates that there is a strong relationship between living in a tiny home and lowered ecological footprints, though no studies currently exist to support this in any measurable way. The paper concludes with a call for research to explore this relationship, suggesting that there are numerous positive implications of such research. Implications include improving practice within the tiny home field itself, potential policy changes, and an academic contribution to the relatively unexplored field of tiny homes.

Keywords: tiny homes, environmental impacts, ecological footprints, occupant behaviors, residential sector, build environment

Introduction

Sustainability can be applied to a variety of contexts, particularly within the building industry. Buildings account for 40% of carbon dioxide emissions and 70% of the electricity load in the United States, which is more than any other sector (EIA, 2017; Negat, Jomehhzadeh, Taheri, Gohari, & Majid, 2015; USGBC, 2004). Furthermore, three-quarters of total energy consumption in buildings is in the residential sector (IEA, 2013; Friedman, 2007; Negat et al., 2015). Carbon dioxide (CO_2) emissions in homes generally are a by-product of energy used for heating and cooling, lighting, appliances, and other electric equipment. The environmental impacts from buildings are even greater when one considers the CO_2 emissions generated from the manufacturing and transportation of building materials, demolition, and other building activities are considered (USGBC, 2004).

In recent decades, the building trend has been to "go big" (Foreman & Lee, 2005; Vail, 2016), resulting in newly constructed homes in the United States generally having the largest average square footage compared to any other country in the world (Palmeri, 2012). Large homes are often considered a symbol of status (Wilson & Boehland, 2005) and single-family homes comprise 63% of residential dwellings in the United States (Wilson & Boehland, 2005; Withers, 2012). The drastic increase in home size is evident through comparisons across decades; in 1973, the average square footage of a newly constructed home in the U.S. was 1,660 square feet (US Census Bureau, 2017), and in 2017, the average was 2,631 square feet (Mitchell, 2014; US Census Bureau, 2017; Vail, 2016) - - a 63% increase. This substantial increase in home size is associated with a number of detrimental environmental impacts, including loss of land, greater air pollution and energy consumption, and ecosystem fragmentation which leads to reduced diversity of species, and many other negative impacts (Johnson, 2001; Parrott, 1997; Wilson & Boehland, 2005; Withers, 2012). The current "go big" building trend can have major negative implications for the environment, since building size is one of the largest predictors of energy consumption for a building (Huebner & Shipworth, 2017; Sandberg, 2018; Wilson & Boehland, 2005).

In addition to building size, studies have shown that occupant behavior greatly influences the energy consumption in a building (Haas, Auer, & Biermayr, 1998; Sandberg, 2018; Santin, Itard, & Visscher, 2009; Steg & Vlek, 2009). This is especially evident in the United States, as research indicates if people from every country were to consume as much energy as the average American, we would need almost five Earths to provide enough resources to accommodate for these behaviors (Global Footprint Network, 2018a). To reduce an individual's environmental impact, the built environment would need to be designed more efficiently. This underscores the importance of encouraging the residential sector to begin adopting innovative solutions and approaches to address both housing size and occupant behaviors (Friedman, 2007; Sandberg, 2018; Withers, 2012). One innovative solution to address these issues is the construction of tiny homes.

Tiny Homes

Tiny homes are developing as a potentially viable solution to reduce building material waste and excessive consumption within the residential industry. Tiny homes counter housing trends of recent decades by emphasizing the value of quality over quantity (American Chemistry Council, 2015; Ford & Gomez-Lanier, 2017; Turner, 2017; Withers, 2012). There is no one universally accepted definition for a tiny home, though in general a tiny home is defined as a small efficient space typically under 400 square feet that often enables homeowners to live a more environmentally conscious, financially stable, and minimalist lifestyle (Campbell, 2015; Small House Society, 2014; Turner, 2017; Vail, 2016). Tumbleweed Tiny Homes, perhaps the most popular tiny home building company in the United States, builds homes that are 200 square feet on average (Tumbleweed Tiny Homes, 2018), which is about the size of two parking spaces. A common range for a tiny home is between 60 and 400 square feet (Waldman, 2017; Wu & Hyatt, 2016). Specifically, the 2018 International Building Code states that tiny homes are "400 square feet in area or less". Tiny homes are also substantially less expensive than single-family homes (Turner, 2017).

The concept of minimalist living has existed for centuries; however, the modern tiny house movement has only been gaining momentum since the early 2000s when one of the first tiny home building companies was founded. The original founder of Tumbleweed Tiny Homes, Jay Shafer, is often considered the inventor of this modern movement. The core principles behind this movement have been evident for centuries. This increasingly popular movement (Campbell, 2015; Dickinson et al., 2016) is largely based on the 20th century mindset that "less is more" (Anson, 2014; Bozorg & Miller, 2014; Ford & Gomez-Lanier, 2017; Heben, 2014), but has roots in the 19th century movements of romanticism and transcendentalism associated with Ralph Emerson and Henry Thoreau (American Chemistry Council, 2015; Anson, 2014; Ford & Gomez-Lanier, 2017). In recent years, there has been an architectural movement exploring stand-alone homes that mimic a modern home on a smaller scale. This movement has been gaining momentum as tiny home festivals, conferences, workshops, television shows, and more have become commonplace. This movement is not only becoming popular in the United States; other countries such as Australia have witnessed a recent surge of interest in tiny homes (Boyd & Clouston, 2004; Campbell, 2015).

Tiny homes are not only smaller than conventional homes, but are often built on mobile foundations, which allows them to be transported to various locations (Byram, 2017; Ford & Gomez-Lanier, 2017; Heben, 2014; Murphy, 2014; Priesnitz, 2014; Wheeler, 2015). However, unlike recreational vehicles tiny homes are generally meant to be permanent residences for their occupants and built to mimic the modern American house (Bozorg & Miller, 2014; Foreman & Lee, 2005). Additionally, tiny homes are often built with high quality, local materials and often implement green technologies such as solar power and greywater harvesting into their designs, enabling them to function off-grid (Anson, 2014; Boyd & Clouston, 2004; Bozorg & Miller, 2014; Calluari & Alonso-Marroquín, 2017; Vail, 2016; Wheeler, 2015).

Tiny homes are architecturally unique, customized homes where the homeowners often have an entrepreneurial, do-it-yourself attitude (Susanka & Obolensky, 2001). Furthermore, they have been popularized by television and are typically fully functional and independent from other homes (Bozorg & Miller, 2014; Foreman & Lee, 2005; Vail, 2016). Tiny homes often have a kitchen, bathroom, bedroom area, living space, and porch (Turner, 2017), and tend to be made of higher quality materials, and with more functions than typical mobile homes or trailers (Heben, 2014). Tiny homes are either built by an individual themselves or purchased from a building company. The cost of a tiny home can vary greatly depending on who builds it and what amenities it provides (Turner, 2017). Currently, there are over 60 tiny home building companies in the United States, ranging in services that can fully customize and build a home, to those that simply provide do-it-yourself kits and plans (Anson, 2014; Kahn, 2012).

The two main demographics of people who downsize (downsizers) to tiny homes are millennials (young adults under 30) who want the freedom of not being tied down by a mortgage, and recently retired baby boomers (over 50 years of age) who are seeking a more simplistic lifestyle. Literature reviews have supported these findings, but also found that these categories are neither exhaustive nor mutually exclusive (Bozorg & Miller, 2014; Foreman & Lee, 2005; Heben, 2014; Murphy, 2014). The literature makes it clear that downsizers choosing to build and live in tiny homes do it for many reasons, including the desire to reduce their environmental impact, live with fewer debts, and have more time and freedom to focus on families, hobbies, and travels (Byram, 2017; The Tiny Life, 2017; Vail, 2016; Wilkinson, 2011). Overall, individuals who are making a conscious decision to downsize to tiny homes are all making a conscious decision towards simpler living (Bozorg & Miller, 2014).

In 2013 survey research was conducted by The Tiny Life, an online resource for tiny living. This survey was sent to tiny home households to gather basic demographic information on tiny home occupants, including age, gender, income, and educational levels. Survey results found that approximately two out of five tiny home owners are over 50 years of age, with the age breakdown as follows: 21% under 30 years of age; 21% between 30 and 40 years of age; 18% between 40 and 50 years of age; and 38% over 50 years of age. It was also found that more women (55%) own tiny houses than men (45%), and the average income of tiny home occupants is $42,038, which is $478 more than the average American. Additionally, tiny home occupants are twice as likely to have a master's degree as the average American (The Tiny Life, 2013).

As presented in this section, tiny homes provide sustainable, affordable, and innovative housing solutions to accommodate a variety of needs and populations. Tiny homes offer the opportunity for homeowners to value quality of space over quantity of square footage. The next section will explore how tiny homes relate to issues of sustainability within our built environment.

Tiny Homes and the Environment

To offset the environmental impacts of conventional homes, many have purposefully downsized to tiny homes to seek a more sustainable lifestyle. With a smaller physical footprint, tiny homes users can potentially reduce their ecological footprint associated with heating and cooling while at the same time purchasing fewer material possessions (Askham, 2014; Susanka & Obolensky, 2001; Vail, 2016; Wu & Hyatt, 2016). One study that interviewed tiny home occupants found that the primary motivations for downsizing included interest in a simpler life, sustainability and environmentalism, cost, freedom and mobility, a sense of community, and an interest in design (Mutter, 2013). Tiny homes are a fundamentally different approach to housing than the traditionally larger homes which have dominated development patterns in America for decades (Foreman & Lee, 2005; Mitchell, 2014; Murphy, 2014; Susanka & Obolensky, 2001; Withers, 2012).

Tiny homes are well-known for promoting a lower ecological footprint by generally reducing their consumption through smaller building square footage, less material possessions, and alternative sources of energy such as solar (Anson, 2014; Bozorg & Miller, 2014; Turner, 2017; Vail, 2016; Wu & Hyatt, 2016). However, no formal studies have been found to confirm this. In fact, some literature even hints that tiny homes can unintentionally prevent some elements of sustainable living. Some examples of this include eating out more often due to small kitchens, driving longer distances due to remote locations, relying on others for storage due to lack of space to store personal belongings, inability to can foods and store bulk items due to small fridges and storage space, and lots of energy needed to heat and cool a tiny home in extreme weather due to a lack of foundation to regulate temperature (Anson, 2014; Murphy, 2014; Williams, 2014).

The Oregon Department of Environmental Quality (DEQ) released a study in 2010 which found that reducing the square footage of one's home is the single most effective measure for reducing one's impact on the environment (DEQ, 2010; Palmeri, 2012). In fact, reducing home size is likely more environmentally beneficial than many green home certifications (DEQ, 2010). By conducting a life cycle assessment (LCA) of a 2,262 square foot medium home and an "extra-small home" of 1,149 square feet, one study found that across all categories (including energy use, materials production, construction phase, maintenance phase, demolition phase, and transportation of materials), the environmental impact of the "extra-small home" was significantly lower-- nearly 40%-- than that of the medium standard home (DEQ, 2010). While the average square footage of a new home built in America in 2017 was about 2,600 square feet, the average size of a tiny home size is about 300 square feet (Mitchell, 2014; US Census Bureau, 2017). Additionally, homes that use recycled materials also have substantially reduced environmental impacts (DEQ, 2010). Therefore, with the DEQ study findings in mind, tiny homes can potentially have even more significant environmental savings than a 1,149 "extra-small home", considering their smaller sizes and tendency for recycled materials (Campbell, 2015; Murphy, 2014; Withers, 2012).

Because of the negative environmental impacts of traditionally larger homes within the residential sector, research in the tiny home field could potentially inform our understanding of how downsizing into a tiny home influences one's environmental impact. Though limited, the academic literature on tiny homes has expressed that tiny homes promote lower environmental impacts for their occupants (American Chemistry Council, 2015; Bozorg & Miller, 2014; Ford & Gomez-Lanier, 2017; Kahn, 2012; Mitchell, 2014; Susanka & Obolensky, 2001; Turner, 2017; Vail, 2016). However, the lack of sufficient literature on this topic indicates an important gap in scholarly research that formally examines how the environmental impact and behaviors of tiny home occupants change after downsizing to a tiny home (Anson, 2014). The significance of this gap is explored in the next section.

Literature on Tiny Homes

In the past decade formal academic literature on tiny homes has steadily emerged as interest in this innovative housing type has increased, although it is limited in terms of quantity according to Anson (2014) and Ford & Gomez-Lanier (2017). Much of the tiny home literature consists of news articles, blogs, personal narratives, and television shows-- rather than peer-reviewed, academically published literature (Ford & Gomez-Lanier, 2017). Most of the published literature that does exist is based on unpublished resources such as blogs, newspaper articles, and television shows, largely due to a lack of academic literature to start with. This presents a gap in the literature and a need for research to aid in the further advancement of the tiny home movement, and exploration of sustainable construction practices within the built environment.

The existing literature has claimed that individuals who downsize to tiny homes will have a significantly lower environmental impact, particularly because they are forced to reexamine their material consumption (American Chemistry Council, 2015; Anson, 2014; Bozorg & Miller, 2014; Ford & Gomez-Lanier, 2017; Kahn, 2012; Mitchell, 2014; Susanka & Obolensky, 2001; Vail, 2016). Conversely, some literature also hints that tiny home living can sometimes lend itself to unsustainable practices such as driving longer distances, dining out more often, and recycling less (Anson, 2014; Mitchell, 2014; Williams 2014).

Despite the common claims that tiny homes promote a smaller environmental impact, there are few academic discussions thus far that explore this concept in detail, posing a gap in the research (Anson, 2014; Ford & Gomez-Lanier, 2017). Upon a thorough review of published literature on tiny homes, it was found that, so far, no empirical research studies exist that comprehensively examine one's changing environmental impact with respect to downsizing to a tiny home. Additionally, no research exists identifying what behaviors influence this change. To comprehensively examine one's environmental impact, one has to not just look at their housing, but also consider other behavioral choices such as food, transportation, goods, and services.

Existing student research, including theses, dissertations, projects, and research presentations have begun to show a trend towards academic attention on tiny homes and their potential impacts on individual environmental impact. One particular student paper explores the theoretical potential for tiny homes to decrease the carbon footprint of their occupants, and in fact, makes a call to future researchers to explore the environmental benefits of downsizing to a tiny home (Carlin, 2014). Another student wrote their thesis on the motivation of downsizers' decisions to live in a tiny home, revealing environmental concerns being among the top reasons (Mutter, 2013). Another thesis offered an analysis of the tiny house movement (Hutchinson, 2016). And in an undergraduate research paper, it was proposed that tiny homes are a viable solution for those wanting to foster a stronger relationship with the environment and their communities (Kilman, 2016). Other student works discussed the trends of the tiny house movement and how they can be used as a sustainable and innovative housing approach (Bartlett, 2016; Beam, 2015; Calluari & Alonso-Marroquín, 2017; Dion, 2015; Hsiao, 2014; Mingoya, 2015; Schenk, 2015; Ubben, 2014; Wu & Hyatt, 2016; Wu, 2017). Although most of these student research efforts did not employ rigorous analytical methods, they do indicate there is interest among young scholars in the tiny home field, and that these scholars are curious about the relationship between tiny homes and the environmental impacts of their occupants. Needed still is research providing quantitative data to understand this relationship. The following section explores this relationship through the concept of an ecological footprint, which is one way to quantitatively measure an individual's impact after occupying a tiny home for a year or more.

Measuring Ecological Footprints

The term "footprint" refers to a measurement in area-based units (Gossling, Hansson, Horstmeier, & Saggel, 2002; Wiedmann & Minx, 2007) and offers a broader measure of environmental impact than other metrics that examine perceptions of environmental impact (Bleys, Defloor, Ootegem, & Verhofstadt, 2018). Specifically, an ecological footprint refers to the amount of biologically productive area that is required by an individual, population, or activity to accommodate for their resource consumption (Global Footprint Network, 2018a; Global Footprint Network, 2018b; Wackernagel & Rees, 1996). The point of calculating an ecological footprint is to determine if consumption is environmentally responsible (Gossling et al., 2002).

An ecological footprint is one way to measure an individual's environmental impact by calculating one's spatial footprint in terms of global hectares considering housing, transportation, food, goods, and services. An ecological footprint is a 3-dimensional metric, considering economic, environmental, and societal aspects of sustainability (Martins, Mata, & Costa, 2007). An ecological footprint converts many types of environmental impacts into a single unit of measure, allowing for meaningful comparisons to be made between different combinations of impacts that are otherwise not easily compared. Specifically, for tiny home occupants, previous lifestyles in prior housing can be compared to current lifestyles while living in a tiny home.

Mathis Wackernagel and William Reese were among the first individuals to systematically calculate an ecological footprint (Bicknell, Ball, Cullen, & Bigsby, 1998; Global Footprint Network, 2010; Kitzes et al., 2009; Wackernagel & Rees, 1996). Wackernagel, now the President of the Global Footprint Network, has worked towards developing and creating standards for the ecological footprint. Ecological footprint standards exist to provide guidelines to ensure the accuracy and transparency of ecological footprint calculators. Data sources, scopes, conversion factors, and communication processes are all outlined using the ecological footprint standards (Global Footprint Network, 2018a). Committees consisting of academics, government officials, and professionals review these standards, with the most recent revision developed in 2009 (Global Footprint Network, 2009; Global Footprint Network, 2018b).

To calculate the area required, ecological footprint calculators use yields of land types including cropland, forest, grazing land, fishing ground, built-up, and energy land to measure this in global hectares (gha) (Global Footprint Network, 2010; Global Footprint Network, 2018b; Kitzes et al., 2007; Moore, Cranston, Reed, & Galli, 2012; Wackernagel & Rees, 1996; Wiedmann & Minx, 2007; Zhao, Heinsch, Nemani, & Running, 2005). A global hectare equates to 10,000 square meters or 2.471 acres and is approximately the size of a soccer field (Global Footprint Network, 2018c). To measure in global hectares, the total amount of a resource is divided by the yield per hectare (Global Footprint Network, 2010). Global hectares (gha) are used as a unit of measure because they look at weight and physical area across various land use types (Borucke et al., 2012).

An ecological footprint calculator is the most comprehensive climate change metric available as it compares all human demands on nature, including food, housing, transportation, goods, and services (Bicknell et al., 1998; Global Footprint Network, 2017, World Wildlife Fund, 2017). Other types of sustainability metrics exist (such as the carbon footprint, water footprint, and the general ecological behavior scale), but the ecological footprint is the overarching metric to calculate human demand on our planet's ecosystem, and an ecological footprint calculator includes components of other popular sustainable metrics (Global Footprint Network, 2018a; Wackernagel & Rees, 1996). The ecological footprint calculator comprehensively examines human demand on the Earth (Borucke et al., 2012; Cucek, Klemes, & Kravanja, 2012; Global Footprint Network, 2010; Kitzes et al., 2007; Moore et al., 2012), and is the world's primary measurement of human demand (Cucek et al., 2012;). As a research tool, an ecological footprint calculator presents the potential for exploring the relationship between downsizing to a tiny home and changing environmental impacts.

Call for Research: Needs and Implications

There is a need for research to investigate tiny homes as a potentially effective way to reduce the environmental impacts in the residential building sector and provide empirical evidence behind the claim that tiny homes reduce one's ecological footprint. Such research could contribute to the relatively unexplored academic field of tiny homes by providing measurable results that may be used by future researchers in the tiny home field.

Findings from this type of research would add to the scholarly research and literature in the tiny home field, potentially improve practice within the field itself, and potentially improve policy related to tiny homes. Results might well lead to changes in current practice to improve the design and development of tiny homes, and to promote lower ecological footprints.

Additionally, these research findings may help current tiny home occupants understand the relationship between their behaviors and their resulting ecological footprint. This in turn may promote a sense of empowerment to intentionally further reduce their footprint.

Other potential implications from this research might include further development of policy allowing tiny homes to be legal in more jurisdictions, or perhaps nationally. Tiny homes are not allowed in many jurisdictions, and some tiny home downsizers occupy their homes illegally or are dissuaded to live in a tiny home because of the strict zoning laws and building codes. Research of this type could serve as a source of support for advocates of the tiny home movement who are urging their jurisdiction to allow tiny homes. The benefits of downsizing to tiny homes lacks the empirical evidence necessary to document such potentials. Tiny homes represent a viable housing solution to negate the current unsustainable impacts of large homes. However, to realize these potentials a body of empirical research is needed that can serve as a stepping stone for shifting the trend from large, excessive homes to smaller, more efficient ones.

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Chapter 3

A Strategy for the Recruitment and Orientation of High School Students for a Manufacturing Online Program in a Rural Region

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Abstract

This paper describes the model used in the recruitment and online orientation of rural high school students in North Central Idaho and South East Washington for a hybrid technology and engineering education program that was developed and implemented through the partnership and collaboration of several stakeholders. The recruitment model is comprised of the following four stages: 1) sensitizing gate-keepers, which includes introducing superintendents, principals, school counselors, and technology and engineering education teachers to the program; 2) marketing the program to students; 3) obtaining parents buy-in, that is, selling the program to parents of students who showed initial interest; and 4) conducting an online orientation. This recruitment model proved very successful as the number of students targeted for recruitment was reached, with an additional few students on the waiting list. Recruitment events and online orientation activities helped in changing negative perceptions held by parents and students had about careers in the manufacturing industry, boosted their confidence in studying online, while at the same time introduced and reinforced the key goals, objectives, and opportunities of the program.

Keywords: recruitment strategy, online engineering and technology education, hybrid CTE, online orientation

Introduction

In August 2017, the Northwest Intermountain Metal Manufacturers' (NIMM) technician curriculum was implemented. The curriculum originated out of the need to create a talent pipeline for the metal supercluster of companies operating in North Central Idaho. The NIMM Supercluster of companies are tied together by common products, services, supply chains, and workforce needs. The metal supercluster encompasses approximately 20% of the Northwest Intermountain region's manufacturers and includes recreational-technology manufacturing, metal parts fabricators, machine shops, and makers of farm and mining equipment (Tacke, 2015). NIMM Supercluster have a National Location Quotient (LQ) of 1.63. This means that there are proportionately more jobs (63%) in that region than the nation (Tacke, 2015).

Partnership and Collaboration

NIMM supercluster companies have consistently experienced a shortage of skilled workers in engineering technician jobs that involve computer aided drafting, machining, fabrication, and electronics (Frei, 2013). This often hampers productivity and growth. Due to its vested interest in the labor force, the Northwest Intermountain Manufacturers' Association (NIMA) provides industry leadership in addressing the shortage of qualified workers. NIMA works closely with economic development partners and education to identify challenges and find solutions. While individual manufacturers are eager to address the needs of their respective companies, collaborative efforts are currently being applied to systematically address the critical workforce issues. On April 24, 2012, a twenty-four-member manufacturing workforce development council was permanently established in the region. Representatives include industry, government, secondary schools, post-secondary Career and Technical Education (CTE), a community college, a four-year land-grant university, economic development associations, unions, and the Idaho Department of Labor. A project was developed through this partnership and collaboration to:

- Create a sustainable entry-level talent development program for mechanical Computer Aided Design and Drafting (CADD) technicians, and Electro-Mechanical Technicians through the development and implementation of an online and summer skills academy curriculum model which offers high school credits and technical competency credits transferable to regional technical colleges and;
- Recruit and retain students from participating schools to take the manufacturers' endorsed curriculum.

The aim of this paper is to describe the model used in the recruitment and online orientation of high school students for an online technology and engineering education program that was developed and implemented through the partnership and collaboration of several stakeholders. In so doing, the paper provides a potential model that may be of use to others in the field attempting to develop similar technology and engineering education programs.

NIMM Technician Training Program

The team involved in developing and implementing the curriculum was multidisciplinary and included members from a regional technical college, a land grant university, Clearwater Economic Development Association (CEDA), Northwestern Intermountain Manufacturers Association (NIMA), the Idaho Department of Labor, and Idaho Digital Learning (IDL). Two technician programs were developed and delivered to address entry-level workforce needs: (1) Mechanical CADD technician program; and (2) Electro-Mechanical technician program. Both programs were designed from information obtained through occupational and job analysis that were performed with regional manufacturers. They were to be offered online through IDL and the technical college. Figure 1 outlines the courses offered by both institutions. Students from this cohort also received laboratory/workshop activities in which they participate in project-based activities in machining and electronics at the technical college during the summer. This curriculum was offered concurrent with the high school curriculum, so students would take courses from the NIMM curriculum as electives. Upon successful completion of the NIMM curriculum, students acquire high school credits and technical competency credits that are transferable to a regional technical college.

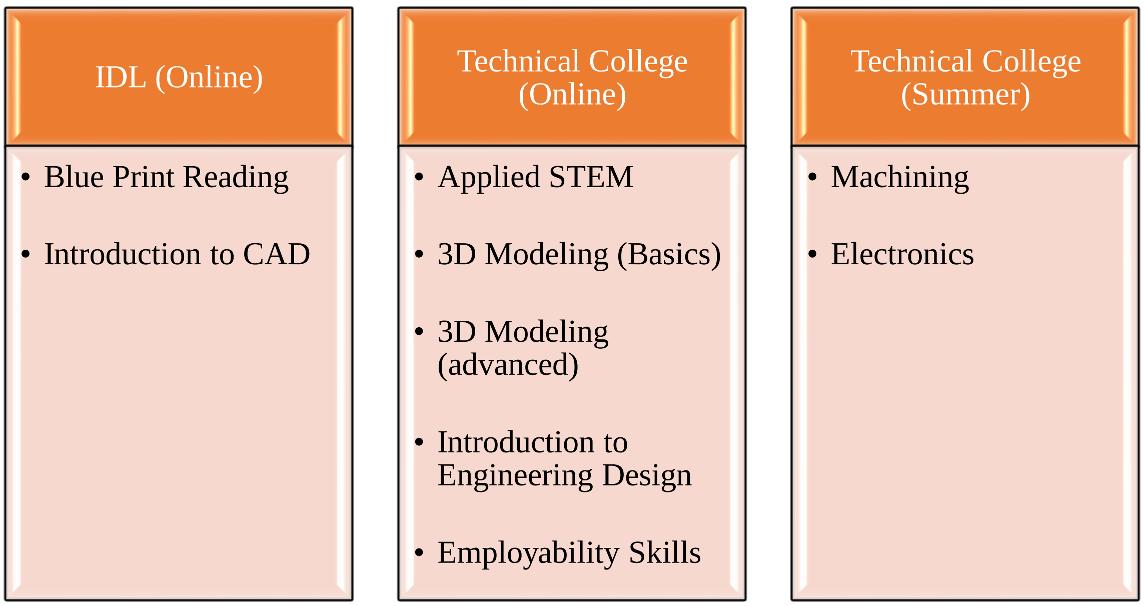

Figure 1. NIMM Program courses

Recruitment Challenges

Filling manufacturing workforce needs for entry-level technician jobs proves to be difficult due to: negative perceptions of the manufacturing industry among some parents and students; a lack of knowledge of the industry; and a lack of educational resources in rural areas to equip students with the requisite technology and engineering skills (Jones, 2018; Frei, 2013). Students are often unaware of the rewards, higher wages, training opportunities, and work-related benefits that careers in manufacturing afford, and so they often “fall through the cracks” or migrate to urban areas in quest of better job opportunities (Jones, 2018). In fact, many students currently perceive jobs in manufacturing as hot, dirty, and physically demanding, with low salary and few real long-term benefits (Jones, 2018). In a recent report (Giffi, Rodriguez, & Mondal, 2017), less than 5 in 10 Americans believe manufacturing jobs to be more interesting and rewarding, clean and safe, and stable and secure than in the past. Also, less than 3 in 10 Americans surveyed indicated they would encourage their children to pursue a manufacturing career. Modern manufacturing, however, has changed dramatically due to automation and new innovative technology (Jones, 2018), and parents who are familiar with the industry are nearly two times more likely to encourage children in pursuing a manufacturing career than others (Giffi, Rodriguez, & Mondal, 2017). The negative perception of manufacturing by parents and students inadvertently affects the level of interest shown by students to pursue careers in manufacturing, and this is particularly evident in the lack of interest shown by students in manufacturing jobs in rural areas. Geographic challenges, limited school resources, and scarce population density are factors which significantly impact the educational system's ability to educate students and provide access to CTE programs. As a result, it can be challenging to recruit students to take manufacturing courses because of the absence of technology and engineering programs in rural areas, as well a lack of financial resources to find and employ CTE instructors and school counselors within the region's twenty-two school districts (Frei, 2013).

The literature on recruitment strategies for students are limited, and those that exist focus on the recruitment of undergraduate students (Shadding, Whittington, Wallace, Wandu, & Wilson, 2016). In a study of the Research Experiences for Undergraduates (REUs) program sponsored by the National Science Foundation (NSF), principal investigators across 106 REU sites were asked to report measures of success of the participants, which included graduate school attendance, participant co-authorship, and participant satisfaction (Beninson, Koski, Villa, Faram, & O'Connor, 2011). The mechanisms used to recruit were the Internet (email, website), direct mailings, media, conferences, the campus recruitment office, and other methods, with the majority of participants recruited by internet or conferences. Shadding et al. (2016) also reported that low cost recruitment mechanism (e.g., email, events, referrals, website) were as effective as high cost mechanism in the recruitment of underrepresented minorities for STEM (science, technology, engineering, and mathematics) research summer programs.

Martin et al. (2011) lay out a strategy developed by the Midwest Alliance, an NSF-funded endeavor to increase the number of individuals with disabilities in STEM. Issues identified that are at the core of the recruiting of students with disabilities in STEM include the lack of data on recruitment of students with disabilities; need for systemic and institutional support; and the influence of guidance counselors, secondary teachers, and postsecondary faculty. Their model includes three sequential steps that can be instructive to general recruitment strategies for students in Advance Technological Education programs: 1) Finding students, 2) Reaching students, and 3) Assisting students.

Finding students involves gaining access to several key stakeholders. The first key point of access that needs to be gained are school districts (Fairweather & Shaver, 1990). Project staff need to take steps ensuring that school districts are familiar with the organization attempting to recruit its students. Second, staff need to cultivate "word of mouth" support from students who have participated in activities provided by the organization (Martin et al., 2011). There is also the need to enlist the support of key gatekeepers, which could span a wide range of individuals, such as various types of teachers, local boards of education, and educational administrators. Finding students also include meeting with parent groups face-to-face and online. Participating in professional conferences and workshops, transition conferences and targeted recruitment of students involved in special programs, are other avenues to find students that are being targeted for the educational program.

Once students have been identified, steps need to be taken to reach students. These include multiple means of dissemination such as email, social media, newsletters, and then sending information or messages to key stakeholders. The final stage involves assisting students who have shown an interest in the STEM program. Assistance can be in the form of creating a community that offers mentoring and answering students' questions; offering career guidance;

having opportunities for exploration; and providing guidance and/or direct financial support (Martin et al., 2011).

NIMM Recruitment Strategy

The first step in recruitment was to decide from where students were to be recruited and whether or not there would be any special interest groups. Based on the project proposal, students were recruited from 22 school districts between North Central Idaho and South East Washington. The program set out to recruit a maximum of ninety (90) students: sixty (60) students for the Mechanical CADD Technician Training Program, and thirty (30) students for the Electro-Mechanical Technician Training Program. The target population was 10th grade students who would cover the NIMM curriculum over a two-and-a-half-year period. Special emphasis was made to not overlook minority and underrepresented groups, including females and students from the Native Nez Perce Tribe.

CEDA spearheaded the recruitment strategy because of its marketing expertise that existed in the organization and the professional alliance between CEDA and the manufacturers. The model for recruitment which is summarized in figure 2 included four stages: 1) introducing and sensitizing school administrators to the program (sensitizing gate-keepers), 2) marketing the program to students, 3) selling the program to parents of students who showed an initial interest (obtaining parent buy-in), and 4) conducting an orientation.

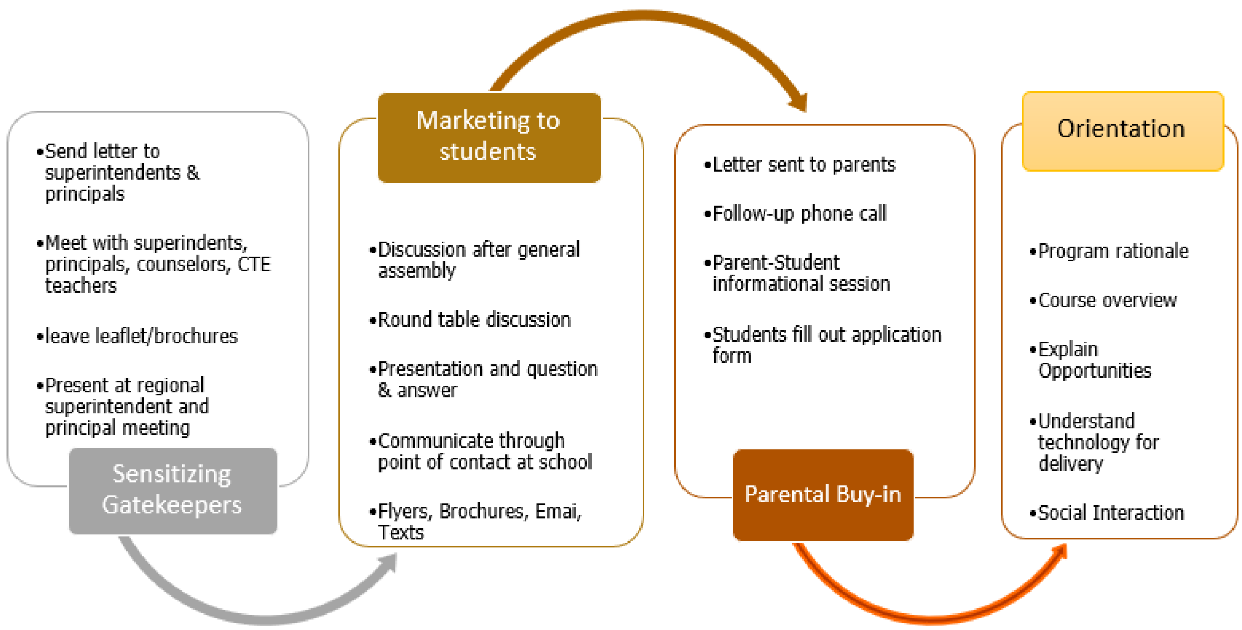

Figure 2. Recruitment Strategy

Sensitizing Gatekeepers

Superintendents, principals, and guidance counselors are often unaware of the career opportunities that exist in manufacturing. A school's size and administrators not having a background in Career and Technical Education (CTE) may influence how they see the relevance of students taking technology and engineering courses (Shanklin, 2014; Malik, 2005), which are often offered as electives in order to pursue STEM degrees in college. Gatekeepers and key stakeholders include superintendents, principals, school counselors, technology and engineering education teachers. Letters endorsed by the manufacturing association were sent by CEDA to superintendents and principals in each school district to introduce the program. These letters were followed-up by CEDA with phone calls and face-to-face meetings with principals and counselors to explain the program. Leaflets explaining the program were left with the schools after these meetings. The director of CEDA also conducted a presentation at the regional meeting of principals and superintendents to make a major pitch about the importance of such a course for regional economic development, the retention of workforce within the region when students decide not to go on to college immediately after completing high school, and the provision of livable wage jobs at the entry level in manufacturing.

Marketing to Students

After the stakeholders in the districts and at the schools were given detailed information about the curriculum, authorization was then given for marketing the program to students in grade 10. CEDA coordinated with the school counselors to arrange face-to-face meetings with students throughout the participating school districts. Representatives from CEDA, manufacturing, the technical college, and the university participated in the informational sessions. The format included slide presentations, round table discussion, and a question and answer session. Information was also disseminated to students through brochures and flyers. Brochures provided students with information about key components of the NIMM program and included questions and answers that the recruitment team expected would be the most frequently asked questions. Flyers mapping the sequence of courses for each career track were also handed to students. Handouts gave students the opportunity to review what was discussed in the presentation and provided information for them to take home to parents.

Schools decided the duration of the presentation —which sometimes were as short as fifteen minutes and as long as one hour—and who was invited to the presentations. Presentations were done before entire junior assemblies or selected groups of students by school counselors and teachers. The recruitment team established a point of contact at each school and this point of contact coordinated and communicated with the recruitment team on behalf of the schools. In some cases, the point of contact may be a school counselor or a CTE teacher. This contact passed on information to interested students, and students could raise concerns or queries through the point of contact. CEDA also communicated directly with students by sending follow up information via email and text. Texting proved to be much more effective.

Figure 3. Director of CEDA in a round-table recruitment session with students

Figure 4. Manufacturer participating in recruitment session with students.

Parental Buy-in

Parents supporting such a curriculum was key to recruiting students into the program. It was determined by the team spearheading the marketing that parents generally need answers to the following:

- Will students gain high school credits from participating in the curriculum?
- Will the course allow for matriculation to college?
- Will students get a certificate that will be recognized by manufacturers?
- Will students be able to get jobs in the region after graduating from high school?
- Will jobs provide good wages and benefits?

Figure 5. Parent-Student Night

In order to inform parents about the program, answer their questions, and gain their buy-in, five parent informational sessions were arranged by the marketing team at hotel venues in the region. These sessions were called "Parent-Student Night." The names of students and their contact information were obtained during presentations to students by the marketing team. Their parents were contacted through letters sent home with students and follow-up reminders about the day and time of the Parent–Student session was done through phone calls. At the Parent-Student Nights, meals and refreshments were provided, and presentations were made by the director of CEDA, representatives from local manufacturers, the technical college and university, and the Department of Labor. This event allowed parents and students to get the opportunity to ask questions about the program. At the end of the Parent-Student Night, applications were given to students to fill-out.

Online Orientation

The NIMM training program required students to complete several courses over two and a half years in order to acquire skills for entry-level technician jobs. Students enrolled in the Mechanical CADD Technician track are required to complete seven (7) online courses, while students in the Electro-Mechanical Technician track are required to complete a hybrid program consisting of five (5) online courses and face-to-face practical classes in machining and electronics during the summer months. From the recruitment sessions, parents and students expressed several concerns. Apart from wanting to know the general details about the program, some concerns expressed were the manageability of the online courses, the technical skills required to work online, anxieties of students working solely online, and the resources that would be required.

Based on the concerns and questions raised by students and parents at the recruitment stage, it was evident that there was need for an orientation program to address a general understanding of the program and consider the concerns raised by parents and students. We also had to take into consideration that many students had only recently chosen manufacturing as their career path. Therefore, the orientation program had to provide students with information about the manufacturing industry and the various career track options; this gave students the opportunity to decide whether the program was right for them, and whether they had the dedication and motivation required to study online.

Several studies have been published about online orientation programs. Robinson, Burns, and Gaw (1996) suggests that orientation for online courses serve the same objectives as orientation for college, in that it can facilitate academic and social interactions, increase students' involvement, enhance the sense of belonging to a virtual learning community, and help retention (as cited in Scagnoli, 2001, p. 20). According to Phipps and Merisotis (2000), students should be fully advised about the online program prior to starting in order to determine if they possess the self-motivation and commitment to learn online and if they have access to the minimal technology required by the course. Advising students about online programs prior to starting is but one of twenty-four benchmarks developed by the National Education Association (NEA) and Blackboard Inc. that are considered essential for quality Internet-based education. Another benchmark for quality online learning was the provision of detailed instructions regarding the electronic media used and practice sessions prior to the beginning of the course. Successful orientation programs should provide learning experiences that help students understand and make adaptations to change (Robinson et al., 1996).

Elements of Orientation Design

According to Scagnoli (2001), when designing orientation for online distance learning, the following considerations should be addressed: the program, the courses, the technological applications used in the program, the social interaction in the virtual learning environment, and the students' location/background. As described below, all of these elements were considered when designing the online orientation program for the NIMM technician training program.

A. **The program.** Students were introduced to the NIMM program. This included the rationale of the program, the goals and objectives, description of the program, and the partnering organizations that are involved in making the program possible. Students were also provided with information about the manufacturing industry, its general job opportunities, average earnings, and job benefits in the manufacturing industry.
B. **The courses.** Students were provided with a description of what each course would entail. General objectives of each course were provided and the general skills they would attain from learning each course. Resources such as software requirements needed for each course was also stated. Students were also provided with a schedule outlining when each course would be offered and whether or not they carry dual credits.
C. **The technological applications used in the program.** The Blackboard Learning Management System (LMS) would be used for online courses. Students were exposed to key features of this LMS and shown how to navigate the system. This was done by watching a series of Blackboard orientation videos.
D. **The social interaction in the virtual learning environment.** A key aspect of any online learning program is social interaction. The orientation offered students the opportunity to communicate amongst their peers and with a facilitator. At the beginning of the orientation, students were asked to introduce themselves on a discussion board. Students would provide general information about themselves and why they chose to enroll in the program. Students were also provided with discussion activities in each module and asked to respond to at least two other student's comments.
E. **The students' location/background.** One important aspect of the orientation was to introduce students to the manufacturing companies in their communities that are in need of skilled workers and those local companies that will provide them with apprenticeships and job opportunities upon completion of the program. Therefore, each module included videos introducing local manufacturers. Videos often included a virtual tour of processes involved, and the products manufactured.

Organization of online orientation content

Open Education powered by Blackboard was the online platform used to develop the NIMM orientation. Open Education powered by Blackboard is a free, fully supported cloud offering for Blackboard customers who are interested in offering Open Online Courses to the public. The layout of this learning management system is similar to the Blackboard platform used by all NIMM courses. The curriculum for the online orientation was divided into weekly modules. Each module covered a general topic, and subtopics were organized into separate folders. Content was presented through a variety of means including, text, videos, images, PowerPoint presentations and links to relevant websites. Each weekly module ended with a task that allowed students to interact with each other on a discussion board. Activities were often in the form of discussions or research.

Figure 6. Welcome page of orientation

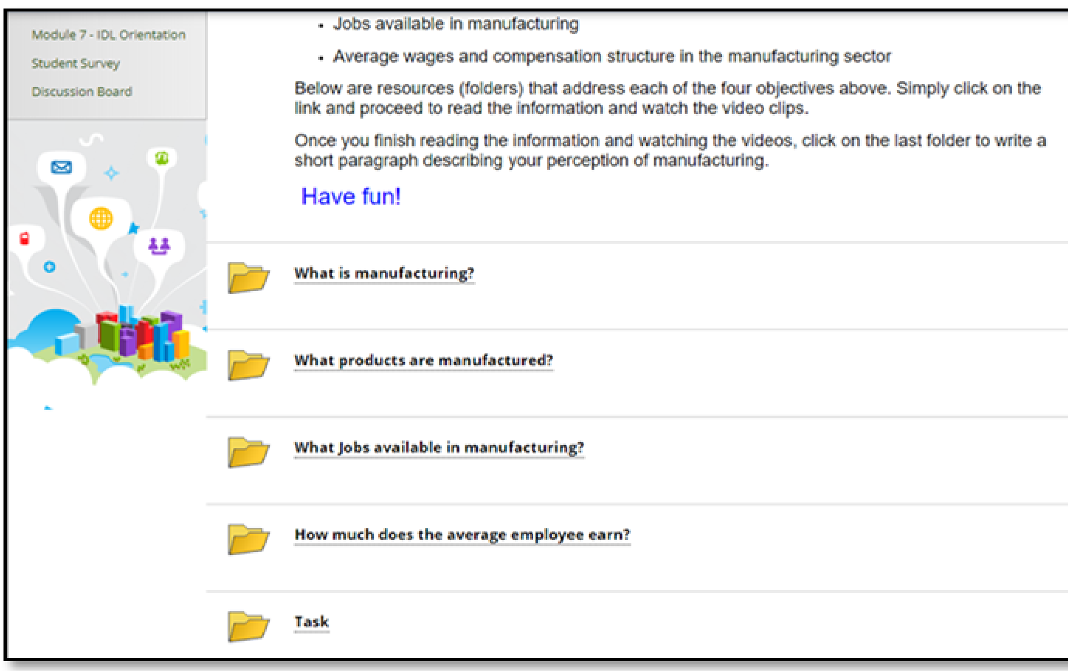

Figure 7. Module 1 of NIMM orientation.

The content covered in each module is outlined below.

1. **Module 1** was designed to give students a general overview of the manufacturing industry. General topics covered were an introduction to manufacturing; products manufactured in the Northwest Intermountain Metal Manufacturing (NIMM) Supercluster; jobs available in manufacturing; average earnings and benefits in manufacturing.

2. **Module 2** was designed to provide students with a better understanding of the program and its various components. Topics covered were an overview of the NIMM program, which included information about the current expansion of manufacturers in the NIMM supercluster and the challenges employers have in finding skilled workers. NSF's role in the program was also discussed, as well as the role of collaborating organizations in the development of the program.

3. **Module 3** was designed to give students a more in-depth look at the two possible career tracks the program focuses on. The role of the electro-mechanical and mechanical CADD technicians were discussed, as well as the skills required for each job. A description of each course offered in the program was also provided.

4. **Module 4** provided additional information about other key components offered within the program. Information was provided on the summer skills academy hosted by the local technical college which offered a hands-on component in machining and electronics; paid apprenticeships; access coaching to support students; field trips to visit local manufacturers; and mindfulness sessions.

5. **Module 5** was an activity session where students did readings on the benefits of the manufacturing in the US and reasons why it is great to work in the manufacturing industry. Students made blog entries based on the required readings and were encouraged to respond to at least two of their peer's blog postings.

6. **Module 6** was designed to give students the opportunity to fully consider their chosen career path and decide if they were making the right decision. This involved doing research using online job boards or interviewing people working in the field. Students were provided with guiding questions to get information such as the skills required, the educational requirements, the earnings, benefits, the working conditions, the working hours, advantages and disadvantages.

7. **Module 7** provided an orientation of the Blackboard Learning Management System.

Conclusion

By all measures the model used for the recruitment of students in the NIMM project proved to be very successful. The number of students targeted for recruitment was reached, with a few students on the waiting list. The model used some low-cost mechanisms such as email, websites, and social media, reported by Shadding et al. (2016), which were important for maintaining contact with students who showed initial interest. Sensitizing gatekeepers in order to gain access to students is critical to the initial stage of the model, and using agents that are intune with the economic landscape and who interface with the manufacturers —the industry that was targeted by this curriculum —adds credibility and was key to properly sensitizing the gatekeepers. Higher cost activities such as Parent-Student Night are very important when recruiting students because even when students express an interest in a curriculum after the marketing stage, it is not necessarily a good predictor of students will be given the greenlight by their parents— especially if parents have a negative perception of the job area and the work that is required in pursuing the curriculum is viewed as “extra.”

Completing online courses is uncharted territory for many high school students. While college students will have more experience doing online courses, high school students (along with their parents) may be skeptical about their ability to complete such a program and also whether those programs can achieve their stated objectives. The Parent-Student Night allowed these questions to be answered in a relaxed, unpressured environment. Equally important was the orientation process that allowed students to be immersed in an online environment where they could build their confidence, while at the same time reminding and reinforcing the key goals, objectives, and opportunities of the program.

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Chapter 4

Engaging Students Through Design Based Biotechnology Literacy

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Abstract

As the field of biotechnology expands, the need for greater education regarding biotechnological applications and innovations is imperative. Biotechnology is defined as "any technique that uses living organisms, or parts of organisms, to make or modify products, improve plants or animals, or to develop microorganism for specific purposes" (OTA, 1988/1991, FCCSET 1992/1993, Wells, 1994). With the goal of Science, Technology, Engineering, and Mathematics (STEM) education focusing on creating technologically literate citizens, it is important that schools and institutions create opportunities for students to explore how biotechnology has evolved throughout the years and the types of challenges biotechnology can help address. In integrating biotechnology literacy within the schools and universities, teacher preparation programs need to modify the way they teach their pre-service teacher by incorporating more instruction in the area of design based biotechnological literacy best practices. This chapter will discuss how the design based biotechnology literacy (DBBL) approach requires a change in an educator's pedagogical practice which leads to a deeper understanding of both content and practice for teacher and student alike.

***Keywords**:* Design Based Biotechnology Literacy, Design Based Learning, Technology Education, Biotechnology

Introduction

Biotechnology has a major impact on the world particularly the medical, agricultural, and educational fields. With the discovery of the double helix in the mid-1950s and the increased need for bioremediation, the field of biotechnology is constantly advancing and seems to play a significant role in our 21st century world. With new technologies emerging every year, it is imperative that the United States educational system creates technologically literate citizens that understand the scientific and technological concepts to make informed decisions. Economic growth and the improvement of America's standard of living is one of the major goals set forth from the Federal Coordinating Council for Science, Engineering and Technology (FCCSET) Committee on Life Sciences and Health (1992). As with any area of study, definitions play a major role in accurately describing a given area. As for biotechnology, there was much confusion regarding its definition particularly in the areas of biology, health care and education. That being said, in the *Design Based Biotechnology Literacy Curriculum* (2017), biotechnology is defined as involving "any technique that uses living organisms (or parts of an organism) to make or modify products, to improve plants or animals, or to develop microorganism for a specific use" (Wells, 2019, p.53).

The field of biotechnology is constantly advancing and many educators have misconceptions that biotechnology needs to have expensive materials and equipment in order to successfully teach these concepts of biotechnology within a technology education classroom (Dunham, Wells, & White, 2002, p.7). In working towards educating individuals to ensure that they have the specific education and training needed to work in these biotechnology companies and industries, the International Technology Engineering Educators Association (ITEEA) has adopted the taxonometric structure developed in 1992 (Wells, 1994) for teaching biotechnology. This taxonomy organized biotechnology content into eight distinct knowledge areas: foundations of biotechnology, environment, agriculture, bioprocessing, genetic engineering, biochemistry, medicine, and bioethics (Dunham, et al., 2002, p.7-8). This research article will discuss the importance of incorporating methods of teaching and learning biotechnology within teacher prepatory programs, as well as ways of increasing student engagement in this area.

In order for biotechnology to be effectively taught in schools, pre-service teachers must be enrolled in teacher prepatory programs that teach them the science content as well as the technological content requisite to their understanding of the concepts. As more and more biotechnologies emerge, students in the 21st Century are required to develop their understanding and abilities to use these technologies throughout their everyday lives. Teachers must not only learn the pedagogical content and practice knowledge for teaching biotechnology literacy, but also experience first-hand the strategies that are most effective in teaching it.

Scientific and Technological Literacy for All

Given the identified context organizers for technological systems are physical, informational, and biological (ITEA TfAAP, 2006, p.16), biotechnology was a content organizer included in the *Standards for Technological Literacy* (2000) within Standard 15 *Students will develop an understanding of and be able to select and use agricultural and related biotechnologies* (ITEEA, 2000, p.149-157). Biotechnology is also aligned to the crosscutting concepts of the Next Generation Science Standards within the Life Science and Engineering Design Disciplinary Core Ideas (DCIs) (Pruitt, 2015). The ability to be both scientifically and technologically literate stems from the ability to think critically, "design and develop products, systems, and environments to solve practical problems" (ITEA TfAAP, 2006, p.1). The standards listed above provided a framework that could be used to develop curricular materials (Wells, 2019) and programs that promote these competencies. If all citizens are not required to learn technological knowledge and pracitces, society will remain technologically ignorant and be poorly equipped for fully integrating in a 21st Century world (Pearson & Young, NAE/NRC, 2002, p.1-2). The goal of technology education is to create technologically literate citizens that "understand the nature of technology, appropriately use technological devices and processes, and participate in societies decisions on technological issues" (ITEEA TLfA, 2006, p.1). Citizens should be able to think critically to design and construct systems to solve real-world problems. Recent research has indicated that schools are not properly preparing graduates to make well-considered decisions or think critically about technology (Pearson &Young, 2002, p.2; ITEEA TLfA, 2006, p.1).

There are many definitions of technology, but ITEEA defines it as " the innovation, change, or modification of the natural environment in order to satisfy perceived human wants and needs" (ITEEA TfAAP, 2006, p.5). It is essential that technology education be made a requirement for graduation. When students are involved in technology education activities they engage in "cognitive and psychomotor activities that foster critical thinking, decision-making, and problem-solving related to the use, management, evaluation, and understanding of the designed world" (ITEEA TfAAP, 2006, p.9). Technology education should not be confused with educational/instructional technologies such a SMART boards and audio-visual equipment that is used to enhance instruction (ITEEA TLfA, 2006, p.9). In 1996, the International Technology Educators Association (ITEA) published the *Technology for All Americans: Rationale and Structure* for the study of technology, which discussed the Universals of Technology that all students should know. Then between 1996 and 2000, ITEA published the *Technology for All Americans Project* (TfAAP) as well as published the *Standards for Technological Literacy* (STL), which focused on the Universals of Technology, which include three areas: knowledge, process, and contexts.

Teaching Biotechnology

The most natural intersection to include the teaching of biotechnology content is through a technology education course. Through an Integrative STEM Education perspective, the biology and technology/engineering concepts can be easily taught in an integrative manner. Technology education focuses on solving real world problems using the technical knowledge to design and construct a product or solution, which is unlike scientific fields that focus on the natural laws and phenomena students observe in order to solve and carry out an investigation (Wells, 1994, p. 72). Thus, it would be beneficial to students if they could engage in a design challenge where they can use the scientific knowledge as well as tacit knowledge to understand the natural intersections between the science and the technology (Wells, 1994, p. 73). One example of integrating the biological processes with the technological processes would be the construction of a hydroponics/aquaponics system.

The Design Based Biotechnology Literacy (DBBL) approach engages students in implementing design based biotechnology challenges intended to further their understanding of science concepts, as well as improves the biology content knowledge of technology education teachers in order to better integrate the science with the technology/engineering (T/E) concepts. Science concepts are inherent within any technological/engineering design challenge, and when engaged in DBBL experiences students are intentionally immersed in biology content while improving their understanding of the connections between science and technology/engineering

(Peterman, Pan, Robertson, & Lee, 2014, p.45). In addition to student achievement, technology teachers can increase their scientific knowledge to better recognize the integration of science, technology, engineering and mathematics content within the lesson design.

Literature Review

Student Achievement

When biotechnology is integrated at a young age, students are able to increase their background knowledge as they cognitively develop and make better interdisciplinary connections. "From research in education, it has been found that if previously learned knowledge is tapped and built upon, it is likely that children will acquire a more coherent and thorough understanding of these processes than if they are taught them as isolated abstractions" (ITEA, 2006, p.20). Bigler and Hanegan (2011, p.253) concluded that hands-on learning could also increase student's motivation and confidence. Teachers know that students become more engaged in their learning when they are participating in a hands-on activity and that this engagement promotes deeper knowledge acquisition (Dunham, et al., 2002, p.8). Biotechnology is a field of science, which requires hands-on learning in order to fully learn and understand the content (Bigler & Hanegan, 2011, p.246). When students are able to participate in hands-on activities it increases their ability for knowledge transfer and gives them meaningful learning opportunities to apply their knowledge to real scenarios. Hands-on learning can be defined as an "educational experience that actively involves people in manipulating objects to gain knowledge or understanding" (Bigler & Hanegan, 2011, p.246). Bigler and Hanegan compared traditional learning environments to an inquiry based hands-on classroom instructional approach and they determined a statistically significant increase in student content knowledge of ($p=0.0481$) which was concluded that hands-on learning "is at the heart of science learning" (p. 246). Not only was less time needed to spend on this topic in only 13 days compared to the traditional learning sequence of 20 school days, students had increased motivation and confidence in the biotechnology content (Bigler & Hanegan, 2011, p.253).

As students engage in DBBL, it is essential educators have appropriate assessments that can evaluate the students' skills and understanding rather than tests that only focus on vocabulary words (Bigler & Hanegan, 2011). In a research study that focused on student attitudes and content knowledge of Genetically Modified Organisms (GMOs), it was concluded that student attitudes changed from argumentation to engagement in critical thinking while working through a digital module what was based on peer collaboration and critique (Noroozi & Mulder, 2017, p.35). Those students attained a 2.85 knowledge gain from 9.37 in their pre-test to 12.22 in their post-test (Noroozi & Mulder, 2017, p.34-35). When students engage in biotechnology project-based learning opportunities, it stimulates excitement, knowledge and confidence in the given subject matter and the students are able to effectively troubleshoot and apply their acquired knowledge to real-world situations (Movahedzadeh, Patwell, Rieker, & Gonzalez, 2012, p.7). "Project-Based Learning is a method in which students engage in intellectually challenging tasks that drive inquiry questions through gaining content knowledge and academic skills to solve complex problems and informatively defend their solution and outcomes" (Movahedzadeh, et al., 2012, p.7). In project-based learning, the teacher acts more like a mentor and facilitator rather than the source of direct instruction to the students. They allow the students to take ownership of their own learning and work collaboratively with their peers to generate questions that help them research what items need to be understood in order to proceed in the activity (Movahedzadeh, et al., 2012, p.5). In addition, students should be aware of how the field of biotechnology can be used to advance scientific knowledge (Borgerding, Sadler, & Koroly, 2013, p. 143).

Whether it is project based learning or problem based learning, they are both critically important for engaging students in the biotechnological content as well as increase their achievement and understanding. Israel, Pearson, Tapia, Wherfel and Reese (2015), shares that a problem solving framework also increases struggling learners, including students with disabilities and those living in poverty (Israel, et al., 2015, p.1). By using these instructional approaches in one's technology education class, diverse learners will be able to expand their horizons and improve their problem solving skills. In one's own observations as an elementary and middle school teacher, one can deduce that students with special needs and high poverty socioeconomic status (SES) benefit greatly from these technology education biotechnology classes as noted from having one's students participate in a Technology Student Association competition in the field of medical and biotechnologies and winning 1st place in their state division (Papadopoulos, 2017). Hanegan and Bigler (2009) indicate that learning is not a passive activity. The National Science Education Standards "call for students to be actively engaged in solving problems that allow them to realize applications beyond the scope of the classroom" (p.248). Hands-on learning is an essential teaching element that promotes scientific literacy and citizens who are scientifically literate not only knowing the science content, but also are able to do science (Bigler & Hanegan, 2011, p.246).

Teacher Pedagogical Content Knowledge

Some of the major reasons that biotechnology is not taught in schools is that there are many teachers who lack the pedagogical content knowledge required to teach biotechnology. "Pedagogical knowledge refers to the specialized knowledge of teachers for creating effective teaching and learning environments for all students" (Guerriero, 2017, p.2; Shulman, 1986). "With a clear definition of biotechnology in place, its position within the Technology Education (TE) curriculum is more evident, and instructors will more easily find points of inclusion they recognize and can attempt to incorporate" (Wells, 1995, p.12). As teachers teach science to their students, it is imperative that they provide multiple perspectives which allow students to make their own opinions and conclusions about what is presented (Goodrum, Rennie, & Hackling., 2001; Hilton, Nichols, & Kanasa, 2011). Where technology education courses are not offered, Bigler and Hanegan suggested that biotechnology education using hands-on teaching methods should be considered by secondary biology teachers (Bigler & Hanegan, 2011, p.246). If more hands-on learning can occur within both the science and technology classrooms, students will be able to understand and transfer knowledge between the classes.

Teacher preparation programs will also need to be changed to include this effective way of teaching in order to produce effective educators in teaching biotechnology. As stated by Shulman (1986) and Grossman (1990), teachers acquire their knowledge from many sources that affect their teaching such as in-service workshops, webinars, professional development opportunities such as lectures and conferences just to name a few. Biotechnology, like the other content areas of technology education, is naturally interdisciplinary and lends itself to a blended approach of behavioral, cognitive, and constructivist principles in the design of instruction (Dunham, et al., 2002, p.68). Just as there is biotechnology pedagogical content knowledge, there is also technological pedagogical content knowledge (TPACK) which focuses on design based or inquiry based learning experiences deriving from a constructivist nature (Chai, 2013, p.44). When technology teachers engage in creating TPACK lessons, they are able to change their epistemological approaches to include "design literacy, flexibility, and creativity" in their lessons (Chai, 2013, p.46). As noted previously, the model depicting the universals of technology includes knowledge, process, and contexts (ITEA TfAAP, 2000). Biotechnology provides for a multidisciplinary and multiple instructional approach to technology education because it allows for the integration of other content areas and 21st century skills (Petrina, 2008; Dunham, et al., 2002, p.69). Middleton (2005) indicated that there are three representations of knowledge which include visual, verbal and tacit, all of which are used within a technology education classroom while conducting an engineering design challenge. When investigating teacher content knowledge and pedagogical content knowledge, Friedrichsen, Abell, Pareja, Brown, Lankford, & Volkmann (2009) indicated three areas of teacher subject-matter knowledge to include the teachers' own K-12 learning experiences, the type of teacher education and professional development they had as well as their own teaching experiences that formed their beliefs and knowledge base (Friedrichsen, et al., 2009). There are many ways to investigate teacher pedagogical content knowledge (PCK). The first can be through a university course and the second can be through a preservice education program (Kleickmann, et al., 2013, p.93). "In the 1980s, Shulman identified research on the content specific characteristics of teachers and of instruction as the 'missing paradigm' of research on learning and instruction" (Shulman, 1986, 1987 as cited in Kleickmann, et al., 2013, p.90).

"Teacher beliefs have been studied to understand teaching practices (Pajares, 1992) since beliefs influence behaviors" Ajzen & Maddenm, 1986 (as cited in Kim, Kim, Lee, Spector, & DeMeester, 2013, p.77). In a mixed methods study conducted by Kim, et al., (2013), the significant findings included that the "epistemological beliefs about *the structure of knowledge* was significantly correlated with teacher conceptions on *learning process* (r = .444) and *teacher role* (r = .447)" as well as "teacher conceptions on *class discussions* was significantly correlated with *lesson design* (r = .692) and *levels of technology use* (r = .882)" (Kim, et al., 2013, p.81). The Pearson correlation coefficient r indicates a positive correlation to all the variables. The correlations regarding teacher beliefs and their teaching practices are consistent with other researchers in the field such as Nespor (1987), Kagan (1992), and Pajares (1992). Teacher beliefs also changed with increased professional development focused on biotechnology content knowledge that promoted the strategies for teaching it (Borgerding, et al., 2013, p. 146).

Implications

The DBBL approach engages students in implementing design based biotechnology challenges that further their understanding in science concepts as well as improves technology education teachers' biology content knowledge to better integrate the science with the T/E concepts. This being said, it is important to increase the biology content knowledge of technology education teachers because they can better understand how the technological processes are used to teach the biological processes that drive the DBBL lessons, activities and projects. Thus, by preparing pre-service teachers with substantial science courses, particularly biology courses, they are more likely to know how to connect the biological concepts and effectively teach them alongside the technology ones. Throughout one's literature review, it is evident that there are many publications that indicate that DBBL is a successful approach to increase student achievement as well as teacher competencies in biotechnology (Casanoves, González, Salvadó, Haro, & Novo, 2015; Dunham, et al., 2002; Fulmer, 2013; Wells, 1992. 1995, 2016, 2017). In addition, it is evident through the literature that at times it is necessary for front-loading content to guide students through a ‘need-to-know basis’ in order to make connections to the STEM content (Dunham, et al., 2002).

Implications for Teaching Biotechnology

There are many implications for teaching biotechnology. Federal investment needs to be organized as well as training and career development in using various instrumentation and biotechnological resources (FCCSET, 1992, p.69-80). The *Standards for Technological Literacy* as well as the *Next Generation Science Standards* have also included biotechnology within their required standards that educational systems must adhere to in order to be compliant with the national demands (ITEEA STL, 2000; Pruitt, 2013). In regards to curricular materials and resources, it is evident from the literature that teachers are limited with various resources available to them (Fonseca, Costa, Lencastre, & Tavares, 2012). Fonseca, et.al. discussed how there are many implications to teaching biotechnology in K-12 education, however the most cited in these articles involved the inadequate content training for teachers, the lack of resources, time, experience and qualifications. Some other areas that teachers perceive challenges are through “material limitations to conceptual, motivational and attitudinal constraints” that deter teachers from teaching biotechnological topics (Fonseca, et al., 2012, p.369).

Lack of Teacher Content Knowledge and Confidence in Biotechnology

The issue of teacher confidence and pedagogical content knowledge in biotechnology was a major implication to this field and the researchers tried to investigate the cause for this issue, which was rooted in teacher preparation programs and professional development workshops. Bigler and Hanegan (2011, p.247) stated that the lack of confidence in knowing how to use biotechnology equipment as well as the lack of content knowledge students possess indicate major implications for this field. Another cause cited is that many educators are not trained in using biotechnology equipment and never had the opportunity to engage in research experiences before graduating with their teaching certificates. It is also essential that the biology teacher is an expert in the field as well as has confidence with biotechnology so that they can teach the knowledge with confidence to prevent students from losing interest or revert back to traditional ways of learning through lecture (Bigler & Hanegan, 2011, p.254). Once the content is mastered, Shulman’s “signature pedagogies” (2005, p.52) can begin to develop for the field of biotechnology. Some issues discussed included the difficulty of the content knowledge and access to courses that teach this content for teachers to be comfortable to teach it. Teachers need to have good teacher knowledge in order to be able to teach it, just as Shulman (1987) stated that “pedagogical reasoning” is necessary for understanding (Moreland, Jones, & Cowie, 2006, p.145). This concept is further supported by Harlen and James (1997) stating that “Good teacher knowledge of subject content has been found to have a positive effect on decision-making related to changing pedagogical strategies for creating better learning opportunities” (as cited in Moreland, et al., 2006, p.144).

Teacher confidence was also a major factor because if the teacher was not an expert in the content that they taught, various topics within the curriculum may not be taught to the students or produce more student misconceptions due to their lack of knowledge in that area (Bigler & Hanegan, 2011, p.247). Teachers and administrators must recognize that this content and hands-on learning approach is worthy and valuable and that students are able to transfer their knowledge between activities and disciplines (Bigler & Hanegan, 2011, p.248-249). Even though it might be more difficult to teach in this kind of inquiry design based approach, it yields better outcomes (Dunham, et al., 2002). Biotechnology infused in Technology Education makes a more natural environment for teaching and learning, which Dunham, Wells and White (2002) supported in stating that "biotechnology activities, given the interdisciplinary nature of the topic, provide a rich setting for student engagement in problem solving, investigation, and discovery – a hallmark of the cognitive orientation" (p. 7).

Design Based Learning Models

Throughout the literature review search about design based learnings strategies, one found many models that could be used to teach biotechnology. "The MISTRE group's definition of a model as 'a representation of an idea, object, event, process, or system" (France, 2000, p.1028). Within each of the listed models (Gilbert & Boulter, 1998; Archer, 1992; Roberts, 1992; DFEE, 1995; MISTRE group, 1997; Grosslight, Unger, Jay, & Smith, 1991), it was evident that there were three levels of thinking in regards to models Levels 1-3 referenced in *Biotechnology teaching models: what is their role in technology education?* (France, 2000, p.1029). Educators need to create activities that provide concrete representations of reality for evaluation (France, 2000, p.1035). Educators can provide formative assessments or summative assessments using the students' Interactive Engineering Journals/Notebooks to gauge student improvement throughout the Engineering Design Process (Wells, 2019; Peterman, et al., 2014, p.46). By using models to teach 'larger than life' concepts, students need to learn how to appreciate models and how they can use them to approach intellectual problems (France, 2000, p.1037).

Lack of Teacher Preparation in Biotechnology

There is also a lack in biotechnology instruction, which an NSF study indicated that biotech was "non-existent" in schools (Hanegan & Bigler, 2009). The goal of teaching biotechnology is similar to what is required from technology education which is being technologically literate citizens through "enabling citizens to perform routine tasks to requiring that they are able to make responsible, informed decisions that affect individuals, our society, and the environment" (Scott, Washer, & Wright, 2006, p.43). Some educators shy away from teaching biotechnology because they may feel ill prepared or unsure about the content knowledge required teaching it (Fonseca, et al., 2012, p.372). By including biotechnology in the K-12 setting, bioethics becomes a major discussion as to how society views the use of biotechnologies and what the cultural beliefs and impacts these technologies may have on humans, the environment and our economy (FCCSET, 1992, p.65).

NGSS Implications & Training

The *Next Generation Science Standards* (NGSS) that were implemented in 2013 have changed the way science is being taught in the K-12 setting and with this new focus on inquiry and engineering design integration. Bybee (2011) indicated that one of the greatest challenges in implementing NGSS is the shift from teacher centered direct instruction to student-centered inquiry using the science and engineering practices. As referenced in Petermen, et al., (2014), the future of public education looks very optimistic with the implementation of the *Next Generation Science Standards* (NGSS), that provides natural intersections of science content with the technology/engineering practices (Petermen, et. al., 2014, p.47). School districts are looking to provide their educators with more NGSS professional development so that they feel comfortable teaching the new way of teaching science.

Implications for the Field of Technology Education

With the new push towards implementing more science within technology/engineering practices, the NGSS is trying to mesh science classes and technology classes in an integrative way of teaching students content to make connections that are more explicit to real-world applications. In discussing these new changes with other technology education teachers, some TE educators are concerned that their signature pedagogies will be taken over from the science educators and potentially lose their jobs or activities that they currently already teach (Microbial Fuel Cells, Water Rockets, Bridges, etc.). Borgerding, et al., (2013) conducted a research investigation to "investigate teachers' awareness, informational, personal, management, consequences, collaboration, and refocusing concerns about biotechnology teaching by employing a qualitative design that allowed for the emergence of teachers' ideas" (Borgerding, et al., 2013, p.133). In teaching biotechnology, it may be required that some phases in the lesson design would be best carried out in a science laboratory while others would benefit from being in a technology education lab/classroom (Borgerding, et al., 2013, p.140).

Elementary Teacher Implications

In regards to learning and teaching engineering to elementary, limited literature and resources are available to teachers and this poses a major concern. The lack of resources continues to be a major issue for elementary school teachers in finding engineering literature and resources they can use to teach engineering design with in their classrooms (Wendell, 2014, p.30). Teachers also restrict their search for information to only a few websites or textbooks and since the field of biotechnology is constantly advancing, much of the information becomes obsolete (Fonseca, et al., 2012, p.374). Fortunately, there are some biotechnology curriculum guides that offer lessons and activities that elementary teachers can use to integrate more biotechnology content within their daily lessons. One curriculum guide is the *Design Based Biotechnology Literacy Teaching Guide* (Wells, 2019) that was established to provide educators with a means to connect theory and practice within an integrative design-based approach, specifically in biotechnology. In addition, the implementation of the *Next Generation Science Standards* has required performance expectations for each grade level that provide students with the opportunity to focus on design as a means of integrating engineering within the lessons. Without extra time in the school day set aside for engineering, new elementary teachers will look for engineering experiences that align with the rest of their curriculum and can accomplish objectives in other content to areas. Teacher education programs need to provide models for connecting engineering not only to science, but also to reading and writing. In order to decrease the amount of information gathering, elementary teachers can use children's literature to integrate engineering design problems within their classroom activities (Wendell, 2014, p.45).

With more exposure to the science and engineering practices mentioned in the NGSS, elementary teachers may find cross-curricular connections that they can use to embrace the learning and teaching of engineering within their classrooms. The biggest challenge would be changing teacher attitudes towards teaching biotechnology and their willingness to learn and grow (Hilton, Nichols, & Kanasa, 2011, p.461). Classroom management in regards to materials and supervision can also become a limiting implication for teaching more design based biotechical lessons within the classroom. Some practical applications to elementary grades would be the use of team jobs where each member is responsible for a specific task such as being the research analyst, design manager, materials specialist and quality control agent (Dunham, et.al, 2002, p.75). The authors looked at the learning theory of technology education and examined behavioral, cognitive, and constructivist philosophies related to teaching biotechnology. Biotechnology education combines a behavioral, cognitive and constructivist approach and provides students with meaningful learning opportunities where they can collaborate and reflect on their possible solutions. Piaget (1966) stated, "The internal cognitive structure of the student is changed as a result of interacting with the environment and being exposed to an increasing number of experiences" (Durham, et al., 2002, p.71). With the growing field of biotechnology, one can be optimistic that this content will be better integrated within the primary and secondary grades as well as taught in teacher preparation programs. Biotechnology can greatly influence student learning and motivation to successfully become scientifically and technologically literate citizens. "Learning to teach engineering design will need to fit into other content and methods courses and therefore approaches that integrate engineering design with as many academic disciplines as possible will be attractive not only to pre-service teachers but also to teacher educators" (Wendell, 2014, p.30). In addition to the engineering design process, Wells (2016) introduced the P.I.R.P.O.S.A.L Model, which is also an iterative set of phases a student would go through to design and construct a product or solution (Wells, 2016).

Conclusions

As a result of literature, research, and observations it has been determined that DBBL approaches truly engage students in implementing design based biotechnology challenges that further their understanding of science concepts as well as improves technology education teachers' biology content knowledge to better integrate the science with the T/E concepts. "Scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it" (Bigler & Hanegan, 2011, p.248). This being said, education in the United States is moving towards a more integrative approach for learning through integrative STEM education and DBBL along with the *Next Generation Science Standards* and *Standards for Technological Literacy* will improve our citizens content knowledge, which in turn will create technologically literate citizens that can be fully integrated within this 21st Century world.

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Scope of the Research Monograph Series

The Research Monograph Series (RMS) is a scholarly publication initiated in 2017 and first published in 2018. The RMS, sponsored by the Research and Scholarship (R&S) Committee of the Council on Technology and Engineering Teacher Education (CTETE), is a unique academic platform designed to support the publication efforts of emerging scholars across the complete spectrum of Science, Technology, Engineering, and Mathematics (STEM) education disciplines. As such, the RMS is devoted to encouraging contributions from new and talented scholars from any STEM education discipline as an avenue for assisting in their development of scholastic abilities and a presence within the global discourse surrounding STEM education.

The scope of the RMS is broad, with the intent to provide a platform for scholarly discussion through publication of empirical research and academic essays that:

- Present evidence-based conceptual frameworks and/or innovative ideas in Technology Education (TE), Technology and Design Education (TDE), and Technology and Engineering Education (T&EE) programs.
- Critique theoretical/conceptual papers, research studies, programs, and policies relating to TE, TDE, T&EE programs, Integrative STEM Education (I-STEM ED) and general STEM Education.
- Address early research, literature reviews, conceptual frameworks, and action research in TE, TDE, T&EE, I-STEM ED and general STEM Education.
- Describe programmatic partnerships and collaborations to promote TE, TDE, T&EE, I-STEM ED and general STEM Education

Editorial Review Process

All manuscripts that appear in the RMS are initially screened by the editor to determine the appropriateness for the monograph's scope, followed by an anonymous, double-blind review by two or more members of the Review Board. Authors of manuscripts that have been subjected to blind review are informed of the review decision within three months of the date of submission.

The views expressed through manuscripts published in the RMS are not necessarily those of the Editor, Co-Editor, Review Board, Research & Scholarship Committee, or officers serving on the Council of Technology and Engineering Teacher Education and the International Technology and Engineering Education Association.

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Topic is significant to technology education and related fields	1 2 3 4 5
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