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Strengthening the STEM Pipeline from High School to University for Engineering Intrapreneurs

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introduction

In the United States, there has been a proliferation of high school-level curricula aimed at teaching entrepreneurship in concert with STEM content areas (Fauzi, 2021). The primary goals of these curricula are to: strengthen entrepreneurial skills in students; connect entrepreneurship to STEM concepts and content areas in order to support interest in STEM areas of the workforce; connect students to industry leaders; and create a bridge between high school and either future employment or undergraduate university education (Londona *et al.*, 2020; Streicher *et al.*, 2019). Likewise, there has been a proliferation of curriculum and programs at the university level to teach entrepreneurship to STEM students, in order to achieve similar goals (Rashid, 2019). While both high school and university level courses tend to aim at some of the same knowledge and skills, the curricula often do not speak to each other; and there are not intentional design choices to create a pipeline. This is a missed opportunity.

Many different versions of "pipelines" have been created, in other areas, between high schools and universities. For example, dual credit programs aim to allow high school students to take university-level courses (with university sourced curriculum) while in high school. Dual credit programs have proven successful in increasing the numbers of students who are ready for, enter, and are retained by tertiary institutions (Bowers, 2016; Allan and Dadgar, 2012). This increase in readiness, enrollment, and retention can also be seen with A.P. courses (Bowers, 2016). We believe that similar pathways and bridges (pipelines) could be created for Engineering and Entrepreneurship.

This paper examines the connections and possible bridges between high school and university curricula from both a general and specific perspective. The paper first provides a brief literature review of entrepreneurship education. Then, the paper examines the literature on curriculum practices and goals of high school entrepreneurship programs. The paper then turns to examining the goals and curriculum practices of entrepreneurship education in higher education, as articulated in the literature on entrepreneurship education in university and college contexts. The paper analyzes the possible connections, as well as the fact that there are few intentional bridges or pipelines between university and high school level entrepreneurship education programs. The paper then gives a specific case of a high school entrepreneurship education in one of the largest districts in the U.S. and their connections to university entrepreneurship programs.

We consider an intrapreneurship program in a department of electrical and computer engineering. Intrapreneurship is connected to, but differs from, entrepreneurship in that entrepreneurship usually assumes that someone will use these skills to start their own business. Intrapreneurship, on the other hand, builds skills so that employees can innovate and start new programs within existing companies. Faculty at the university have recently had the opportunity to work with teachers from a large urban school district that focuses on entrepreneurship, intrapreneurship, and STEM content areas. The paper provides this specific case study in order to

support ‘lessons learned’ about building bridges between high school and university in order to strengthen the STEM pipeline. The paper concludes by suggesting future avenues of connection.

review of literature on entrepreneurship education

While a focus on entrepreneurial education has become more ubiquitous in the last fifteen years, there are still debates around how to define entrepreneurship education (Fejes *et al*., 2019). For example, Fejes *et al.* (2019) have argued that there are two main definitions of entrepreneurship education. “The narrow definition equates entrepreneurship education with a specific course aimed at training young people to start their own business, while the wider definition equates entrepreneurship education with general skills that all students should learn, and which are construed as helpful for preparation for life in general.” (p. 554-555). Both high school and university programs vary around these two general definitions. Some programs focus on specific skills and experiences designed to support a student as they set up a business. Other programs focus more on skills that could be used in either entrepreneurial or intrapreneurial contexts, but with a strong focus on practices that support innovative thinking and productive risk taking as well as strong collaboration with a view to future product or process development.

Many scholars have argued that entrepreneurship education, especially the programs that focus on entrepreneurship skills as the outcomes (rather than launching a business as the desired outcome) can cultivate many ‘goods’ for student learning. For example, Listiningrum *et al.* (2020) argues the entrepreneurship education “is designed to cultivate skills aligned with “creative and innovative ability so that it can produce something new and different” (p. 88). Listiningram *et al.* (2020) further highlight the fact the entrepreneurship skills often overlap with leadership skills and, therefore, can benefit a wide swath of students.

We do not develop an argument for the benefits of entrepreneurship education because that has been done so well by previous scholars. For more information about the benefits and various definitions of entrepreneurship education, we refer you to studies by Putro *et al*., (2022); Boldureanu *et al*. (2020); Gianiodis and Meek (2020); Ahmed *et al*. (2020); and Brune and Lutz (2020). The paper now turns to the main goals and curriculum practices of entrepreneurship education at the high school level.

entrepreneurship education in high school

Many scholars have argued for the benefits of entrepreneurship education for high schools students, particularly when the entrepreneurship program is connected to STEM education as well as developing skills in leadership, collaboration, creativity, and innovative thinking (Paray and Kumar, 2020; Isabelle, 2020; and Rodriguez and Lieber, 2020). Rodriguez and Liber (2020), in particular, call out the goals, and potential benefits, of entrepreneurship education. They highlight the ways that entrepreneurship education in high schools can, and should, be linked to the development of skills linked to design-thinking, to thinking toward innovative practices and processes, and the ways that entrepreneurship programs can be a ‘gateway’ to actual entrepreneurship projects. As we examined curricula from several different high school programs, we saw the connection of the assignments, readings, and projects to the skills-development listed above. Additionally, we noted that assignments and projects also supported connections to community members (often through the use of guest speakers or even

internships) and connections to future employers (again through the use of guest speakers and internships). Furthermore, in the high school curricula, there was a strong focus on developing communication skills (through both written and oral presentations), developing collaboration skills (through many group projects and peer evaluation opportunities), and also a connection to digital literacy. In fact, entrepreneurship education programs at the high school level were often linked (in both advertising materials provided by the schools as well as in language form syllabi) to 21st Century Skills development.

Many high school courses or modules included assignments specifically designed to cultivate skills associated in the literature with entrepreneurship practices. These skills were articulated in the syllabus as being transferrable to many different contexts (intrapreneurship contexts, leadership contexts). For example, it was common for high school programs to include an activity where students responded to guest speakers from the community or from large corporations who talked about entrepreneurship skills and opportunities. Many programs included collaboration activities with a strong focus on project-based learning. Some of the more robust programs also included mandatory internships with either a small business that had started out as an entrepreneurial goal, or internships with large companies that were still trying to cultivate innovation in the company. When high schools had dedicated courses or even programs of study that focused on entrepreneurship, there was also a focus on bringing in core content areas (Science, Math, Reading, Social Studies) into the entrepreneurship activities.

Several scholars have argued that high school programs, in particular, have strengths in their ability to cultivate dispositions, skills, and connections to core content areas that set students up to make connections between entrepreneurial processes and other contexts, and that the high school programs are often more innovative in their connections to school communities as well as their connections to core content areas when compared to entrepreneurship programs in higher education, that are often isolated to Business programs. For example, Rodriguez and Lieber (2020) talk about the ways that high school programs that provided students with hands-on experiences working with small businesses were successful in developing entrepreneurial mindsets, competencies, and desires. They write: “Students in entrepreneurship education showed an overall statistically significant increase in entrepreneurial mindset, specifically in communication and collaboration, opportunity recognition, and critical thinking and problem-solving. Moreover, there was a positive association between entrepreneurial mindset gains and perceptions of future career success.” (p, 87).

Fossen and Sorgner (2021) argue that high school programs are more likely than other types of programs to focus on technical and digital literacies as being integral to entrepreneurship education. They write: “we provide evidence that digitalization is significantly associated with entrepreneurial entry at the individual level. The results suggest that high-skilled employees and employees in ICT occupations facing destructive digitalization have an increased likelihood of becoming entrepreneurs” (p. 548). They argue that the best entrepreneurship programs set high school students up to be highly technically literate, because that appears to be an ‘entry level skill’ for many entrepreneurship pathways. Thus, the best high school programs integrate digital and technical literacy into their curriculum.

Elert *et al*. (2015) foreground the fact that high school entrepreneurship courses are often highly correlated with starting your own business, even if that is a side business that does not last

very long. High school programs often support students into as they try things out, even if the 'small business idea' is something like a side gig building apps or a "drop-shipping" scheme. Godsey and Sebora (2010) concur that high school programs that provide hands-on opportunities to practice entrepreneurship skills in small community business contexts often start some form of business on their own, even if it is not sustained.

Finally, Ghasemi *et al*. (2011) even argue that high school entrepreneurship programs are often more correlative to increases in student motivation, productivity, and even creativity than courses developed in other contexts such as higher education. They write: "After collecting and analyzing the data, the results indicated that there was a meaningful relation between students' creativity and entrepreneurship. There was also meaningful positive relation between achievement motivation and entrepreneurship. Among the components of creativity, fluency and initiative had positive relation to entrepreneurship. Among components of achievement motivation, hard-working, purposefulness, and insistence had positive meaningful relation to entrepreneurship." (p. 1291). This increase in skills for the high school programs are often attributed to the fact that high school courses are often connected to other parts of the high school curriculum and core content areas, as well as the fact that high school programs are often more integrated into connections with the community than university programs.

As we examined both the literature on high school level entrepreneurship programs, as well as curricular examples of these programs, it became clear that some programs are done as more of an 'add on' to an existing course. For example, rather than having entrepreneurship as its own course or program, or even rather than having entrepreneurship skills that weave into many courses, when entrepreneurship was taught as a 3-week module as part of a financial literacy course, for example, those benefits mentioned above did not accrue. This aligns with the literature. Iwu *et al*. (2021) conducted a study that found that, at secondary level, programs that support entrepreneurship rarely ever make a difference if they are an add-on to another program. Courses that specifically teach entrepreneurial skills and provide entrepreneurship experimentation pathways do make a difference—but this puts an enormous load on the teachers of the course. The teacher and the activities that support entrepreneurship skills make the strongest difference to whether students are acquiring entrepreneurship competencies and mindsets. This has implications for high school programs: in order to accrue the benefits that are listed above in the literature we cite, the program needs to connected to intentional, robust, and prolonged experiences. In some ways, this finding is aligned with research around university programs as well.

entrepreneurship education in higher education / university

In many ways, the goals of entrepreneurship education in high education are the same as the goals in high school. As Linton and Klinton (2019) point out, higher education programs also focus on skills linked with innovation processes, design thinking, and are also seen as a 'gateway' to starting your own business. As we examined curricula from several programs, we also noticed a strong connection to future employers in many of these programs (through supporting internships) as well as a support for collaboration and communication skills (through the use of project-based learning activities). There were not as many mentions in university-level curricula of 21st Century skills. However, there was often a connection to STEM subject areas and digital literacy skills.

The connection in university programs to design-based thinking was particularly strong. As Linton and Klinton (2019) point out "The world of entrepreneurs is a quite different, usually highly uncertain environment, and therefore requires a different type of skill set." (P. 1). If curriculum is going to support people as they aim to take part in this kind of environment, then the curriculum needs to focus on design-based thinking as well as quick iteration. They argue that there also needs to be a focus on teaching students how to establish 'through line' or a parameter that does not change because so much of the entrepreneurial context is dynamic. Thomassen *et al*. (2020) also highlight design-based thinking and argue that, within entrepreneurship curriculum, design-based thinking needs to also involve attention to context. The design process will be shaped by the context, so a focus on the context of the future business or the problem that is being solved or the gap in the market…all of that needs to be linked to the specific context (location, time, culture) for the business idea.

In addition to a focus on design-based thinking, many university programs also focus on creating 'mastery experiences' or experiences where students get to try out some of the skills and processes associated with entrepreneurship. Scholarship by Wardana *et al*. (2020) is particularly helpful in explaining the focus on 'mastery experiences' in university-level entrepreneurship programs. They write that students' mindsets about entrepreneurship are a strong determiner of gaining entrepreneurial skills as well as starting a new business or aiming for innovative opportunities at already-developed companies. When a student has a strong sense of self-efficacy around entrepreneurship as well as a strong sense that entrepreneurship is important and attainable, they are more likely to develop the skills and abilities necessary for entrepreneurship to be successful. Wardana *et al*. (2020) argue: "The findings of this current study indicate that entrepreneurship education successfully influences entrepreneurial self-efficacy, entrepreneurial attitude, and the entrepreneurial mindset. On the other hand, entrepreneurial self-efficacy promotes entrepreneurial attitude instead of the entrepreneurial mindset. Furthermore, entrepreneurial attitude plays an essential role in mediating both entrepreneurship education and self-efficacy toward students' entrepreneurial mindset." (p. 1). They further argue that the curriculum needs to focus on increasing self-efficacy and positive mindsets by providing those 'mastery experiences' that allow students to try out entrepreneurship skills in supported environments. In practice, this looks like supporting more internships, providing more opportunities for simulation activities, and scaffolding more of the skills that go into connecting with, communicating with, and collaborating with others. They write: "These findings suggest that, first, the university needs to change the curriculum of entrepreneurship courses by bringing practitioners as instructors, conducting fieldwork with more compositions than theories in the classroom." (p. 7). Wardana *et al*. (2020) also argue that, if universities were serious about entrepreneurship, they would provide capital for small projects, developed by students, that could become a sustained business. While capital is important, the main point is to provide more opportunities for students to gain real experience with, not just theories about, entrepreneurial practices.

While many studies focus on beneficial aspects of university-level curricula, there are also several studies that elucidate the ways that entrepreneurship education can miss opportunities. For example, as illustrated in the work of Jena (2020) when curricula focuses on skills and ideas, without providing a way to try out the skills or apply the skills in a context, then entrepreneurship education is less likely to make a difference to students' abilities and desires to continue toward entrepreneurial pathways. Both Otache *et al*. (2021) and Voda and Florea

(2019) argue that entrepreneurship programs miss out on opportunities to cultivate entrepreneurial practices if the programs don't include opportunities to hear from and participate with actual entrepreneurs or those who are in already-developed companies that are involved in intrapreneurial projects. Having hands-on experiences, mastery experiences, as well as vicariously learning form others, seem to be key to entrepreneurship programs making a positive difference.

It also bears noting that both Otache *et al*. (2021) and Voda and Florea (2019) pinpoint the need for a pipeline between secondary and tertiary entrepreneurship education programs. Both groups of scholars highlight the fact that developing these skills and mindsets takes a long time, and a more intentional pipeline between secondary and tertiary education could benefit all students.

bridges and divides

Both high school and higher education entrepreneurship education programs have the goal of supporting entrepreneurial mindsets, developing entrepreneurial self-efficacy, developing communication and collaboration skills, and both the high school and higher education programs also put a premium on mastery experiences. Both types of programs support the notion of hands-on opportunities. High school programs are more embedded in their communities and tend to draw on community businesses more than the university programs. Furthermore, high school programs tend to support more 'experimental' opportunities for students to create a business venture without the need or even explicit desire to sustain that business. Students being encouraged to try out a business idea for a set time period was a more common practice in high school curricula.

While there are similarities and differences between the two types of programs, the goals are similar enough that it is odd that there isn't a more common desire to create a pipeline between high school and university coursework and high school and university students. This lack of a pipeline has been called out in the literature. For example, Igwe *et al.* (2021) note that an entrepreneurship pipeline between high school and higher education would benefit both groups and could be accomplished by connecting the curriculum and creating 'beyond the curriculum' or 'extra-curricular' activities that both secondary and tertiary students could participate in as collaborators. Elliott *et al*. (2020) argues that creating a pipeline for STEM-focused entrepreneurship would be particularly helpful to women and underrepresented minorities because the transition between high school and college is often where we lose women and minorities in STEM fields. Megri *et al*. (2021) conducted a study on a group of students from both a high school and a university who collaborated on an Engineering Entrepreneurship project and note that this collaboration created a pipeline between the high school and the university, and created a peer mentoring system that supported students at both the high school and university.

There are many reasons why a pipeline between high school and higher education entrepreneurship programs makes sense. There are many reasons that vertical alignment or even just awareness of the secondary and tertiary curricula could help both levels. However, it is still rare to have this kind of pipeline. In the next section, we will focus on a case of a high school

program and its connections to a university program that might offer some lessons for how the creation of a pipeline might be supported.

connection between college and high school programs

An intrapreneurship training program for electrical and computer engineering students was implemented through an NSF S-STEM grant at an R1 university. The intrapreneurship program was designed to teach students how to be innovative and entrepreneurial within an existing company, since the vast majority of students will not be interested in starting their own company right out of college. The goals of this program include: (1) increasing the number of minority and low-SES students who are trained and aspire to be innovators and attain leadership positions, (2) producing graduates who understand how both company culture and employee activities contribute to new product development, and (3) providing hands-on entrepreneur experiences. The curriculum includes understanding the various ways intrapreneurship is manifested in various companies, how to take initial steps to commercialize a product or service, and hearing from experienced entrepreneurs to better appreciate all the successes and challenges that come with launching a new endeavor. The program includes mentorship, internships, and multiple hands-on activities that guide students toward collaborating on entrepreneurial ideas. Students report an increased desire to be intrapreneurial as they progress through the program.

In a large, urban school district, there is a high school that is dedicated to the support of entrepreneurial competencies and dispositions. This high school focuses on developing skills that would be used in both entrepreneurship and intrapreneurship contexts. The curriculum includes project-based learning activities that bring together core subject areas (Science, Math, Reading, Social Studies) and even elective areas (Art, Music, *etc*.) with projects that are focused on entrepreneurship. This high school has a strong connection to STEM subject areas, and the large majority of students who come to this high school went to an elementary and middle school that were STEM-focused. Projects in the past have both involved redesigning products that the students thought could get better, as well naming gaps that they saw in the marketplace, and trying to develop designs to address those gaps. Students have also iterated on projects they created as younger students where they had to design a product that would have been useful to a character in a novel that they read. The whole school focuses on ways to cultivate creativity, innovative thinking, design thinking, and iteration processes. Additionally, the school creates many opportunities for students to grow and demonstrate collaboration and communication skills. This high school is deeply connected to their community, and actually assigns mentors to each student from the community or a company that supports the community. From the ‘get go’ these students are talking to and working with adults who are involved in starting small businesses, sustaining small businesses, or trying to do innovative things inside companies. The school also guides students toward internship opportunities. The high school curriculum and, in fact, the whole degree process at the school is designed to cultivate competencies and dispositions, as well as networks and mentors, that enable students to be confident in their entrepreneurial abilities once they graduate high school.

The high school program has been in the news, cited in articles in Forbes and The Wall Street Journal, as well as other outlets, where they have highlighted this unique program. The program earned the prestigious NAF (Name a Future) Achievement Designation. In order to earn this designation, schools are evaluated by NAF staff as well as outside experts in innovative

corporations. The evaluation focuses on the curriculum design as well as the quality and quantity of internship or corporate experience that these students are able to accrue. “To reach the Distinguished Level, academies must be operational for four years, participate in work-based learning experiences, build professional relationships and secure internships, undergo site visits, observations, review of student data and complete cross-curricular projects.”(NAF Designation Press Release, 2020). As one journalist noted in a recent article: “’the program’ has a strong commitment to learning through internships and mentorship. Starting in tenth grade, students are supported and advised in looking into the community to find their interest in choosing an internship. They have advisory every morning and every student receives AVID training. There are no sports but instead, the program offers student-run clubs for academics and interest on Fridays. It was evident throughout the building that the program operates as a community or a family, more than a school. In fact, there are regular “family meetings” or restorative practice circles that are student-led and support learners in developing conflict resolution skills.” The journalist continued: “While at the program, we experienced one of our favorite student panels to date. They all shared that the school treats them like a family and makes them feel welcome. They readily express an appreciation for working at their pace and for having personalized options as well as flexible space in the school for learning.” (Midles, 2019). The school focuses on supporting each student with personalized pathways that connect to their interests, connect to the community, and connect them to the workforce. These connections are the backbone of the entrepreneurship activities that provide the ground for these students to learn entrepreneurial competencies and dispositions or mindsets.

Both the college and high school programs are in the nascent stages of creating a pipeline where we collaborate more intentionally on activities and projects. The goal is to create collaboration moments between the two groups of students, as well as a support network among the college and high school faculty. Already, we have learned that discussions about the curriculum are key. Researchers from the university have met with teachers and administrators from the program to discuss possible activities where high school and undergraduate students might collaborate. We have also begun to find ways for mentoring and peer-evaluation to happen across the spaces. We are thrilled with the possibilities.

One of the things that has been harder than expected concerns the need to address different standards in the curriculum. The high school is beholden to very strict standards that are enforced by the state educational agency. The TEKS (Texas Essential Knowledge and Skills) guide all curriculum, so the high school program teachers are accustomed to ensuring that the entrepreneurial activities still address the state standards. The teachers are used to creatin projects that bridge between teaching and allowing students to develop entrepreneurship skills while also ensuring they are addressing the standards around Math, Reading, Language Arts, and other core areas. Meanwhile, the university program is embedded in the Department of Electrical and Computer Engineering, and, as such, is still beholden to ABET standards. The college coursework focuses on intrapreneurial skills and activities within the context of Engineering, and the Engineering discipline is still very much a focus. While TEKS standards and ABET standards do not really conflict, they are different. Thus, it has become important to develop a shared language and understanding around what each program must accomplish. This has been the backbone of the collaborative activities that are planned for the future.

Additionally, the university and the high school have begun to collaborate on project-based learning ideas. Here, too, there have been some tensions around how to create projects that would allow students to develop intrapreneurial competencies while also gaining and leveraging Engineering-specific knowledge while completing the projects. This tension has arisen based on the differences in knowledge domains of the undergraduate students vs the high school students. We are solving this problem, we believe, by creating projects where the undergraduates can act as experts and mentors on the projects of the high school students.

imagining curricular activities together

This partnership between the university and high school is still in the nascent stage. However, to support the development of both mentoring and the creation of a pipeline, we have begun to imagine and develop curricular activities that could be used by both partners and meet the needs of both partners. For example, we are developing a 'mentoring partnership' model where the high school students use Canvas for planning their entrepreneurship projects, and the university students use Canvas for their projects, and the students (both university and high school) meet via zoom once per month to share their 'lessons learned'. Our assumptions are that the university students may have more well-developed projects, but that both groups might learn from each other. In this way, while there would be a chance for 'mentoring' from the university students to the high school students, there would also be the expectation that both groups find ways to offer critical feedback as well as 'cheerleading' for each other's projects.

implications and conclusion

Specific implications, and conclusions thus far, that emerge from this project, include the need to spend more time with each other sharing resources and knowledge about curriculum demands and accreditation / standards requirements. Both teams assumed that, while there might be some overlap in goals and knowledge between high school and undergraduate curricula, there would be many differences in the vocabulary that is used, the specific knowledge that has to be accrued, and the types of skills that need to be acquired. To our surprise, while there were differences in knowledge that was meant to be taught, the vocabulary and skills overlapped more than expected. For example, as we looked at curriculum from an undergraduate Engineering course focused on Entrepreneurship, there was the use of design-based thinking skills, there was the use of the Business Model Canvas Template, there was the focus on collaborative building and developing of an early product model. These same terms, processes, and templates were used at the high school level. The undergraduate course aimed to interweave undergraduate-level engineering concepts as part of the process. The high school course aimed to interweave standards (TEKS) from Math, Engineering, and Physics content areas.

One of the issues emerged when the "deliverables" from the courses was discussed. The undergraduate course focused on a large project that was the primary assignment for the course, with "check-ins" and "presentations" as the other assignments of the course. The high school course also used a large project as the culminating activity. However, there were more scaffolding activities along the way and the large project was not worth as great of a percentage of the total grade. This aligns with the ways that undergraduate and secondary education tends to operate. In many ways these differences are positive and productive. High school students may, in fact, need more scaffolding than undergraduate students. However, the differences in how the

grades were being calculated meant that, as we looked at the possibility of using these courses as points of collaboration between the schools, created barriers to collaboration. Nevertheless, making changes to these courses is being considered.

General implications and conclusions from this project thus far include the need for more research into how these collaborations might work. For example, it is true that many high schools offer college credit through "dual credit" courses where the high school student takes a course, in their own high school, that uses curriculum that is sourced from undergraduate courses. This is most often done in more core content areas such as Math, English, Biology, and more. However, there are opportunities for the creation of dual credit options that focus on Engineering and Entrepreneurship.

There needs to be more research on ways to develop bridges and pipelines between high school and undergraduate engineering entrepreneurship knowledge domains. We believe that there are opportunities for these pipelines and that they should focus on mentorship and project collaboration. While differences in knowledge between the two populations, as well as differences in curricula and knowledge standards create a tension or a barrier for creating these pipelines, we believe these barriers can be overcome.

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