A systematic review of student entrepreneurial failure in engineering education

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A systematic review of the literature on student entrepreneurial failure in engineering education

Abstract:

This paper specifically focuses on a systematic review of research on and pedagogical methods related to failure within the context of undergraduate and graduate entrepreneurial engineering curriculum and programming. The article examines the basis for, methods to teach, and research being done to support the commonly held and repeated beliefs that students learn through failure, entrepreneurs need to persist through failure, and we need to teach our students to fail fast and fail forward.

Systematic reviews of literature enable fields to collate research findings, highlight areas of interest and research activity, summarize areas where various viewpoints and research results are being debated, and identify potential areas of interest for further work to advance a particular field. Systematic reviews also provide a succinct opportunity to summarize the state of the art in a field, providing researchers a base of foundational work to support future advances in the field. Given the rapid increase and interest within colleges of engineering in introducing and exposing students to entrepreneurial curriculum and experiences, and the corresponding increase in research and publication in this space, it is timely to pursue systematic reviews on entrepreneurship within engineering education.

While the importance of learning from failure is often repeated in the literature, this article highlights a glaring lack of research on the topic within the context of engineering education, and pedagogical approaches that are being used to attempt to teach students these concepts.

Keywords: Engineering Education, Entrepreneurship, Failure, Systematic Review

Introduction

University entrepreneurship programs and curriculum have greatly expanded over the past decade, with an increasing number of curricular and co-curricular programs dedicated to entrepreneurship often housed within engineering colleges. The foci of these programs range from teaching basic foundational skills and the entrepreneurial mindset required throughout the entrepreneurial journey to designing programs that allow students to have founder experiences and launch their own business ventures. The intention of these programs is for engineering students to gain a skillset and orientation towards being more innovative and entrepreneurial in their careers once they leave the university, whether they choose to try to immediately start a company or not.

Many of the activities that are designed into entrepreneurship programs, however, result in students experiencing varying degrees of failure with the most extreme case being student-

launched ventures that fail. While entrepreneurship programs typically talk about embracing failure and learning to fail fast, it's unclear what impact these failure experiences have on students.

This paper reflects a study on curricular pedagogical methods used to teach engineering students participating in entrepreneurial programs and ventures about failure and the research being done to advance the community's understanding of how to positively teach students about and through failure. We conducted a systematic literature review of student failure in the overlapping context of engineering education, entrepreneurship, and psychology. The primary research question being explored is: How is failure studied in the engineering entrepreneurship education literature? This research question is broken down into several sub-questions: 1) What theoretical frameworks are used to study entrepreneurial failure in this literature?, 2) How has failure been defined, operationalized, and measured?, 3) What are the research questions that are used to study failure?, and 4) What are the research methods that are used to study failure? The methods used in the systematic review follow recommended practices by Borrego, Foster, & Froyd (2014).

Background

Entrepreneurial education has been rapidly expanding within universities over the past 15 years with colleges of engineering being amongst the most active participants in embedding entrepreneurship into curricular and extracurricular activities (Pittaway & Cope, 2007). Well-developed and theoretically grounded educational interventions have been shown to increase entrepreneurial skills and perception among students (Pittaway & Cope, 2007; Matlay & Caray, 2007; Duval-Couetil & Wheadon, 2013; Duval-Couetil & Rheed-Roads, 2012). Organizations including the National Science Foundation through the Lean Launch Curriculum and I-Corps program, VentureWell through curriculum development grants and their E-Team program, and the Kern Family Foundation through the Kern Entrepreneurial Education Network (KEEN) have provided significant funding to embed and transform entrepreneurial teaching and practice into colleges of engineering (Matthew et al., 2017; Pistrui, Blessing & Mekemson, 2008; Smith et al. 2017).

Entrepreneurship education includes content that can be classified into three categories of business basics, entrepreneurship basics, and entrepreneurial mindset (Kuratko & Morris, 2018). While the first two categories of content are largely skills and tools required for being an entrepreneur including setting up operations, understanding financial statements and lean startup processes, the category of entrepreneurial mindset includes many behavioral characteristics that are believed to be associated with entrepreneurial success such as passion, persistence and tenacity, optimism, and, for the purposes of this paper, learning from failure. Within the context of entrepreneurship education, the concepts of learning from failure, failing fast, and failing forward have been championed as key attributes to entrepreneurially-minded individuals. Developing an attitude that failure is learning and leads to perseverance (Kuratko 2014; Kuratko & Morris, 2018), that tolerance of failure is a key entrepreneurial factor during the growth stage

of a venture (Kuratko 2014), that persisting through and learning from failure are key to creating value (London et al. 2018), and that even when failure occurs the entrepreneur has an opportunity to learn from the experience to improve their chance of success in the next entrepreneurial endeavor (Minniti & Bygrave, 2001) is a desired outcome for those teaching entrepreneurship. Shepherd (2004) points to excerpts from entrepreneurship texts that further support this with, "Businesses fail, but entrepreneurs do not. Failure is often the fire that tempers the steel of an entrepreneur's learning and street savvy" (Timmons, 1999: 47). "In order to succeed one first has to experience failure. It is a common pattern that the first venture fails, yet the entrepreneur learns and goes on to create a highly successful company" (Timmons, 1999: 30). There is evidence, however, that suggests that previously failed entrepreneurs are less likely to survive in their next venture and more likely to experience bankruptcy (Gottschalk, Greene, Höwer, Müller, 2014).

While entrepreneurship programs generally espouse the encouragement of learning through failure and resilience, little is known about how students are being taught about and responding to the failures that they encounter as part of these programs. In fact, while failure is consistently referenced as central to various aspects in entrepreneurship education, there isn't an agreed upon definition of what failure even is to support the consistent reference to its value. Many of the definitions of failure are quite narrowly constrained in reference to business failure. Bankruptcy, for instance is specifically tied to a very definable event for a venture that is commonly used in entrepreneurship literature in reference to failure (Shepherd & Haynie, 2011; Zacharakis, Meyer, & DeCastro, 1999). Bankruptcy represents a clear point in time and has its own legal definition making it a well understood definition for failure (Moulton & Thomas, 1993). Shepherd (2003:318) defined failure such that, "Business failure occurs when a fall in revenues and/or a rise in expenses are of such a magnitude that the firm becomes insolvent and is unable to attract new debt or equity funding; consequently, it cannot continue to operate under the current ownership and management." Similar to Shepherd, failure has also been defined based on "the market" where the test of failure is if revenues sufficiently exceed costs to make the business attractive to continue (Coelho and McClure 2005). These definitions, while very applicable to the broader field of entrepreneurship and make for very clear definitions when doing research, are not applicable to the experiences that most entrepreneurship students encounter during their studies. In addition, simulating experiences that replicate these definitions of failure in the classroom is exceedingly difficult if not impossible.

Others have defined failure less in pure market terms, but are linking failure with the expectations of the entrepreneur. Ucbasaran (2010) add to pure market-related definitions, such as those above, to also define failure as closing down a business because it failed to meet the expectations of the entrepreneur. Reuber and Fischer (1999) go further and eschew any business or financial metric from the definition but speak of failure in terms of "facing major setbacks", which begins to be more relatable for a larger percentage of students experiencing university entrepreneurship curriculum and programming.

When speaking about entrepreneurial failure in the university context, however, an even larger body of work speaks about failure without providing a concrete definition (Korach & Gargach, 2019; Li et al., 2019; Hirschfield, Huang-Saad & Libarkin, 2017; Jamison IV, D, 2017) or implicitly define it as the inability to properly accomplish a given task on the first try (Davis & Beyette Jr., 2017; Shooter & Orsborn, 2013).

Given the large range of contexts and definitions of failure, it is not surprising that educators need to consider that each of these contexts will have a different effect on and importance to students resulting from students own emotions (Shephard, 2004) and the level of self-identity that the student's place on the failure. As an example, it's not surprising that students' self-identity in a 30-minute entrepreneurial in-class activity will be quite different than students' self-identity in a business that they start through a university entrepreneurship center. Huerta (2018) begins to see how students self-identify with various entrepreneurial activities by profiling several students and their journey through curricular and co-curricular university entrepreneurship programming. It is well understood, however, that failure can result in varying levels of stigma. Across multiple frameworks, researchers have found that individuals will go to great lengths to maintain a positive view of self in response to negative attributions of others (Shepherd & Haynie, 2011). This is true looking through the lens of social identity theory (Ashforth and Mael, 1989; Maltby and Day, 2003), impression management theory (Elsbach, 1994; Sutton and Callahan, 1987; Tedeschi, 1981), and narcissism (Brown, 1997). Shepherd and Haynie (2011) point out however that "there is evidence that runs counter to this closely held assumption. Some individuals appear to take actions to reduce others' impressions of themselves, in order to cultivate a negative self-identity. For example, across a series of studies it was found that individuals with a negative self-view: (1) preferred to interact with evaluators who had an unfavorable impression of them, as opposed to evaluators who assumed a favorable impression of the individual (Swann, Stein-Seroussi, and Giesler, 1992; 2) were more likely to opt for separation or divorce from a partner who held a positive view of them than a negative view (Cast and Burke, 2002); and finally (3) were more likely to make plans to find a new roommate when the roommate held a more favorable impression of them than a less favorable impression of them (Swann and Pelham, 2002)." It is also noted that views on this social stigma are vary by culture and impact rates of and interest in entrepreneurship (Geibel, Askari & Heinzel, 2014). In addition, it has been noted when studying students' response to failure in the context of STEM education that considering orientation toward fixed vs. growth mindset of the students has correlation to maladaptive vs. adaptive coping post failure (Henry et. al., 2019), which may provide insight into entrepreneurship education.

Given the growth of entrepreneurship curricular and extra-curricular programs within colleges of engineering or offered to engineering students and the fact that enough time has passed that a sufficient body of literature now exists researching entrepreneurship in the context of engineering education, it is timely to conduct systematic reviews to help academics and practitioners understand and learn from best practices that have been developed. Systematic reviews at a minimum provide context by which future academic contributions can be placed (Borrego, Foster & Floyd, 2016), make important contributions to the evidence base of a

discipline by providing synthesized reviews on important issues or topics (Gough, Oliver & Thomas, 2012) and demonstrate gaps in recent work or highlight areas where a concept is accepted as true but little evidence exists to support it (Petticrew & Roberts, 2006).

If a goal of entrepreneurship educators is to teach students to learn from failure, then it is expected that a body of literature would exist and be accumulating that focus on best practices and research related to how to help students learn from failure. This is particularly true in the field of entrepreneurship where the failure rate of entrepreneurial ventures is so high. This paper attempts to summarize the research, research methods, and pedagogical techniques being used to understand, contextualize and teach students about failure within the context of engineering education and entrepreneurship using the frameworks and learnings above as a guide and base of knowledge from related fields and contexts.

Research Questions

The purpose of this paper is to conduct a systematic review of research on engineering student failure relating to entrepreneurship endeavors. The primary research question to be explored follows: How is student failure studied in the engineering entrepreneurship education literature? Figure 1 provides a graphic description of the literature to be examined in this study. Literature examined in this study focused on the intersection of business (entrepreneurship), engineering education, and psychology. While it is the ultimate goal of the authors to review the literature on student entrepreneurial failure more broadly (such as entrepreneurial failure by science or business students or failure in other contexts such as academics in general), for the purposes of this study, the literature reviewed only relates to the study of failure by engineering students in an entrepreneurial context.

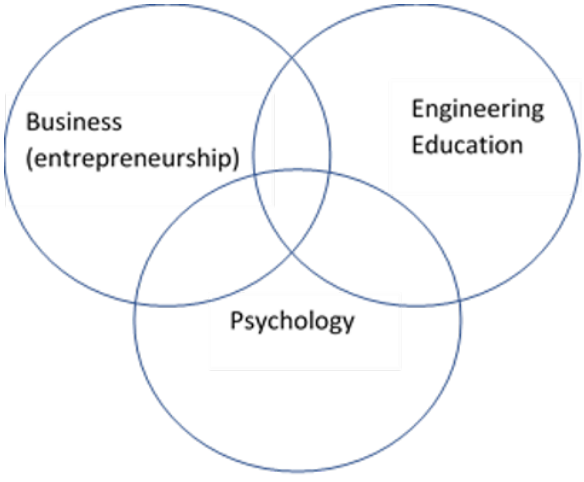

Figure 1: Intersection of the discipline areas to be targeted by the systematic review.

The primary research question is broken down into several sub-questions: 1) What theoretical frameworks are used to study entrepreneurial failure in this literature?, 2) How has failure been

defined, operationalized, and measured?, 3) What are the research questions that are used to study failure?, and 4) What are the research methods that are used to study failure?

Methods:

Inclusion criteria and search strategy

The process of conducting the systematic review followed the recommendations by Borrego, Foster, and Froyd (2014) and Gough and Thomas (2016). The authors developed a set of criteria for inclusion in the systematic review. To be included in the review, articles should:

- discuss failure relating to entrepreneurship in the engineering context,
- be a research study using either qualitative or quantitative methods **OR** be an example of a pedagogical method meant to address failure with some assessment of that method,
- relate to either undergraduate or graduate education (excluding K-12),
- include either faculty or students as either research participants or those involved in the pedagogical method being implemented,
- were published as an accessible conference paper or journal article in the last 20 years (1999 through 2019) which approximately coincides with the timeframe when colleges of engineering began including entrepreneurship in their programming.

Several databases were identified that were included in the initial search. The databases were chosen to be at the intersection of business (entrepreneurship), psychology, and engineering education. These databases were: ABI Info, American Society for Engineering Education (ASEE) PEER, Business Source Premier (Smarttext Search), ERIC, IEEE Explore, and PsychInfo. Descriptions of each of these databases follow:

- ABI Info - database of scholarly work from business researchers
- ASEE PEER - database of publications from ASEE conferences and meetings
- Business Source Premier - business research database funded by EBSCO Industries
- Education Resources Information Center (ERIC) - database of education research sponsored by the Institute of Education Services (IES)
- IEEE Explore - database of materials from computer science and engineering fields sponsored by the Institute of Electrical and Electronics Engineers (IEEE) and the Institute of Engineering and Technology
- PsycInfo - database of peer-reviewed literature in behavioral science and mental health produced by the American Psychological Association (APA)

Assistance was obtained by an engineering librarian located at one of the author's institutions. This librarian ran an initial search of the above databases (with the exception of the ASEE PEER database) using a combination of keywords. The librarian then created a table of searches with the number of records found in each database by the combination of search terms. This initial search helped to provide information on the prevalence of failure research in the various disciplines and to plan the scope of the study. Based on this initial search, the authors decided to narrow down the review to only focus on articles that focused on failure in engineering entrepreneurship education. The keywords that were used in the database search had to include

the terms *engineering education, entrepreneurship,* AND *failure* anywhere in the Subject Terms. Articles also had to be less than 20 years old; the search was performed from October through Mid-November 2019.

The search of the ASEE PEER database used slightly different search criteria, due to the broad use of two of the three search terms. By default, almost every paper published in ASEE is returned under a search of engineering education and an unmanageable number of unrelated papers are returned for the keyword failure because of papers on failure analysis, failure in engineering design, etc. To account for this, the terms *engineering education, entrepreneurship,* AND *failure* had to appear anywhere in the article and the research team decided to only focus on the annual ASEE conference proceedings of the two divisions (Educational Research and Methods and Entrepreneurship & Engineering Innovation). This is a potential limitation of the study, but the authors believe that due to the topical division of papers at the annual ASEE conference, an overwhelmingly large percentage of the relevant papers were identified in the search.

Selection of articles

Articles that were identified using the above search strategy were then subjected to a closer inspection by the authors. Authors reviewed the abstracts of each article and performed keyword searches of the articles from the initial search criteria to identify if it was likely that the terms were used in the context of the methods for inclusion that were discussed above. In addition, this step also identified some articles that were duplicated in the search and duplicates were eliminated resulting in a clean data set for further analysis. All papers that either clearly met the search criteria or the authors were unsure of were passed through this stage of the sorting. A questionnaire that was used by the authors only for the next level of sorting was developed online that would help to determine whether each article met the selection criteria and to gather data to answer the research questions. At least one author completed the questionnaire for each article with approximately half of the articles being reviewed by more than one author. This questionnaire was administered using Qualtrics survey design software with the survey (available in the Appendix A). All articles that at least one author thought were relevant to the research questions for this paper were passed through this level of sorting and findings included in this systematic review.

Figure 2 below shows the successive stages of the sorting process from each database with the associated number of articles that passed the screen criteria at each stage. The most common reason for articles being included in the initial database search, while not being included in this systematic review, was that many articles mentioned or referenced the need to learn from failure in the article, thereby passing the keyword database search, but then did not have any content related to failure experiences, or teachings on failure. A second common reason for articles being included in the initial database search while not being included in this systematic review was that similar to failure, many articles had passing references to engineers in the context of entrepreneurship, but the articles were not about engineers or engineering students.

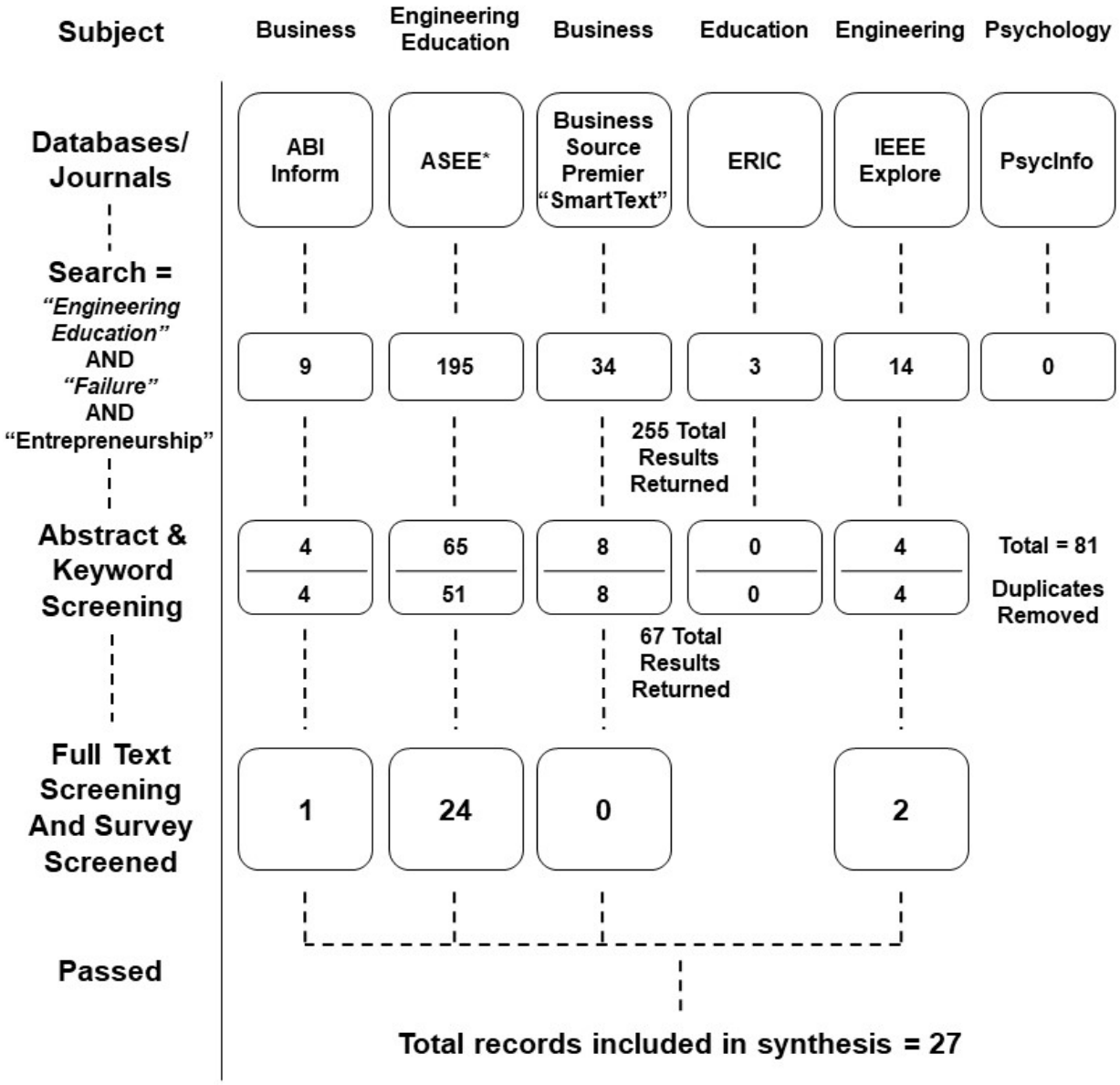

Figure 2: Successive stages of the sorting process from each database with the associated number of articles that passed the screen criteria at each stage

Results

A total of 27 articles were identified that met the criteria. Of these, all but one paper were published in conference proceedings. All but two of the conference papers were published in the proceedings of the ASEE annual conference. The other two articles were published in the co-sponsored ASEE/IEEE Frontiers in Education Conference and the IEEE Global Engineering Education Conference. Figure 3 displays the counts of the articles by year. Only one article was identified prior to 2010; this article is also the only journal article identified.

Appendix B displays details of the 27 articles, including the purpose of the study, the theoretical framework used (if any), description of participants, type of research design and data, and a categorization of whether the primary focus is on failure or another construct. Several key themes relating to the research questions were identified from the coding and analysis of the identified articles. These are discussed below.

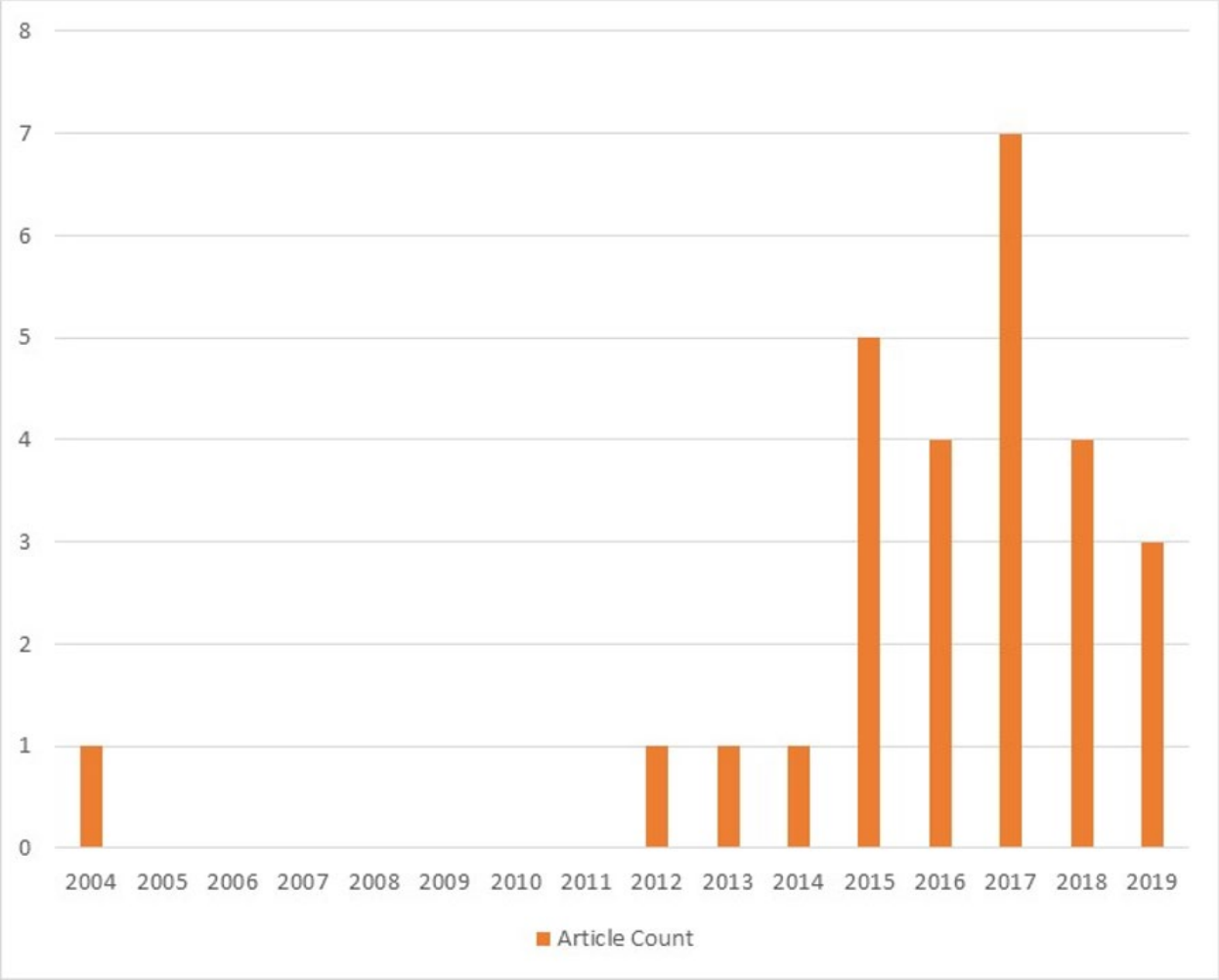

Figure 3: Number of articles identified by year of publication

Key Theme #1: None of the articles specifically focused on failure as the primary construct of interest. The study that most closely approached researching of failure was Huerta (2018), who conducted a qualitative study of engineering students' critical entrepreneurship experiences and their impact. The initial focus of the interview was not specifically on failure, but on entrepreneurship experiences in general. However, the author found that failure was a key experience that students in this context faced. Through interviews, Huerta documents the

journeys of three engineering undergraduates as they face various challenges, such as funding competitions and advancing course entrepreneurship projects.

Some other studies focused on entrepreneurship or innovation more generally, with themes relating to failure emerging in results of the study. For example, Atkins and co-authors (2015) conducted interviews with 60 innovators (including professors, researchers, entrepreneurs, and others) about the experiences that would help students be more innovative. One of the themes that emerged was the need to change students' expectations about failure. Concepts that emerged from the interviews included 1) discouraging the fear of failure, rather than encouraging failure, 2) focusing on the concept that failure is a result of a process or an obstacle and should not be blamed on a person, and 3) the ability to manage risk. Hilliger and co-authors (2017) conducted a similar study of entrepreneurship stakeholders, which included entrepreneurship instructors, researchers, and business leaders. Being able to "persist through and learn from failure" was found to be a competency that the study participants felt was important for creativity and value creation. A survey of engineering capstone faculty asking how they incorporate entrepreneurial practices into their capstone courses indicated just over half encouraged the use of failure or fail forward in the design iteration process (Matthew et al., 2014).

Researchers at the University of New Haven (Li, et al., 2016; Li, et al., 2018; Li, et al., 2019) developed an instrument intended to measure entrepreneurial mindset. This instrument contains several items relating to failure, which they conceptualize as being a part of the entrepreneurial mindset. Again, while these studies and the instrument are not focused on failure per se, they suggest that failure is an important concept to consider for engineering students who are engaged in entrepreneurship activities.

Other studies focused on other primary constructs in their research, such as innovation or the design process. For example, Fila and Purzer (2017) conducted a phenomenographic study studying students' experiences with innovation. While failure was not part of the initial framework or research question, the results of thematic analysis of participant interviews included an emergent theme that "being confronted with failure or persistent tensions supported new perspectives." The authors felt that the students' experiences suggested that "...failure provided a more acute means for participants to arrive at deeper understandings of innovation." In an interview study with three entrepreneurs who taught entrepreneurship, Hirshfield, Huang-Saad, and Libarkin (2017) examined how perceptions of the design process compared to Lean Launch. The interviewees believed that failure and risk, in addition to other constructs such as collaboration and empathy, were integral to Lean Launch. Risk and failure were also things perceived of as being critical in the design process. The authors note that, "the use of a Lean Launch curriculum would allow engineering design instructors to teach and assess important engineering skills...such as...failure." Finally, Wang and Wong (2004) conducted a research study of entrepreneurial interest; the scale that they use includes items relating to perceived risk of failure.

Key Theme #2: Many of the articles we identified are the description and assessment of a pedagogical technique, course, or program. These papers tended to focus on the concept of learning from failure, either as an intended learning outcome or a serendipitous consequence of

an instructional activity. The scope of the activities included small scale exercises, online modules, course projects or larger programs.

Jablokow, Zhu, Matson, and Kakde (2016) asked students in a massive online open course on innovation, creativity, and change (MOOC) to complete the Shoe Tower Exercise, which asked them to build "the tallest free-standing tower" made entirely of shoes. Part of the exercise required the participants to report on their problem solving processes, "including their approaches to and experiences with failure and application of IFF [Intelligent Fast Failure] principles." Data in the article focused on number of attempts (or failures) and how it correlates with their perceptions of perceived beauty of the towers and perceptions of personal creativity. Results suggested that the more attempts/failures experienced by participants related positively to their perceptions of personal creativity. The authors argued that teaching IFF was important for engineering students, "particularly in the context of design and technology-based entrepreneurship." Entrepreneurship was a core part of the MOOC.

Other small-scale exercise to have students learn from failure are discussed by Korach and Gargac (2019), who describe a series of active learning techniques. Some of the techniques include the often-used "Marshmallow tower" experience and a "Fear of Failure" exercise. Activities such as these are intended to help students learn from failure and to understand their own self-perceptions of failure. As another example of an in-class activity, Jamieson (2017) discusses the development of an ideation project to be implemented in a biomechanics course. Interestingly, students' perceptions of their ability to persist and learn from failure decreased on a post-survey. This could potentially suggest that ideation activities may not be the most appropriate instructional technique for students to learn from failure. As another example of an instructional technique found in the literature, Mikesell and colleagues (2015) developed a project-based learning module intended to teach students concepts of sustainability and entrepreneurial skills, by asking students to redesign a product with sustainability in mind. Although one of the learning outcomes of this module was that students would, "persist through and learn from failure," the authors are not explicit on how or why the project-based learning activity would work to meet this goal. A pre/post survey of students who completed the module showed mixed results whether students had more positive perceptions of their abilities to learn from failure. As another example, Shooter and Orsborn (2013) describe an interdisciplinary course on innovation that includes failure as a topic. The authors wanted students to experience failing forward, by participating in a physical challenge where they had to hold a textbook above a table using a limited amount of paper and tape.

A series of related papers on the development of e-learning modules on entrepreneurial mindset are another example of an instructional strategy relating to failure. A team from the University of New Haven (Harichandra, et al., 2015; Erdil et al., 2016) developed a set of online e-learning modules intended to help students attain the knowledge, skills, and characteristics needed to have the entrepreneurial mindset. One of the 18 modules focuses on learning from failure; the module is intended to be implemented in a freshman project planning and development course. The module focuses on providing students with the skills of "accept the possibility of failure, persist in the face of failure, and learn from the experiences to achieve objectives." The authors further

describe the module as intending to increase students' "knowledge to explain the potential risks of failure, i.e. identify what can go wrong, propose solutions that identify how to plan or react quickly to avoid issues that cause a project to failure, and in case of failure, develop strategies to deal with the outcomes." Several activities are embedded in the module including learning from others who have failed, completing reflections, and completing a final exam. Assessment took place in terms of a set of 8 likert-type items about students' perceptions of failure. The authors continue to expand on this work in their work with Erdil, et al. (2017) with a discussion of how these modules were deployed at 25 institutions.

As another example, Gerhart and Carpenter (2012) discuss a summer program incorporating a curriculum focusing on innovation and ingenuity. Learning from failure is one of the learning outcomes reported as being found in their assessment of the program. Jablonski (2014) describes the assessment of a fluid mechanics course where she integrated fast failure activities, with the intention that students will learn from failure. Plumanns, et al. (2019) discusses the development of a workshop intended to foster entrepreneurial thinking in students, with a focus in part on learning from failure, reducing the risk of failure, and conveying a positive mindset about failing.

Key Theme #3: The most common framework guiding the articles was the KEEN learning outcomes.

One of the coding strategies was to identify the theoretical or guiding framework for the research. The most common framework used to study failure stems from the KEEN learning outcomes (KEEN, Retrieved 2020). KEEN uses a framework of the 3Cs (curiosity, creating value, and connections) to define the entrepreneurial mindset. For example, Bernal and co-authors (2017) describe the assessment of a new engineering course taught using an integrated design studio. Students were asked to complete reflections relating to the 3Cs. In reflections on creating value, a common theme that students mentioned concerned learning from failure or persistence through failure. The e-learning modules developed by Erdil, et. al (2016; 2017) as well as the instrument development and subsequent research by Li and colleagues (Li, et al., 2016; Li, et al., 2018; Li, et al., 2019) also use the 3Cs framework as their guiding structure. As indicated in the table in Appendix B, quite a few of the papers identified relied on the KEEN 3Cs structure as the framework guiding their work.

One of the likely reasons for the commonality of the KEEN framework is the number of universities and instructors who have partnered with the organization to develop instructional changes based on the entrepreneurial mindset. For example, Bernal, et al. (2017) explicitly mentions that the course was developed with funding from the foundation.

Key Theme #4: No articles explicitly define failure.

None of the authors for the papers included in this systematic review explicitly defined failure in their papers. No operationalized definitions were identified and definitions used in other disciplines, some of which were contained and highlighted in the background section, were not

adopted in the context of engineering education. Part of the reason for this lack of definition is that failure was typically a peripheral construct studied in the papers.

The context of the student failure as well as its degree (major failure or minor failure) is important to consider. For example, Davis and Bayette (2017) discuss students' failure as it relates to conducting an elevator pitch, which was the focus of an e-learning module they used in a senior capstone design course. The consequences of a failed elevator pitch would be different than a failed student start-up, or a failed in-class exercise. While not explicitly defining failure, Fila and Purzer (2017) distinguished between "persistent tensions" and "acute failures." Persistent tensions may be described as small steps and changes that need to be done to meet an overall goal, perhaps, in our view, analogous to more micro-level challenges that sometimes require the need to pivot in the face of obstacles or challenges. Acute challenges might be considered more "macro-level" failures that may be more emotionally impactful to individuals (such as a student who felt "distressed" at not being able to develop a solution).

In some cases, the authors' conceptualization of failure was unclear. For example, Novick and Kendall (2018) mention "failure immunity" as an activity in their junior-level course sequence in engineering design and entrepreneurship, but do not define failure immunity nor describe the activity. Interestingly, in their description and assessment of a seminar on developing entrepreneurial failure, Plumanns and colleagues (2019) state that "the term failure is interactively defined in collaboration with the participants" of the seminar. However, this definition is not shared.

As research continues to grow in studying failure in the entrepreneurship education context, having an operationalized definition of failure and what constitutes failure, or segmenting failure into different categories to clarify degrees of failure, will be important to reduce construct confusion (MacKenzie, 2003).

Key Theme #5: Methods used in the articles included both qualitative and quantitative studies with a variety of data collection approaches.

Out of the 27 articles identified, there was a mix of qualitative and quantitative approaches. Many of the studies used surveys or rating scales, but often, these were developed by the authors to assess their pedagogical approach or measured other constructs. As an example, Raber, Fraley, and Kemppainen (2018) conducted an assessment of modules relating to innovation and entrepreneurial experiences, using a scale intended to measure entrepreneurial intentions. This scale includes an item relating to students' approaches given the possibility of failure.

No rating scales or other types of instruments were found that explicitly were intended to measure just failure explicitly. For researchers who wish to conduct studies more explicitly targeted at failure, this finding suggests that appropriate measures may either need to be developed or drawn from other disciplines. Instruments that explore students' perceptions of failure, their experiences with failure, and their responses to failure would likely be helpful in furthering research in this area.

Discussion/Conclusions/Future Research Areas

This review provides a foundation of past learning from different fields to determine future research areas and interventions to consider in the area of engineering entrepreneurship education. An obvious conclusion from the systematic review is that the concept of failure has a very limited research base in the area of engineering entrepreneurship education. The studies that were found were often focused on other constructs (such as creativity) or were focused on broader concepts, such as entrepreneurial mindset. This suggests a need that student entrepreneurial failure should be studied in the engineering entrepreneurship education context. Future researchers will need to draw from other disciplines as this is a construct not studied in the engineering entrepreneurship education context.

The papers that focused on pedagogical activities or experiences often discuss failure as an outcome, but there was little evidence of failure from an evidence-guided, research-based perspective being used to develop the activities. Many researchers talk about the need for students to learn from failure, but don't talk about what it is or how to do it.

None of the articles explicitly defines what failure is. The context of failure is very important, as failures can have minimal impact (such as failing the Marshmallow tower exercise) or have major, devastating impact (such as failing at a student-led venture with a lot of emotional or financial investment). Context of failure needs to be studied.

While the research and teaching base of material on failure in engineering entrepreneurship education is limited to date, there are suggestions for teaching about failure from other fields that should be expanded and appropriately adapted to this field. For instance, Shepherd (2004) details a range of specific activities designed for entrepreneurship or MBA courses that provide guidance for engineering entrepreneurship educators. Shepherd outlines methodology and preparation materials for lectures, specific attributes to look for with external guest speakers, specific Harvard Business Review case studies and the context to use them, role-play exercises, and even looks to articles from death literature to have discussions with students on grief. Notably, Shepherd also suggests that some of these classroom activities may be traumatic for the students and assistance from either a professor in psychology or a professional psychologist who specializes in bereavement or trauma would be recommended practice. This in itself, however, raises the question of support from the psychology community that should be considered by entrepreneurship centers that provide programming that results in students directly, as opposed to indirectly, experiencing increasing levels of failure in co-curricular programming.

While the literature on failure is extremely limited in the engineering entrepreneurship education context, we could likely learn much from business and psychology. A future research direction is to conduct a systematic literature review in the broader field of business and psychology, which can be used to inform the engineering entrepreneurship education community.

The authors also note that much of the failure literature from the entrepreneurship field focused on business failure for individuals much older and advanced in their careers than undergraduate and graduate students. While the learning from this material is definitely appropriate to consider in evaluating its application to undergraduates and graduate students, it's important to note that

the two groups have very distinct differences which may affect their response to and ability to learn from the failure event.

While the number of articles on failure seems to be increasing, this is likely due to the increase in the amount of research being conducted in engineering entrepreneurship education. The number of articles published at the ASEE conference focusing on entrepreneurial mindset has increased dramatically in the past decade. Part of this increase in research emphasis also relates to the number of articles found that used the KEEN 3Cs framework to guide their work. With the initiatives and funding being made available to instructors and universities for entrepreneurship education, the impact of KEEN on studying different concepts relating to entrepreneurship education is apparent. That being said, much of the research on entrepreneurship mindset also suffers from construct confusion.

The study does have some limitations. One of these is the use of search terms. A broader search using other words such as "goal persistence" or "risk" might have yielded other articles that fit the criteria of the search. An additional limitation is the restriction of the ASEE PEER search to only the ERM and Entrepreneurship and Innovation divisions. While we feel that most of the work in this area would fall in these divisions, it is possible that we may have missed articles from other divisions that focus on student entrepreneurial failure. Another limitation is that we only focused on the narrow slice of the literature focusing on student entrepreneurial failure in the engineering context. An initial broader search that we have begun has suggested that there is more work on student entrepreneurial failure in other disciplines, such as business. This is a future research step that we hope to take.

In conclusion, student entrepreneurial failure is a vastly understudied construct in the engineering education context. Researchers are encouraged to draw from interdisciplinary contexts in order to expand our knowledge of students' experiences related to entrepreneurial contexts. This research will be helpful to prepare students to learn from failure and to help students recover when they experience acute failures.

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Appendix A: Questionnaire used in article search strategy

Article Information

Title _____

Author (last, first initial, middle initial)

_____

Source (journal/proceedings) _____

Year (articles should be between 1999 and 2019)

_____

Does the article meet the selection criteria? (Criteria for Research Articles)

- ○ **Discusses failure in academic settings**
- ○ **Relates to undergraduate or graduate education**
- ○ **Includes faculty or students as research participants**
- ○ **Research participants are from engineering context**

What is the purpose of the study?

_____

_____

_____

_____

_____

Theoretical frameworks and/or theories used in article:

How do the authors define failure? (Type n/a if authors do not define failure)

Research questions and/or hypotheses presented in article:

Describe the research participants (number, description):

_____

_____

_____

_____

_____

Is the study qualitative or quantitative?

- ○ **Qualitative**
- ○ **Quantitative**
- ○ **Mixed methods**

What instruments are used in the study? (if applicable)

_____

_____

_____

_____

_____

Provide information on the methodology used in the study below:

_____

_____

_____

_____

Major findings as presented in article

Any comments or notes on this article you feel are important to share

Appendix B: Articles Included in the Systematic Review with Various Coding Identifiers

#	Author	Overview	Theoretical Framework	Participants	Research Design	Type of Data	Primary construct or concept studied
1	Atkins, et al. (2015)	Research on innovators' perceptions of the critical skills needed to teach students to be innovative	None	60 innovators including professors, researchers, and others	Qualitative	Interviews	Innovation
2	Bernal , et al. (2017)	Assessment of a new degree program in engineering design which features a studio experience	KEEN	Undergraduate engineering students	Mixed methods	Reflections; Surveys	Entrepreneurial mindset (ase defined by KEEN)
4	Davis & Beyette (2017)	Development and assessment of an instructional module about elevator pitches	KEEN	69 engineering seniors	Quantitative	Rubrics scoring pitches	Student performance on elevator pitches
5	Erdil et al. (2016)	Description and assessment of e-learning modules intended to develop students' entrepreneurial mindset	KEEN	Engineering undergraduate students	Quantitative	Pre/Post survey	Entrepreneurial mindset (includes focus on failure)
6	Erdil, et al. (2007)	Description of the deployment of learning modules at 25 institutions	KEEN	Engineering undergraduate students	Quantitative	Pre/Post survey	Entrepreneurial mindset (includes focus on failure)
7	Fila & Purzer (2017)	Research study examining the ways that students experience innovation	Phenomenography; Non-dualist ontology	33 engineering students (mostly undergraduate)	Qualitative	Interviews	Innovation
8	Gerhart & Carpenter (2012)	Description and assessment of a summer program focusing on creativity, innovation, and ingenuity related to manufacturing	Generative Theory research	20 engnineering undergraduates	Quantitative	Pre/Post survey	Creativity and Innovation
9	Harichandran et al. (2015)	Description and assessment of e-learning modules intended to develop students' entrepreneurial mindset	None	N/A (Plan for assessment of students discussed)	Quantitative	Pre/Post survey	Entrepreneurial Thinking Skills
10	Hilliger, et al. (2017)	Research to examine perceptions of competencies needed for creativity and comparison with ABET criteria	ABET; KEEN	20 entrepreneurship stakeholders (instructors, researchers, business leaders)	Qualitative	Interviews	Creativity and value creation
11	Hirshfield, et al. (2017)	Research to identify similarities and differences between engineering design and Lean Launch	Design process; Lean launch	3 entrepreneurs who teach entrepreneurship	Mixed methods	Interview; Checklist	Lean Launch/Engineering design

12	Huerta (2016)	Explores two research questions: "What are the types of critical entrepreneurship experiences engineering students have? What was the impact of these critical entrepreneurship experiences?"	Critical incidents	3 undergraduate engineering students	Qualitative phenomenogr-aphy; Critical incident technique	Interviews	Entrepreneurship experiences
13	Jablokow et al. (2016)	Description and assessment of a pedagogical technique to simulate Intelligent Fast Failure	Intelligent Fast Failure	Participants of a MOOC	Mixed methods	Task performance ; Rating	Creativity
14	Jablonski (2014)	Description and assessment of open-ended projects that are intended to allow students experience failure	None	Engineering undergraduate students	Mixed methods	Rating scale; Student comments	Entrepreneurial Mindset; Fail Forward
15	Jamison (2017)	Description and assessment of an ideation project	KEEN	18 engineering undergraduates	Quantitative	Pre/Post survey	Entrepreneurially minded learning
16	Korach & Gargac (2019)	Description and assessment of active learning exercises intended to support entrepreneurial mindset development	KEEN	66 first-year engineering students	Quantitative	Survey	Active learning; Entrepreneurial mindset
17	Li, et al. (2016)	Development of an instrument intended to measure the entrepreneurial mindset of engineering students	KEEN	227 first-year engineering students	Quantitative	Rating scale	Entrepreneurial mindset
18	Li, et al. (2018)	Research comparing entrepreneurial mindset for students based on different demographics (year, gender, family background)	KEEN	394 first-year and senior engineering students	Quantitative	Rating scale	Entrepreneurial mindset
19	Li, et al. (2019)	Research on growth in students' entrepreneurial mindset after participating in curricular and extracurricular experiences	KEEN	24 engineering students	Quantitative	Rating scale	Entrepreneurial mindset
20	Matthew, et al. (2015)	Research on how faculty incorporate entrepreneurial elements into capstone design classes	None	225 capstone design faculty	Mixed methods	Survey	Entrepreneurial practices
21	Mikesell, et al. (2015)	Description and assessment of a problem-based learning module on sustainability and entrepreneurial skills	Problem-based learning; KEEN	219 engineering undergraduates	Quantitative	Pre/Post survey	Problem-based learning; Sustainability; Entrepreneurial skills

22	Novick & Kendall (2018)	Description and assessment of a two-course sequence on engineering design and entrepreneurship	None	25 junior engineering students	Quantitative	Survey	"Designing your life"
23	Plumanns, et al. (2019)	Description and assessment of seminar on how to become an entrepreneur	None	109 engineering students	Quantitative	Survey	Entrepreneurial thinking
24	Raber, Fraley, & Kemppainen (2018)	Description and assessment of design-thinking modules into engineering design courses	Design thinking	154 engineering students	Quantitative	Survey	Design thinking
25	Richards (2016)	Description and assessment of course on creativity and new product development	None	Engineering students	Mixed methods	Surveys; Reflections	Creativity
26	Shooter and Orsborn (2013)	Description and assessment of a course on innovation	None	Undergraduates including engineering students	Quantitative	Survey	Innovation
27	Wang & Wong (2004)	Research study examining the level and determinants of interest in entrepreneurship among university undergraduate students in Singapore	None	5326 undergraduate students including engineering students	Quantitative	Survey	Entrepreneurial interest