



Work-In-Progress: Facilitating Engineering Students' Entrepreneurship Through Self-Regulated Learning Instructions

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Abstract

This Work-in-Progress study investigates the implementation of an innovated engineering entrepreneurship education program integrated with self-regulated learning (SRL) practice at a southeastern public university. Entrepreneurship education programs have become prevalent across engineering schools nationally and globally. While SRL demonstrates positive effects on students' learning, little is known about how to integrate SRL in teaching that facilitates engineering students' learning in entrepreneurship. Through a quasi-experimental study, we assume that students who participate in SRL activities will improve their entrepreneurial skillset and mindset and demonstrate improved learning outcomes in an entrepreneurship course.

Research has suggested that SRL is beneficial for students to develop entrepreneurial skills [1]. In other words, effective entrepreneurs regulate their cognition, metacognition, and motivation to adapt to new environments and unexpected challenges, make appropriate decisions, and overcome obstacles, which overlap with the essential elements in SRL [2], [3]. SRL describes a phase-like learning model that includes students' goal setting and planning before a task, strategic actions and monitoring during a task, and self-reflection and evaluation after a task [4]. To understand how SRL plays a role in understanding and fostering engineering students' learning in entrepreneurship, we are conducting an ongoing intervention study that provides students with SRL support in addition to the regular teaching activities. Our main purposes of the study include 1) contextualizing SRL into the entrepreneurship course; 2) providing students with SRL practice to support their learning in entrepreneurship; 3) identifying and assessing the learning and psychological outcomes related to SRL that indicate students' growth in entrepreneurship and entrepreneurial mindset.

The work-in-progress study is the pilot study of the ongoing intervention study. Students receive self-reflection relevance writing prompts throughout the course. The writing prompts are designed to facilitate students' self-regulatory skills in cognition, metacognition, and motivation in a way that cultivates students' learning and application of entrepreneurial knowledge and skills. Specifically, students self-reflect upon their learning experiences related to the topics taught in the entrepreneurship course and potentially form entrepreneur identities from connecting their real-life experiences and the learning content in the course.

Currently, we have started implementing the writing prompts in an introductory entrepreneurship course to test our study materials in Spring 2022. We plan to conduct a full-scale study in Fall 2022. Data include pre- and post- entrepreneurial knowledge familiarity tests, entrepreneurial self-efficacy scales, creative mindset scales, an epistemic curiosity scale, and students' written self-reflection responses. We expect results to show increases in students' learning and the impact of SRL on students' learning in entrepreneurship-related concepts and application through self-reflection in the full-scale study. The findings of this work will demonstrate the impact of SRL in an entrepreneurial learning context using theory-grounded pedagogical practices.

Introduction

The Engineering of 2020 Project envisioned that colleges and universities should foster engineering students' curiosity, creativity, innovation, and leadership and problem-solving abilities to meet the fast-changing world [5]. Along with this vision, the Kern Entrepreneurial Engineering Network (KEEN) calls engineering education for facilitating engineering students to become entrepreneurial-minded individuals who create societal and global value. In response to this call, in addition to teaching students the technical knowledge of engineering, the entrepreneurship education program at our university provides students with curricular entrepreneurship education programs where students gain entrepreneurial knowledge and skills, and resources to pursue an entrepreneurial career path. We aim to not only support engineering students with the resources to start their startup companies but also instill entrepreneurial mindset and self-efficacy into students throughout their learning and creation experiences for any potential career paths. We believe such an effort will create long-term benefits for students' learning and career development. Recently, researchers and educators in our entrepreneurship education program have initiated an ongoing research project on examining and assessing the outcomes of the established curricular programs in entrepreneurship. Notably, we borrowed perspectives from educational psychology and grounded the pedagogical practices in self-regulated learning [4] and the expectancy-value theory [6]. We aim to examine the effect of such pedagogical practices on students' learning and related psychological constructs in the entrepreneurial education program at our university. This work-in-progress study is part of the research initiative. Specifically, we explore and examine the effect of the self-reflective relevance writing assignments on students' entrepreneurial mindset, self-efficacy, and learning outcomes.

In the 21st century, engineering entrepreneurship is not solely about starting and operating companies [7], [8]. The numerous entrepreneurship education programs in the United States and other countries have developed entrepreneurship into a critical subject domain in higher education that focuses on fostering engineering students' academic and professional skillset through the delivery of effective pedagogical practices and the investigation of students' learning processes. Existing systematic reviews suggested that effective engineering entrepreneurship education programs should be able to prepare students with evidence-based entrepreneurial knowledge and skills to become life-long learners [7], [8]. Therefore, to design and implement effective entrepreneurship education for engineering students, the examination of students' cognitive, metacognitive, and motivational processes throughout their learning is needed. Prior research has started investigating the cognitive aspects of entrepreneurship. For example, Mitchell, Busenitz, Lant, McDougall, Morse, and Smith [9] introduced the concept of entrepreneurial cognition, which refers to "the knowledge structure that people use to make assessments, judgments or decisions involving opportunity evaluation and venture creation and growth." Alternatively, entrepreneurial cognition focuses on how individuals learn through processing and connecting information. From a cognitive perspective, for example, when an engineering student learns about customer discovery in an entrepreneurship education course, the student needs to connect the basic principles of customer discovery with their venture ideas so that they can target the appropriate customers. As such, through understanding the cognitive

aspects of entrepreneurship, researchers and educators can facilitate students' learning through explicit instructions that encourage students to connect relevant information with their venture ideas and personal experiences in an entrepreneurship course [10].

Given that the cognitive aspect of entrepreneurship helps to explain students' learning processes, the vast research on self-regulated learning (SRL) has suggested that learning is a complex process, which involves the dynamic interaction among learners' cognition, metacognition, and motivation [11]. SRL refers to a set of cyclical processes that describes learners' learning behaviors and processes before, during, and after a task [4]. Specifically, effective learners should have high self-efficacy, appropriate goals and plans to start a task, use effective strategies during the task, and evaluate and self-reflect upon their task performance after the task. During these processes, students need to have the ability to intentionally regulate their motivation and strategy use to succeed through their cognitive strategy use and metacognitive awareness. As such, this demonstrates the importance of SRL in students' learning in entrepreneurship and the opportunity for researchers and educators to contextualize and incorporate SRL into entrepreneurship education for engineering students.

Accordingly, previous research has shown that self-regulatory skills are beneficial for students to develop entrepreneurial skills [1]. In higher education, given the curricular and co-curricular nature of entrepreneurship education programs, entrepreneurship can be considered as a knowledge-intensive subject that requires students' SRL and instructors' effective teaching instructions. Specifically, under the umbrella of SRL, we can assume that effective entrepreneurs or individuals with entrepreneurial mindset are able to regulate their cognition, metacognition, and motivation appropriately to adapt to new environments and unexpected challenges, make appropriate decisions, and overcome obstacles, which overlaps with the essential elements in SRL [2], [3]. Fortunately, engineering education researchers have initiated the examination of SRL in the context of entrepreneurship education [1] [12], [13] [15], [16]. For instance, Winkler, Fust, and Jenert [12] suggested that entrepreneurial learning involves SRL, such as setting goals and plans, use effective learning strategies, and self-evaluate one's work. For instance, when students make appropriate plans for their entrepreneurial-related tasks and projects, they are regulating their learning in entrepreneurship intentionally and strategically [12]. In addition, students usually form teams to create projects for their startup ideas in entrepreneurship education courses, which requires students to have self-regulatory abilities [1], [16]. For example, students in teams need to have the ability to reflect upon their creation processes and strategy use to make improvement in their ventures [16]. In addition, students need to have high entrepreneurial self-efficacy beliefs as a team to start their ventures [16]. The self-reflection and building one's entrepreneurial self-efficacy are critical self-regulatory processes for individual students as well as for teams. Therefore, given the context of entrepreneurship education, SRL is essential for students to develop entrepreneurship and foster entrepreneurial learning and knowledge.

However, the extent to which SRL can benefit students' learning and faculty and instructors' teaching in entrepreneurship, especially within an engineering education environment needs to be further examined through longitudinal and well-designed intervention studies. In addition, a

critical component of SRL is motivation. Learners’ motivational processes are complex that involve multiple motivational constructs. Previous studies and the expectancy-value theory (EVT) [6] suggested that a self-reflection relevance writing activity has the potential to foster students’ academic motivation and facilitate students to perceive the utility value of the course content and further influence their career choices [17]–[19]. Therefore, in the present study, we adopted the theoretical guidance of SRL to support and investigate students’ self-efficacy throughout the semester. We also adopted the theoretical guidance of EVT to design the writing prompts and examine students’ written responses. We expected that students’ engagement with the SRL practice (i.e., self-reflection relevance writing assignments) in the course would have positive effects on their learning, entrepreneurial self-efficacy, and entrepreneurial mindset.

Theoretical frameworks

The study was guided by Zimmerman’s SRL framework [4]. Specifically, according to [4], SRL includes three phases: the forethought phase, the performance phase, and the self-reflection phase. At the forethought phase, learners make judgment of the task and set appropriate goals and plans. At the performance phase, learners use strategies and other available resources to facilitate their learning and task completion. At the self-reflection phase, students evaluate their task products and gain insights on future similar tasks. Notably, these three phases interact with one another and involve learners’ regulation of their cognition, metacognition, and motivation. In alignment with this framework, we administer three self-reflection writing prompts at the beginning, middle, and end of the semester to foster students’ self-reflective thinking and metacognitive processes in SRL throughout the semester. Fig. 1 displays Zimmerman and Moylan’s SRL framework.

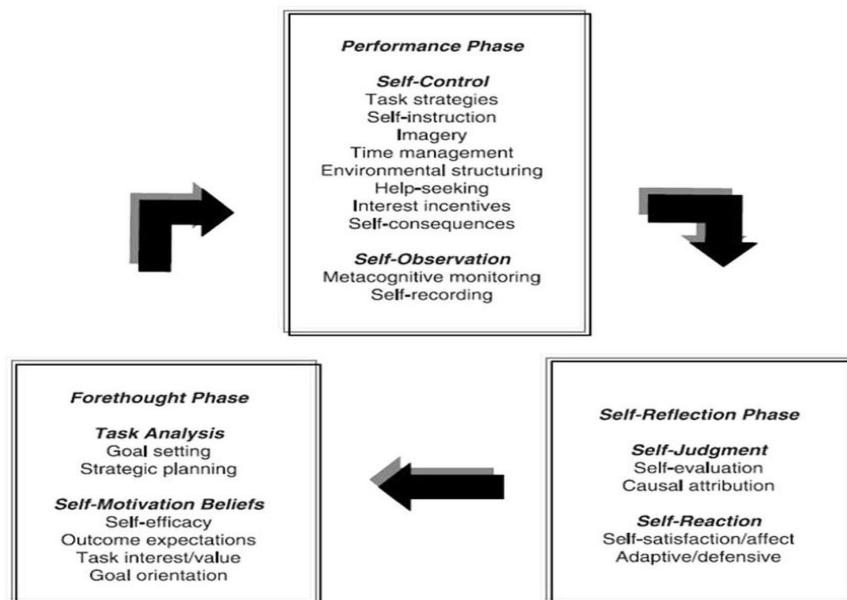


Fig. 1. Zimmerman and Moylan’s SRL framework [4].

Additionally, the study was guided by expectancy-value theory (EVT) [6]. The EVT is a theory in academic motivation, which suggests that students’ motivation or motivation-related activities

are influenced by their expectations and subjective task values. According to the EVT [6], students with high utility value are able to see the connections between abstract concepts and real-world applications and are more likely to be motivated to learn and apply the content topics. One evidence-based approach is explicitly asking students to think about the relevance of certain concepts they learn in a class to their real lives [18], [20]. As such, the self-reflection relevance writing activity in the intervention was designed to potentially increase students' utility value. As a result, students are expected to build connections and perceive the value of learning entrepreneurship, which also corresponds to the entrepreneurial mindset framework by KEEN. In conclusion, we drew theoretical guidance from SRL and the EVT to improve engineering students' entrepreneurial learning, self-efficacy, and mindset through 1) facilitating students to make connections among the concepts learned from the course and their real-life experiences and 2) invoking students' reflective thinking of how the concepts are potentially connected to the real world and the problems they are trying to solve.

Method

Study design

Our target student population is those who are enrolled in a credited and lecture-based entrepreneurship course with several sections. Both undergraduate and graduate students are eligible to enroll. In this course, students learn about the basic principles and knowledge related to entrepreneurship. Currently, in Spring 2022, we have obtained the IRB approval, developed the study materials, and initiated data collection. However, due to the small class sizes in Spring 2022, currently, we are piloting our study materials to gain insights on and prepare for the full-scale study implementation in Fall 2022.

Measures and materials

Familiarity with entrepreneurship

We asked students to rate their familiarity with the content topics that would be covered in the course on a 5-point Likert scale ranging from *Never heard of it* to *Can explain in depth and can apply it*. The key content topics included evidence-based entrepreneurship, business model canvas, business thesis, customer discovery, value proposition, customer segments, hypothesis creation and testing, minimum viable product development, new product development, and product/ service delivery channels. Each topic was one item for students to rate their familiarity. We administered this familiarity scale to measure the extent to which students were familiar with the content topics about entrepreneurship. We also asked students whether they have participated in various forms of entrepreneurial activities. See Table 1.

Entrepreneurial self-efficacy

We adopted and adapted the Entrepreneurial Self-Efficacy instrument developed by [21]. The original instrument included 16 items. We selected 10 out of the 16 items and created two additional items that aligned with the learning objectives and content topics in the course. A sample item was *How much confidence do you have in your ability to identify the need for a new*

product or service. Students rated each self-efficacy item on a 100-point scale with 0 indicating *Cannot do at all* and 100 indicating *Highly certain can do*. See Appendix A for all items.

Epistemic curiosity

We adopted the epistemic curiosity subscale of the Curiosity Questionnaire developed by [22]. Epistemic curiosity refers to the knowledge gap, an unsolved problem, or an unknown fact that drives individuals to learn and know [23]. Given that students enrolled in the course would learn the knowledge related to entrepreneurship, we selected the subscale of the epistemic curiosity intentionally as it fits the learning context students are in. Specifically, the epistemic curiosity subscale included 10 items. Students rated each item on a 5-point Likert scale ranging from *Never* to *Always*. A sample item is *I enjoy exploring new ideas*. See Appendix B for all items.

Creative mindsets

The creative mindsets were developed according to the theory of growth and fixed mindset [24]. To measure students' entrepreneurial mindset, we administered the creative mindsets scales to measure the extent to which students hold fixed or growth mindsets toward creativity [25]. In other words, the scales measured whether students believe that their creative abilities are malleable. Specifically, the scales included 10 items with five items measuring growth creative mindset items and five items measuring fixed creative mindset. Students rated each item on a 5-point Likert scale ranging from *Definitely not me* to *Definitely me*. A sample item was *Anyone can develop their creative abilities up to a certain level*. See Appendix C for all items.

Reflection relevance writing

We provided students with three explicit self-reflection writing prompts at the beginning, middle, and end of the semester. The writing prompts were adapted from [20], [26]. In the prompts, we asked students to make connections with the specific content topic that they learned that week and express how the topic was useful and valuable for their venture ideas or company building. For example, after the course covered the topic of the business model canvas, part of the writing prompt was:

Research demonstrated that when students make meaningful personal connections between the content they learn and their own life, they find the content more interesting, important, or useful, they understand and apply it better.

In this course, we are studying now about the **business model canvas**. How might the business model canvas have relevance to you personally and professionally? How might knowing about the business model canvas be interesting, or important, or useful for you and your future? You can be creative and think of any connection that is meaningful to you. The more meaning the connection is, the more likely it is to contribute to your learning, understanding of it, and application of it in your real life.

In the space below, explain in as much detail as possible: (1) What aspect of the business model canvas do you think connects to your goal, ideation, or future

business? (2) Why and how much is the connection meaningful to you and your startup? (3) Why and how does this connection make you feel confident about starting your company?

As shown, the writing prompt includes three parts. In the first part, we let students know that the writing assignment is supported by research that will support their learning. In the second part, we explicitly and specifically connected the assignment to the specific content topic (i.e., business model canvas) they were learning in the course. In the third part, we provided students with explicit writing points for students to make self-reflection. Students would receive 10 points after completing each writing prompt. Our next step is to establish a coding scheme to identify the themes emerging from students' written responses through qualitative coding procedures.

Course grade

We will also collect students' course grades at the end of the semester to indicate students' academic performance in the course.

Procedures

Overall, the study included three phases. First, at the beginning of the semester, students completed the pre-survey, including familiarity with entrepreneurship concepts, entrepreneurial self-efficacy, epistemic curiosity, and creative mindsets. Second, during the semester, students will respond to three self-reflection writing prompts that were designed to enhance their metacognition and motivation. We would also give students feedback on their written responses. Third, at the end of the semester, students will respond to a post-survey, which will include the same measures as in the pre-survey. In addition, we will also ask students to indicate whether they think the self-reflection relevance writing assignments are helpful for their learning. Due to the limited sample size in the course sections in the Spring semester, we are planning to conduct a larger-scale study following a quasi-experimental design in Fall 2022.

Preliminary results and discussion

We conducted preliminary quantitative and qualitative results based on the data we have collected so far. Specifically, the quantitative data were from students' responses to the self-report instruments and demographic questions. The qualitative data were from students' written responses to the first self-reflection relevance writing prompt that we administered at the beginning of the semester. We plan to further analyze both the quantitative data using inferential statistical analysis and the qualitative data using thematic coding as the study progresses.

Quantitative results

Given the small class sizes (total $n = 50$) in the Spring semester, we reported the descriptive results only below. Currently, 32 students responded to the pre-survey in the beginning students. Among the 32 students, most students ($n = 23$) majored in various schools of engineering, such as biomedical engineering, electrical engineering, mechanical engineering, and industrial engineering. Eight students majored in analytics or data science-related programs. One student did not report their major. In addition, more than students reported male ($n = 18$; 58.1%) and 13

(40.6%) students reported female. One student did not report their gender. In terms of race and ethnicity, four students reported Hispanic/ Latino (12.5%), 15 students reported White (46.9%), 12 students reported Asian (37.5%), and one student reported Black or African American (3.1%). Students' average age was 22.45, SD = 4.61, including both undergraduate and graduate students.

When asking students whether they have any previous experiences or knowledge related to entrepreneurship, most students did not have much experience and were not familiar with entrepreneurship-related knowledge. However, and interestingly, 34.4% of students have experience in developing a product or service before taking the course to learn the knowledge and basic principles of entrepreneurship. Further, overall, students demonstrated low familiarity with the content topics included in the course. Tables 1 and 2 display students reported entrepreneurial experience and knowledge, respectively.

Table 1
Students' self-reported relevant experiences to entrepreneurship.

Question	Yes (N)	Percentage
1. Attending a "Start your own business planning" seminar or conference.	5	15.6%
2. Writing a business plan or participating in seminars that focus on writing a business plan.	4	12.5%
3. Putting together a start-up team.	4	12.5%
4. Looking for a building or equipment for the business.	1	3.1%
5. Saving money to invest in the business.	5	15.6%
6. Developing a product or service.	11	34.4%

Table 2
Students' familiarity with the content topics taught in the course

Key Content Topic	Average familiarity score	Standard Deviation
Evidence-based entrepreneurship	1.97	0.90
Business model canvas	1.94	0.95
Business thesis	2.19	0.97
Customer discovery	2.66	1.10
Value proposition	2.97	1.23
Customer segments	2.74	1.37
Hypothesis creation and testing	3.84	1.20
Pivoting	2.72	1.30
Minimum viable product development	2.78	1.41
New (Agile) product development	2.41	1.27
Product/ service delivery channels	3.06	1.13

Note. The familiarity score for each knowledge item ranged from 1 to 5.

In addition, overall, students reported moderately high entrepreneurial self-efficacy, high curiosity toward learning the relevant knowledge, moderately high growth creative mindset, and low fixed creative mindset. Table 3 displays the descriptive results of the instruments. These

results suggested that students were confident and curious about learning knowledge and basic principles of entrepreneurship in the course. Importantly, students, in general, believed that one's creativity is not fixed and can be developed and fostered through learning, exploration, and support and resources.

Table 3
Descriptive results of the self-report instruments

Scale	Minimum	Maximum	Mean	Standard Deviation
Entrepreneurial self-efficacy	331.00	1178.00	788.31	185.43
Epistemic curiosity	30.00	50.00	42.00	5.61
Growth creative mindset	16.00	25.00	20.81	2.73
Fixed creative mindset	5.00	19.00	12.19	4.25

Qualitative results

As of today, we have collected 33 written responses to the first self-reflection relevance writing prompt and 27 written responses to the second self-reflection prompt. We are currently in the process of analyzing students' written self-reflection responses. The third self-reflection writing prompt will be released in early April.

Before the first writing prompt, students learned about the business model canvas. According to the initial analysis, we found that most students were able to connect their personal experiences and goals with the content topic taught in the class at the beginning of the semester. For example, one student found that the business model canvas can be applied to their job searching. A direct quote from this student is as below:

The position and company would be considered the “customer” and I would be considered the “startup” in this scenario. When looking at positions available, they provide a job description, skill requirements and ask for your resume. This information is useful to determine whether you think you qualify for the job.

As such, we can see that this student was able to transfer the knowledge of the business model canvas to a scenario that is beyond starting a company. The student was able to make connections between the business model canvas and their personal important life event and to see the value of learning about the business model canvas in the course.

Further, students also expressed that they identified the connection between the business model canvas and the ideation of their products or services, used the business model

canvas to explain certain business models, or applied the business model canvas to recognize the difficulties they ran into. See one sample direct quote as below:

...ever since we went after this new idea, we came up with many different obstacles which we still haven't solved, such as establishing a clear market fit. Exactly here is where the business model canvas we are learning in class comes into play. Looking at the customer segments section, we actually haven't reached a niche market fit...

In conclusion, based on the current quantitative and qualitative data, we found that most students were not familiar with the specific content topics related to entrepreneurship in the course. However, students reported high entrepreneurial self-efficacy, high curiosity about learning, and belief in a growth creative mindset, which indicated that students were confident in and curious about learning about entrepreneurship. Additionally, students' written responses showed that the self-reflection relevance prompt potentially fostered students' understanding of the learning content and invoked students' application of the content topic taught in class. The preliminary results showed the potential benefits from designing class activities or assignments based on the theoretical guidance of SRL and EVT.

Future work

Engineering entrepreneurship education is multidisciplinary. This work-in-progress shows our initial efforts in connecting engineering entrepreneurship education with the fields of learning sciences and educational psychology and in grounding entrepreneurship teaching and students' learning in learning theories. Although such connections among fields or disciplines seem to be perceivable, research on the intersection is inadequate. In this work, we connected literature in engineering entrepreneurship education and educational psychology in several ways. First, we were guided by SRL and EVT to design the study and develop study materials. Second, we adopted and adapted established instruments in educational psychology to measure students' curiosity and creative mindset, which also corresponded to the entrepreneurial mindset framework by KEEN. Further, we drew conclusions based on SRL and EVT to gain insights on effective pedagogical practices in the entrepreneurship education program at our university. We plan to further analyze the data being collected in Spring 2022 and conduct a full-scale study to systematically examine the effects of the SRL components in teaching on students' learning processes and outcomes, motivation, and entrepreneurial skills and mindset. With the data collected in Spring 2022, we also plan to examine students' self-reflection within each team. We are interested in examining the extent to which self-regulatory elements are demonstrated by each team and how the self-regulatory elements affect their teamwork. Examining the intersection of SRL and engineering entrepreneurship education may guide future curricular change and assessment development and approaches in engineering entrepreneurship education programs.

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Appendix A: Entrepreneurial self-efficacy scales

Rate your degree of confidence in following items by recoding a number from 0 to 100 using the slider below.

0 = Cannot do at all, 50 = Moderately can do, 100 = Highly certain can do

How confident are you that you can

1. Brainstorm (come up with) a new idea for a product or service.
2. Identify the need for a new product or service.
3. Design a product or service that will satisfy customer needs and wants.
4. Estimate customer demand for a new product or service.
5. Determine a competitive price for a new product or service.
6. Estimate the amount of start-up funds and working capital necessary to start my business.
7. Design an effective marketing/ advertising campaign for a new product or service.
8. Get others to identify with and believe in my vision and plans for a new business.
9. Network – i.e., make contact with and exchange information with others.
10. Clearly and concisely explain verbally/in writing my business idea in everyday terms.
11. Pitch your ideas to potential investors.
12. Use various resources to overcome obstacles in your business.

Appendix B: Epistemic curiosity scale

1. I enjoy learning about subjects that are unfamiliar.
2. It fascinates me to learn new information.
3. I enjoy exploring new ideas.
4. I like to learn something new and find out more.
5. I enjoy discussing novel concepts.
6. When I see a complicated piece of machinery, I ask someone how it works.
7. I like to solve new kind of arithmetic problem and enjoy thinking about solutions.
8. When there is an incomplete puzzle, I try and imagine the final solution.
9. I am interested in discovering how things work.
10. When there is a riddle, I am interested in trying to solve it.

Appendix C: Creative mindsets scales

1. Everyone can create something great at some point if they are given appropriate conditions. (Growth Mindset)
2. You either are creative or you are not—even trying very hard you cannot change much. (Fixed Mindset)
3. Anyone can develop their creative abilities up to a certain level. (Growth Mindset)
4. You have to be born a creator—without innate talent you can only be a scribbler. (Fixed Mindset)
5. Practice makes perfect—perseverance and trying hard are the best ways to develop and expand one's capabilities. (Growth Mindset)

6. Creativity can be developed, but one either is or is not a truly creative person. (Fixed Mindset)
7. Rome wasn't built in a day—each creativity requires effort and work, and these two are more important than talent. (Growth Mindset)
8. Some people are creative, others aren't—and no practice can change it. (Fixed Mindset)
9. It doesn't matter what creativity level one reveals—you can always increase it. (Growth Mindset)
10. A truly creative talent is innate and constant throughout one's entire life. (Fixed Mindset)