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A Qualitative Analysis of Student Learning After the Completion of Maker Education Programs: Influences on the Choice of Engineering Majors*

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The aim of the study was to analyze the learning growth of students who previously underwent maker education training and to investigate the factors that influenced their decisions to choose engineering majors. The research focused on tracing the learning trajectory of each student from the completion of the maker program to college admission. Ten college students majoring in engineering disciplines were interviewed. A phenomenographic and qualitative research method was adopted. The research findings confirmed that computational thinking and engineering design skills, emphasized in maker education, had a positive influence on the learning performance of students in subsequent technology-related courses. Furthermore, experiences in maker learning reinforced the determination of students to choose engineering majors.

Keywords: maker education, qualitative study; phenomenographic research; engineering major; education reform

1. Introduction

Since 2014, the Engineering Education Research (EER) Lab at the National Pingtung University of Science and Technology has promoted the teaching of engineering epistemology [1]. Within the scope of engineering epistemology, elementary students have been shown through their drawings to incorrectly perceive engineers [2]. Emerging technologies can be used to enhance knowledge of fundamental engineering concepts among elementary students [3]. Furthermore, studies have indicated a moderate level of understanding among elementary science teachers regarding engineering education [4]. These findings underscore the potential for enhancing conceptions of engineering education through targeted learning strategies, irrespective of participant demographics.

In exploring engineering learning mechanisms, our focus shifted to science, technology, engineering, and mathematics (STEM)-based maker education. Tailored after-school maker programs, inspired by various engineering disciplines, were created to foster hands-on learning experiences for students. These experiences were structured around various project-based scenarios. For example, in the Robot MakerSpace program, elementary students assumed the role of junior electrical engineers and conceptualized and executed engineering projects [5]. Similarly, mechanical engineering design activities were central to the Drone Maker Program [6], and a computer engineering program encouraged students to develop programming games aligned with their learning goals [7]. To date, more than 150 elementary students have engaged in our maker programs, and our programs have yielded positive and promising research outcomes.

In 2020, we led the publication of a special issue focusing on maker spaces in engineering education for the *International Journal of Engineering Education* [8]. This publication highlighted global scholarly perspectives on the empowering potential of maker education in nurturing the engineering design thinking and professional development of students. However, it raised a question about the extent to which students sustain engagement with maker learning activities, within and outside of school, after completing maker programs. Traditionally, educators have focused on in-class learning analytics. However, career development and learning trajectories of students after educational training, such as educational experiments, have not been a primary focus.

The current study, conducted by the EER team, aimed to trace the learning journeys of students who had completed engineering training in the maker education programs. Collaborating with elementary school administrators, we reconnected with several college students who had previously participated in the maker programs. These students had disengaged from maker learning for 6 years.

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Subsequently, we selected 10 college freshmen majoring in engineering disciplines for in-depth interviews. The primary goal was to chart their educational progression from completing the maker program to their college admission. Specifically, the research sought to answer the following questions:

1. What did the students think about maker education?
2. What STEM-related learning experiences did the students have in and outside of school?
3. How did the students react to the technology education curriculum in high school?
4. What influenced the decision of students to choose engineering as their college major?

2. Theoretical Foundations of Maker Learning

In 2018, educators in the field of learning sciences introduced an expansive concept of maker education in the publication *How People Learn 2*. This concept emphasizes that engaging in the act of making motivates students to create their own knowledge by developing practical applications [9]. According to Chou [5], maker learning is grounded in three educational philosophies: Papert's constructionism theory (emphasizing making), Dewey's experiential learning approach (focusing on doing), and Montessori's educational methods (focusing on playing). Thus, the philosophical core of maker learning involves learning through making, doing, and playing.

Maker learning aligns with the theory of project-based learning due to its emphasis on project development. Krajcik and Blumenfeld [10] identified five key features of project-based learning:

1. Driving questions: Student learning originates from real-world contextual questions. For example, students might develop a solution to air pollution problems by using their learning resources.
2. Situated inquiry: Students investigate problems within the learning context, applying existing and newly acquired knowledge. An example includes using knowledge of electronic sensors to explore the feasibility of air pollution detection.
3. Collaborations: Students collaborate with peers to identify optimal solutions. A case in point is discussing the programming structure of electronic sensors with classmates.
4. Technology tool utilization: Students use onsite instructional tools to aid in solving problems during the design process. An example is using a three-dimensional (3D) printer to create sensor cases.
5. Artifact creation: Students test product prototypes to see if the design problems have been resolved. For example, student makers assemble a $PM_{2.5}$ sensor for air pollution detection.

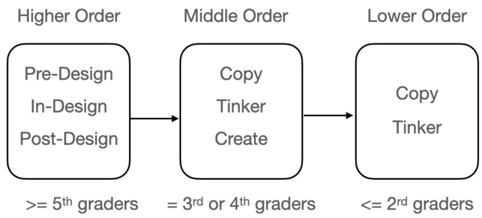

Fig. 1. Three instructional models of maker learning.

The aforementioned theoretical foundations have increasingly shifted toward a conceptional framework. Consequently, we have developed three practical instructional models to aid in the enhancement of the teaching methodologies used by instructors [5–7]. The first model, comprising predesign, design, and postdesign stages, is suitable for upper-grade elementary students. During the predesign stage, students replicate designs presented by teachers. In the design stage, they substantially modify the teacher's designs, infusing their own creativity. In the postdesign stage, students share their work, engage in reflective learning through peer feedback, and explore innovative ideas.

To accommodate the cognitive development of middle-grade students (third and fourth grade students), the first teaching framework was simplified into a three-stage model: copy, tinker, and create. Initially, in the copy stage, students replicate the teacher's work for learning. In the tinker stage, they modify the teacher's work for further learning. Finally, in the create stage, students develop individuated works, drawing inspiration from the teacher's examples. However, for lower-grade elementary students, a third model decreases the cognitive complexity further, consisting only of the copy and tinker stages. Fig. 1 illustrates the differences among these three models.

3. Research Method

3.1 Research Design

The study adopted a phenomenographic research method to examine the past learning experiences of students. Phenomenography, a novel qualitative research approach, enables researchers to investigate common and diverse experiences of participants in maker learning scenarios [11]. This method also assists in the generation of more objective and scientific results (i.e., figures or tables) from qualitative data [12].

3.2 Research Participants

The study adopted purposeful sampling [13] to recruit students who had previously participated in maker programs. Ten college students (seven men and three women) majoring in engineering disciplines were selected for interviews. According to Sediman [14], although qualitative interview samples can be freely chosen, they must reach data saturation. In this study, ten participants were deemed a sufficient number to provide rich information regarding the past learning experiences of the engineering students.

3.3 Research Instruments

In-depth interviews were the primary data collection method for a phenomenographic study [11, 12]. The study adopted a one-on-one interview format, with each interview lasting between 1.5 and 2 hours. A semi-structured interview guide (Table 1), based on Diehm and Lupton's [15] phenomenographic framework, was developed to streamline the interview process. The validity of this guide was confirmed by three educational experts.

3.4 Data Trustworthiness

The study employed four strategies to ensure the trustworthiness of the qualitative data [11]:

1. Data verification during interviews: During in-depth interviews, participants were requested to present relevant materials, such as their status in technology learning, to corroborate their statements.
2. Transcript checking: Following the transcription of the interview recordings, three research assistants sequentially cross-checked the transcripts against the audio recordings to ensure consistency.
3. Member checking: Interviewees received the transcripts to confirm their accuracy in reflecting the original interview content.
4. Category consistency: Once qualitative data were categorized to a certain extent, the research team conducted a dialogic reliability assessment to ensure that the classification of the research results aligned with research requirements.

3.5 Data Analysis

The study adopted Forster's [12] seven-step phenomenographic research analysis method to examine qualitative transcripts:

1. Familiarization: Researchers carefully and repeatedly reviewed the interview transcripts to understand the verbal expressions of the interviewees.
2. Condensation: Irrelevant information was eliminated from the transcripts, leaving only key phrases.
3. Comparison: All selected key phrases were collectively analyzed to identify differences.
4. Grouping: Similar key phrases were grouped together.
5. Articulation: Each group was described in detail to highlight critical meanings.
6. Labeling: Labels were assigned to each group to encapsulate key concepts.
7. Contrasting: Similarities and differences among the groups were clearly delineated.

4. Results and Discussion

4.1 Qualitative Findings

Through the analysis of qualitative data, several themes emerged, each supported by representative quotations:

Theme 1: State-of-the-art experiences

All surveyed students reflected positively on their experiences with technology tools in maker education programs. Although some students could not

Table 1. Semi-structured interview guide

Item	Interview Questions
1	What is your understanding of engineering design?
2	How do you define "maker"?
3	Please describe your past experiences with maker education and training.
4	Can you outline your problem-solving process during past experiences in maker learning?
5	Please describe the classroom learning experiences that are most relevant to maker education.
6	How has maker training, especially in engineering design, influenced your learning experiences?
7	Please describe the differences between maker education and traditional learning methods.
8	What is your perspective on the teaching processes and strategies used in traditional courses?
9	How do you perceive the concepts of learning through failure and developing problem-solving skills in maker education?
10	What are your thoughts on the current technology learning plans in schools?

recall specific course content, they vividly remembered using various technologies, such as 3D printers and laser cutters. Many students, in their subsequent educational journeys, began to engage more with these technological tools. They viewed the maker education activities as innovative, positioning them at the forefront of technological advancement. For example, one male student said, "When I entered middle school, I realized that I was one of only a few students who had ever used emerging technologies. My teacher even asked me if I had taken computer classes outside of school." Similarly, one female student stated, "Most of my classmates at senior high school wondered why I was so familiar with the 3D printer. They were shocked to learn that I had used a 3D printer several years earlier."

Theme 2: Outdated technologies in high schools

Although most students fondly remembered their past use of technology, some expressed disappointment with the technological facilities in their former schools. Students had expected that their school's technological equipment would be modern; however, they instead found that during their high school years, the available maker tools were notably insufficient. For example, one male student jokingly said, "I used various educational robotics in the maker education programs when I was a sixth grader. I expected that I could try more advanced tools one day at my high school. However, schoolteachers only showed us a limited number of basic educational robotics, which I had already used before." Another female student took the 3D printer as an example and stated, "The school's technology tools were really limited; in our junior high school, we only had one very old 3D printer, and it often broke down. Every time I wanted to create a product, I had to wait a long time to use it."

Theme 3: Maker learning outside of school

More than half of the students expressed that after participating in maker education, they requested assistance from their parents in finding similar extracurricular courses. Although some parents assisted in their children's enrollment in technology classes outside of school, others were deterred by the high costs involved. However, those students who did enroll in these technology classes found the course content substantially different from their previous learning experiences. Consequently, many students discontinued their participation after approximately one term. For instance, one male student recounted how his parents had enrolled him in an extracurricular robotics course following his maker training. However, after a few months, he lost interest and ceased attending, having expected the course to be similar to his maker education experience.

Theme 4: Criticisms of traditional classroom education

Students frequently criticized traditional classroom education, perceiving it as monotonous and rigid. One male student expressed deep frustration with general education, lamenting its lack of engagement compared with the interactive and enjoyable nature of maker education. Additionally, students felt that maker education introduced engaging and innovative topics that made them want to continue learning. Conversely, they viewed traditional education as overly focused on exams and repetitive daily routines. A female student remarked that traditional teaching often involved memorizing textbook content and completing paper-and-pencil assessments, which she found tedious. Despite these sentiments, students generally remained compliant and respectful with their school's curriculum.

Theme 5: Frustration with technology education in schools

Although schools offered various technology courses, students believed that past maker education programs provided more in-depth exploration of specific technology topics. School courses often adopted a standardized approach with limited technological content. For instance, a female student mentioned, "The public education system did not provide diverse teaching tools; at most, a few electronic or 3D printing tools were available. An extensive array of tools, such as that provided in maker education programs, was not provided." She emphasized that maker education provided a diverse array of robots, appealing to different interests. Another male student reflected that even in his university courses, the variety of robot teaching tools was limited, with such diversity only encountered in previous maker education courses.

Theme 6: Learning in school clubs

Many students, participating in after-school or on-campus computer and robotics clubs, found the teaching methods notably different from their past maker learning experiences. Playful learning, a hallmark of maker education, was absent in these clubs. Students felt that traditional teaching methods were being used in the clubs, substantially dampening their enthusiasm for learning robotics or programming. Furthermore, the instructional content and tools in these clubs were less diverse compared with those in maker education programs. For instance, according to one male student, "The school computer club was really just for show; it could not compare to maker education, and the teacher was very strict. If you made a mistake in coding, they would loudly scold you." According to a female student, "Even though the club's teaching was outdated, I still immersed myself in my learning, regardless of the teaching style."

Theme 7: Computational thinking skills

Upon advancing to junior and senior high schools, students were required to enroll in programming courses. Because of their previous engineering and maker training, they were able to apply their learned computational thinking skills to the courses in their junior and senior high schools, completing required projects with ease. For example, a female student said, "In the information technology class, I demonstrated the problem-solving methods I had learned before, such as algorithm flowcharts. My programming speed was faster than my peers, and as a result, I often had to assist other classmates in debugging their programs." A male student said, "What impressed me the most in junior and senior high school programming classes was that my programming writing speed was faster than my classmates. I was often assigned by the teacher to guide other students. When the teacher asked me why I was familiar with related programming concepts, I replied that I had learned it in maker education!"

Theme 8: Engineering design skills

With the introduction of a new technology curriculum in Taiwan, students who had undergone maker education found strength in junior and senior high school technology courses. They applied the engineering design principles learned in their studies to their current coursework. For example, a male student said, "The technology course in junior high school began teaching 3D printing. Before the teacher provided instructions, I applied the engineering design principles I had learned previously. I continuously experimented with and refined 3D modeling designs, eventually identifying the optimal design approach." Another male student said, "The most profound effect of engineering design was the problem-solving approach. When faced with challenges, I approached them like writing programming code, attempting to break down complex problems into smaller ones, and then determining the best strategy."

Theme 9: The maker effect

The students, having been selected for maker learning programs through a screening process, exhibited a learning style more inclined toward maker-oriented approaches compared with their peers. Maker training further accentuated their learning characteristics. For instance, a male college student said, "I enjoyed creating projects by hand, and whenever I had free time, I searched the Internet for interesting things to learn. I believe that maker training is not only additive but also synergistic and that it enhances my personality traits." A male junior high school student said, "Although maker training might have some degree of influence, individual personality traits are also influencing factors. Perhaps both have an effect, but the degree of influence is roughly equal."

Theme 10: The definition of a maker

Students reflected on their experiences in maker education, initially perceiving it as synonymous with practical hands-on activities or using technological tools for specific projects. However, it was not until their junior and senior high school technology courses that they began to comprehend the true essence of maker education. This essence involves utilizing engineering design and computational thinking for problem-solving and with learning from the experience of failure. For instance, a male student said, "It wasn't until high school that I truly grasped the definition of maker education. It was only then that I understood why we had to continually revise failed projects in our previous maker learning experiences." A female student said, "I only learned about the principles of failure learning and engineering design when I took technology courses in later stages of my education. I still remember facing obstacles during the simulation of programming robots, and tears would come every time I encountered failure. However, my teacher consistently encouraged me not to give up."

Theme 11: Toward career goals

The students consistently expressed a preference for STEM courses from a young age, especially those with practical applications, and expressed less interest in literature and art subjects. By high school, they had all opted for the science track. They attributed this choice to their early exposure to maker education, which not only enhanced their imagination regarding future careers but also made the pursuit of engineering more tangible and appealing. For example, a male college student said, "The robotics training I received in the past set a clear goal for me in high school to become an electrical engineer in the future." A female student said, "I have had a STEM-oriented mindset since childhood, and after undergoing maker training, it further strengthened my pursuit of STEM learning. I aspire to become a computer engineer in the future."

These qualitative themes are summarized in Fig. 2. Overall, in comparison to traditional formal school instruction, students expressed a strong preference for their past maker education experi-

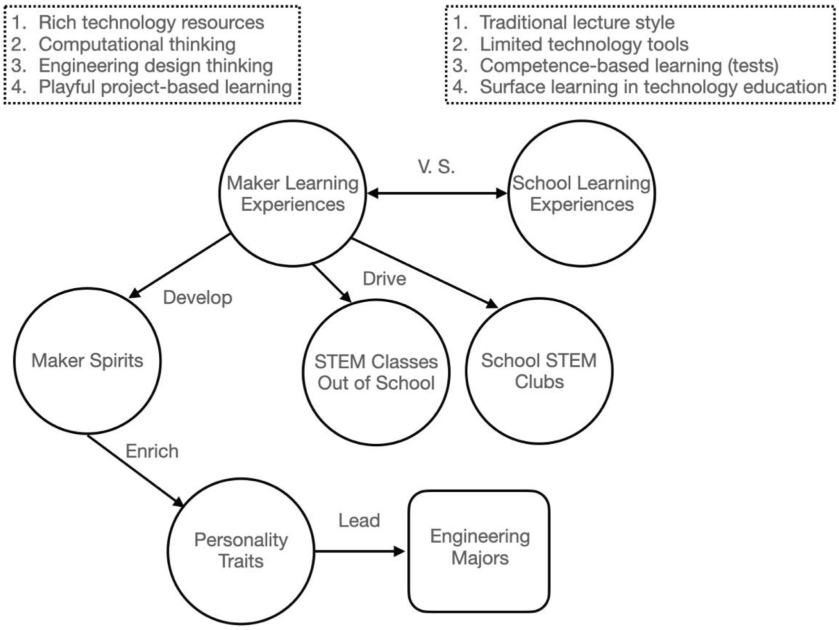

Fig. 2. Summary of phenomenographic analysis.

ences. Following their completion of maker learning programs, they actively sought additional opportunities for maker education both inside and outside school settings. This prolonged immersion in maker education cultivated a maker spirit within them, indirectly deepening their aspirations in engineering. Ultimately, this learning pathway led students to choose engineering disciplines as their field of study.

4.2 Overall Discussion

1. Perceptions of maker education among students (RQ1)

The students perceived their maker learning experiences in a more positive and optimistic light than they did their experiences under traditional teaching methods. This perspective may stem from cultural influences [16]. Following a year of maker education, where the students engaged with various advanced technological tools and embraced contemporary thinking skills, such as computational thinking and problem-solving and engineering design thinking, students were inclined to critically assess traditional teaching methods.

Initially, students tended to perceive maker education as the application of technology (e.g., educational robotics) or practical exercises (e.g., project creation), understanding it at a basic level. However, as they advanced in age and encountered courses related to maker education (e.g., school technology classes), their comprehension deepened. They began to grasp substantial aspects of maker learning, including engineering design, learning through failure, project-based learning, computational thinking, and problem-solving. An explanation for this phenomenon is that students connected their prior knowledge with new learning points in these related courses [17].

2. Other STEM-related learning experiences of students inside and outside of school (RQ2)

After completing maker training, students often sought out instructional activities related to maker learning. Outside of school, this included enrollment in technology talent classes, similar to cram schools. Despite the high costs, many students convinced their parents to enroll them in robotics courses. However, these courses often turned out to be rigid and unengaging, leading to eventual disengagement. The technology talent classes did not align with their expectations of maker learning, resulting in disillusionment for many students.

Due to the availability of extracurricular computer and robotics clubs in both elementary and high schools, students actively enrolled in these clubs. Nonetheless, as they participated in these clubs, they evaluated the teaching processes through the lens of their maker learning experiences. Many perceived the traditional teaching methods to still be prevalent in these clubs, diminishing their enthusiasm. Moreover, the curriculum often focused on a narrow range of technological tools, limiting the learning experience. Despite these challenges, students persisted in these club activities, seeing them as opportunities to revisit concepts from maker education programs.

3. Responses of students to high school technology education curriculum (RQ3)

Following the implementation of Taiwan's new educational policy, the 108 Curriculum Guidelines, students had the opportunity to enroll in technology education courses previously unavailable. These courses elicited mixed emotions among students. Students criticized the hardware equipment and instructional design of these courses. They perceived the level of technology education in junior and senior high schools as elementary, noting a substantial disparity from their experiences in maker learning. For example, maker education featured small class sizes, playful learning, and various robotics explorations, whereas the technology education tended to focus more on exploring basic robotics concepts.

The acquisition of substantial computational thinking and engineering design skills by students [5–7] enabled them to excel in assignments for technology courses. Their outstanding performance often surprised both teachers and peers, prompting inquiries about their previous course experiences. Although students found technology courses in junior and senior high school relatively straightforward, their past learning experiences instilled a confidence in expressing their abilities. This confidence led to recognition from peers, further reinforcing their determination to pursue engineering careers in the future [18].

4. Factors influencing the choice of college majors by students (RQ4)

This study, adopting a qualitative exploratory approach, could not quantify the primary factors influencing the choice of engineering majors by students (i.e., quantitative causal effects). However, the interviews revealed three major contributing factors. First, during the initial selection for maker education courses, students exhibited a strong interest in technology and excelled in hands-on activities. Many had played with LEGO bricks since childhood, reflecting inherent personal traits. Second, a solid foundation in mathematics, often their strongest subject from an early age, became a critical driver for pursuing engineering majors. Third, engaging in maker learning allowed students to fully leverage their abilities. The emphasis on computational thinking, engineering design, project-based learning, and problem-solving strategies in maker education played a supportive role, reinforcing their suitability for engineering careers.

Additionally, most students came from families with a high socioeconomic status, where parents were university professors, executives, or senior engineers. These students grew up in secure environments with parents providing financial support. When these students expressed interest in maker training, their parents were supportive and encouraging, hoping that such activities would help their children discover their strengths and carve their life paths. Therefore, the supportive home environment served as another factor influencing their choice to pursue engineering majors [19].

5. Research limitations

Because of the nature of qualitative research, the study findings may not be generalizable to other research contexts or learning environments. Nevertheless, the research presents several implications for future studies. First, the emphasis on resilience and learning from failure within maker education highlights the potential for studies that examine the development of perseverance among students who have undergone maker training. Second, this study did not address the academic performance of students. Future research may analyze their grades in mathematics and science subjects, as well as their performance in technology courses. Third, the limited sample size of this study and the lack of exploration of gender differences in engineering warrant further investigation. Future research may analyze performance differences in engineering design among maker students from a gender perspective. Finally, future research may examine the postgraduation employment status of students who have undergone maker training, assessing whether they have maintained their initial aspirations to pursue engineering careers.

5. Conclusion

This study aimed to analyze the learning growth of students who had previously undergone maker education training and to investigate the factors influencing their decision to choose engineering majors. We found that students, initially perceiving maker education as basic technology application or practical exercises, later developed a deeper understanding of engineering design, learning through failure, project-based learning, computational thinking, and problem-solving. After maker training, students sought maker-related instructional activities but were disappointed by costly and rigid technology talent classes, leading to disengagement. Despite challenges in extracurricular computer and robotics clubs, students persisted, using them as opportunities to revisit concepts from maker education programs.

Following Taiwan's new educational policy, students excelled due to acquired computational thinking and engineering design skills from prior maker learning experiences, fostering confidence and determination to pursue engineering careers. The study also revealed that in deciding on a university major, the cumulative effects of past maker education synergistically reinforced the determination of students inclined toward mathematical and scientific learning to choose engineering majors. These findings contributed to offering a deeper understanding of students' learning and future paths after the completion of Maker Education Programs.

References

1. JEE Special Report, The research agenda for the new discipline of engineering education, *Journal of Engineering Education*, **95**(4), pp. 259–261, 2006.
2. P. N. Chou and W. F. Chen, Elementary school students' conceptions of engineers: A drawing analysis study in Taiwan, *International Journal of Engineering Education*, **33(**1B), pp. 476–488, 2007.
3. P. N. Chou, W. F. Chen, C.Y. Wu and C. Robert, Utilizing 3D open source software to facilitate student learning of fundamental engineering knowledge: A quasi-experimental study, *International Journal of Engineering Education*, **33**(1B), pp. 382–388, 2017.
4. P. N. Chou and W. F. Chen, Elementary Teachers' Perceptions of Engineering Education: A Survey Study in Taiwan, *International Journal of Engineering Education*, **38**(2), pp. 505–511, 2022.
5. P. N. Chou, Skill development and knowledge acquisition cultivated by maker education: Evidence from Arduino-based educational robotics, *EURASIA Journal of Mathematics, Science and Technology Education*, **14**(10), pp. 1–15, 2018.
6. P. N. Chou, Smart technology for sustainable curriculum: Using drone to support young students' learning, *Sustainability*, **10**(10), p. 3819, 2018.
7. P. N. Chou, Using ScratchJr to foster young children's computational thinking competence: A case study in a third-grade computer class, *Journal of Educational Computing Research*, **58**(3), pp. 570–595, 2020.
8. P. N. Chou, Guest editorial: Maker Spaces in engineering education, *International Journal of Engineering Education*, **36**(4), pp. 1134–1135, 2020.
9. National Academies of Sciences, Engineering, and Medicine, *How People Learn II: Learners, Contexts, and Cultures*, The National Academies Press, Washington, DC, 2018.
10. J. S. Krajcik and P. C. Blumenfeld, Project-based learning, In Sawyer R. K. (Ed), *The Cambridge. Handbook of The Learning Science* (pp. 317–333), Cambridge, New York, 2006.
11. G. Akerlind, Variation and commonality in phenomenographic research methods, *Higher Education Research and Development*, **24**(4), pp. 321–334, 2005.
12. M. Forster, Data analysis issues in phenomenographic investigation of information literacy in nursing, *Nurse Researcher*, **21**(2), pp. 30–34, 2013.
13. J. A. Hatch, *Doing Qualitative research in education settings*, State University of New York, Press, Albany, New York, 2002.
14. I. Sedman, *Interviewing as qualitative research: A guide for researchers in education and the. social sciences* (3rd edition), Teachers College Press, New York, 2006.
15. R. A. Diehm and M. Lupton, Approaches to learning information literacy: A phenomennographic study, *The Journal of Academic Librarianship*, **38**(4), pp. 218–225, 2012.
16. P. N. Chou and W. F. Chen, Chinese students' perceptions of online learning on western discussion boards: A cultural perspective, *International Journal of Instructional Technology and Distance Learning*, **7**(2), pp. 35–43, 2010.
17. P. L. Smith and T. J. Ragan, *Instructional design* (3rd edition), John Wiley & Sons, Hoboken, NJ, 2012.
18. P. N. Chou and W. F. Chen, Female engineering students' perceptions of college learning experiences: A qualitative case study in Taiwan, *International Journal of Engineering Education*, **31**(1), pp. 2–11, 2015.
19. P. Tough, *How children succeed: Grit, curiosity, and the hidden power of character*, Mariner, Books, New York, 2013.

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