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Case Study

Development of the Self-efficacy Beliefs of Engineering Undergraduates Preparing for an International Contest

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ABSTRACT

This study was designed to understand the everyday experiences influencing the self-efficacy of a group of engineering students preparing for the TECO Green Tech International Contest. It also aimed to understand whether participants' self-efficacy levels fluctuated under the influences of these experiences. The paper takes a qualitative approach using focus group discussion, journaling, and one-to-one interviews as data gathering tools. Our study confirms previous theoretical assumptions and empirical findings that four sources of self-efficacy information are related to self-efficacy beliefs. In addition, the study also supports the role of collective efficacy and context in influencing engineering students' self-efficacy. During the first two weeks of the contest preparation period, participating students experienced a low sense of self-efficacy under the influence of perceived lack of knowledge and skills, contest pressure, doubt of team ability, and negative feelings. A couple of weeks prior to the contest, as the students draw inspiration from a growth in knowledge and skills, verbal feedback, and positive feelings, their self-efficacy was enhanced. Comparison with team members and trust in the advisor's credibility also strengthened their sense of self-efficacy. This research has the potential to inform the development of engineering undergraduates' contest self-efficacy.

Keywords: Contest, engineering, qualitative, self-efficacy

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INTRODUCTION

Technology development in a global context has recently required a supply of competent engineers to keep up with the technology growth rate to secure any country's economic prosperity and national security (Huiyao, 2019). The countries' sustainable economic development is likely to be affected by a variety of factors, including the quality of engineering education. However, in some areas of the world, engineering students seem to have difficulty applying textbook knowledge to challenging work situations. In addition, their critical thinking skills, problem-solving skills, and teamwork skills are in question (Bodewig et al., 2014; Nguyen, 2011; Trines, 2017). As such, the importance of equipping engineering undergraduates with practical knowledge and skills while they are still at university is essential to the sustainable development of the workforce. One method used to solve the problem involves encouraging undergraduate students to join in contests to expose them to engineering knowledge and skills at work (Nguyen, 2011; Trines, 2017), thus validating their textbook knowledge and increasing their awareness of social demands for the practical techniques, skills, and experiences (Verner & Ahlgren, 2004). Recently, engineering contests are identified as a good vehicle to better engage professional societies with engineering undergraduates (Furse, 2019). However, little has been done to understand how students keep their perseverance and what can boost their performance in this challenging context (Stewardson et al., 2019). Performance and perseverance while preparing for contests appear to depend on students' beliefs in the ability of themselves and team members to achieve desired outcomes (Ahlgren & Verner, 2009; Furse, 2019). Self-efficacy is defined as "[belief] in one's capabilities to organize and execute the courses of action required to produce given attainments" (Bandura, 1997, p. 3). It is likely that raising the self-efficacy beliefs of engineering students in well-preparing and winning a contest can help future students gain their contest perseverance and performance, and increase the quality of engineering graduates in the long run.

Based on the above-mentioned arguments, an in-depth understanding of what factors can influence the self-efficacy of engineering students preparing for a contest, hereby referred to as students' contest self-efficacy, may engender it. Furse (2019) stated that the domain of engineering students' contest self-efficacy has not been paid much attention in the available self-efficacy literature. Therefore, our study aimed to explore what experiences affected the self-efficacy of a group of engineering students preparing for the TECO Green Tech International Contest. It also tried to understand whether participants' self-efficacy levels fluctuated under the influences of these experiences. Given that engineering exposure to practical knowledge and skills at contests is important to engineering undergraduates' future career and their contribution to the economy, it is hoped that the experiences identified in this study may be useful in suggesting practical ways to develop and strengthen the students' contest self-efficacy. Investigating the self-efficacy of engineering students in a contest will likely contribute to the growth of research in tertiary students' self-efficacy. The present study answered the following research questions:

1. What are the perceived day-to-day experiences that influence the self-efficacy beliefs of engineering undergraduates preparing for an international contest?
2. How do these experiences affect their self-efficacy?

LITERATURE REVIEW

Self-efficacy Beliefs

Social Cognitive Theory (SCT) (Bandura, 1997) provides the lenses through which the present study was conducted. As Bandura (1997, p. vii) stated "people are producers as well as products of social environments", the theory highlights both people's power to change the social environments where they live and the role of environmental factors in meditating behaviors. Self-efficacy helps to understand the relationship between the amount of effort people put into their behaviours, the effectiveness of their thoughts and actions, and the perseverance people show in the face of difficulty (Bandura, 1997). Self-efficacy beliefs have been reported to strongly predict students' academic performance and learning and positively correlate to their retention (Bartimote-Aufflick et al., 2015). Bandura (1997) and Klassen and Klassen (2018) stressed that self-efficacy is concerned with what people believe they can do with the necessary knowledge and skills to achieve their goals, not with how many sub-skills they possess.

Self-efficacy is task- and situation-specific (Bandura, 1997), and assessing self-efficacy at a micro-analytic level is necessary to a comprehensive theory of self-efficacy (Schunk et al., 2008; Srisupawong et al., 2018). Under the influence of a range of factors, for example, physical conditions (mood or health conditions) and other environmental factors (classroom environment, resources), students' levels of efficacy vary as they perform different learning tasks, challenges, or endeavours in different contexts. For example, engineering students may hold different self-efficacy levels when they join a contest or attend an online science course. Besides, it is possible that the self-efficacy levels of the students will change as they perform different tasks set by the contest. The engineering students can also judge their self-efficacy to perform similar tasks differently at various points in time. The description of what is associated with the fluctuations in self-efficacy can help researchers and educators to improve students' self-efficacy levels more effectively. However, little is known about what factors influence engineering students' contest self-efficacy and how they affect the students' self-efficacy levels due to a lack of studies investigating this research area (see below). The present study fills the gap by expounding on diverse efficacy-relevant experiences to shed light on engineering students' contest self-efficacy.

There are four sources of information shaping self-efficacy identified by Bandura (1997): enactive mastery experiences (past performances), vicarious experiences (models' comparison), verbal persuasion (verbal judgment from important people), and physiological/affective states (stress or fear). According to some researchers (e.g. Bandura, 1997; Usher & Pajares, 2008), since mastery experiences provide clear, measurable evidence for the capability of success, they are the most consistent in predicting student achievement. The other sources of self-efficacy information are believed just as important (Usher & Pajares, 2008). It is important to note that sources of self-efficacy information become active only when people weigh and select different types of self-efficacy information (Bandura, 1997; Chen & Usher, 2013; Klassen & Klassen, 2018; Wyatt, 2018). People may vary in applying rules of weighting and interpreting sources of information to construct their self-efficacy. Under cultural influences, forms of self-efficacy information sources may vary in different contexts and situations (Phan& Locke, 2015). As a result, inconsistent findings have been found among studies conducted in diverse settings (Keefe, 2013; Srisupawong et al., 2018; Wyatt, 2018).

Collective Efficacy

Bandura (1997, p. 477) defined collective efficacy as "a group's shared belief in its conjoint capabilities to organize and execute the courses of action required to produce given levels of attainments". He argued that it is individuals' need to co-operate and make use of unified effort to solve problems and improve their life which has activated and encouraged the development of collective efficacy. In essence, perceived collective efficacy is more than the sum of individuals' self-efficacy beliefs but individuals' beliefs in the group's abilities as a whole. Self-efficacy and collective efficacy are similar in the sense that both focus on the amount of effort and persistence that individuals are dedicated to a task and perceptions of task success (Ahlgren & Verner, 2009). Both types of efficacy operate through similar processes and serve similar functions. In addition, perceptions of self-efficacy and collective efficacy are interrelated and together drive behaviour (Goddard et al., 2004). Engineering students' sense of self-efficacy in the successful performance of their own tasks is stronger and more likely to persist in their own efforts when they hold firm beliefs in the capability of the whole team to complete tasks and succeed in the contest. Conversely, engineering students with a low sense of collective efficacy may doubt the successful performance of the team and subsequently lower the expectations of their own tasks' success.

Factors Influencing Engineering Tertiary Students' Self-efficacy Beliefs

The research into factors influencing students' self-efficacy beliefs is not entirely new, yet few studies have been conducted to understand this research area in engineering education. Scholars who are interested in this topic have been investigating either the impact of environmental factors or sources of self-efficacy beliefs of university engineering students.

Regarding the influences of the environment, what the researchers have found supported Bandura and other researchers (e.g. Reisberg et al., 2012) confirmation that such environmental factors as university context (e.g. physical conditions, student characteristics) and academic climate (e.g. professional development, academic achievement, educational values, and norms) correlate with engineering students' self-efficacy. The students' self-efficacy varies according to context, that is, context can mediate self-efficacy. For example, Fantz et al. (2011) surveyed 322 engineering freshmen from four departments to understand the relationship between pre-collegiate experiences (e.g. working in engineering-related environments) and self-efficacy beliefs. Findings indicated that the more exposure to pre-collegiate experiences the students had, the more efficacious they became. Similarly, Raelin et al. (2015) conducted a longitudinal study to explore whether engineering sophomores' work experience and contextual support influenced the students' three types of self-efficacy beliefs (work, career, and academic efficacies). The researchers also compared the self-efficacy beliefs of students who participated in the programs to those who did not. Findings of the study stated that students joining the work experience programs displayed a significant increase in their self-efficacy beliefs, whereas those who did not have such experience got a lower sense of self-efficacy. The quality of the work experience strengthened students' work self-efficacy and contextual support predicted three forms of self-efficacy beliefs.

Research investigating sources of self-efficacy of engineering undergraduates is sparse. The findings of the available studies have yielded mixed results. For example, Purzer (2011) used a mixed-methods approach to understand how verbal exchanges affected engineering students' achievement and self-efficacy. Unlike the findings of other studies, giving verbal feedback, agreements, praises, and acknowledgements, rather than receiving verbal persuasions, were likely to increase the self-efficacy of the feedback giver and feedback receivers. Similarly, Srisupawong et al. (2018) surveyed 524 computer-science students from Thai universities to explore how sources of information influenced their self-efficacy beliefs. The findings of the study, however, did not support Bandura's (1997) assertion that mastery experiences were the most powerful source. Students' perceptions of verbal persuasions, vicarious experiences, and emotional and physiological states positively correlated with self-efficacy.

Common themes resounding in the available literature are the strong influence of environmental factors on engineering undergraduates' self-efficacy and the mixed results regarding the strength of efficacy information sources. Most of the available studies are quantitative in nature and self-efficacy beliefs and environmental factors are accessed by students' self-reports on Likert-scale items. Researchers have reached an agreement that engineering undergraduates' self-efficacy beliefs differ as a function of context. However, it remains unclear how engineering students select, weigh, and internalise different sources of efficacy information to construct their self-efficacy beliefs in quantitative studies (Wheatley, 2005). Likert-scaled instruments fail to provide an in-depth understanding of how context mediates engineering students' construction of self-efficacy beliefs and how the students exercise their control over contextual influences to build up their self-efficacy. Also, what causes a change in students' self-efficacy cannot be demonstrated clearly in quantitative research though participants may answer several questionnaires at different points in time.

Regarding quantitative studies investigating sources of engineering undergraduates' self-efficacy beliefs, Usher et al. (2015) noted that items in questionnaires fail to capture the complexity of affective states since they are often negatively worded. The positive dimensions of this source have not been paid much attention to in self-efficacy literature. Also, the number of items to assess vicarious experiences and affective states is too few compared to that of other sources. Accordingly, the multidimensional nature of these information sources cannot be elicited fully in such research (Usher & Pajares, 2008).

Although the need to understand the relationship between student self-efficacy, perseverance, and academic performance has been noticed by a number of researchers (e.g. Ahlgren & Verner, 2009; Furse, 2019; Trines, 2017), engineering educators have not yet understood what experiences impact on engineering students' contest self-efficacy beliefs due to a serious lack of studies investigating this issue in engineering education. Given the paucity of research, the questionable quality of some quantitative studies, and methodological problems, there is a gap in the self-efficacy literature that has not been addressed fully by existing research. Therefore, this study, using a qualitative approach, aims to fill this gap by exploring factors affecting the self-efficacy beliefs of a group of engineering undergraduates preparing for an international contest.

MATERIALS AND METHODS

Research Context and Participants

The TECO Green Tech Contest started 12 years ago and has become one of the most attended green technology events in Taiwan. The contest has attracted students from many countries worldwide to share their creativity and innovations in green technologies. In 2019, a total of 60 international teams were entered for the first round. In the final round of the contest, 20 teams competed for seven awards.

The study included eight male engineering undergraduates from two universities forming a team to register for the 2019 TECO Green Tech International Contest. Table 1 below shows the team's profiles.

Table 1
Profiles of team members

Team member	Gender	Age	Nationality	Years of study	Major
S1	Male	19	Taiwanese	Junior	Mechanical and Electro-Mechanical Engineering (MEME)
S2	Male	19	Taiwanese	Junior	MEME
S3	Male	19	Taiwanese	Junior	MEME
S4	Male	19	Taiwanese	Junior	MEME
S5	Male	18	Taiwanese	Sophomore	Electronic Engineering
S6	Male	19	Taiwanese	Junior	Electronic Engineering
S7	Male	19	Vietnamese	Junior	Electrical Engineering Technology
S8	Male	19	Vietnamese	Junior	Electrical Engineering Technology

Methodology and Data Tools

A qualitative case study approach is chosen for our study. One purpose of qualitative studies is to understand contextual conditions that are relevant to the phenomenon being explored (Creswell, 2012). The inquiry holistically enables researchers to illuminate people's perceptions within a context and interpret their daily experiences (Walia, 2015). A rigorous qualitative case study uses multiple data sources to enhance data credibility and provide a greater understanding of the phenomenon under study (Baxter & Jack, 2008). Three data instruments: a focus group discussion, two rounds of one-to-one interviews, and journaling, were used to answer the research questions in the present study.

Focus group discussion has been long known in the literature as a stimulation of the co-construction of knowledge and meaning arising from group members' productive interactions (Tuckett & Stewart, 2004). In the present study, the researcher (corresponding author) used a semi-structured set of questions to conduct a focus group discussion with eight engineering undergraduates three days before the end of the data collection period. Students were invited to talk about whether their self-efficacy levels fluctuated over the course of three months and what led to the changes. Sample questions used in the focus group discussion are: "The contest will begin in several days. How do you feel now?" and "What can you say about the level of your confidence now compared to that in the first two weeks of the preparation period?".

One-to-one interviews helped the researchers focus on the data presented by one respondent versus a whole group to distinguish individual opinions about the issue in question (Boyce & Neale, 2006). The purposes of the interviews were to understand students' perceptions of the influence of the daily experiences on their beliefs in their abilities to accomplish assigned tasks and whether their self-efficacy beliefs were subject to change under the influence of such experiences. Examples of individual interview questions are: "What makes you feel the most confident while preparing for the contest?" and "Can you tell me one example of how you overcame a task challenge?" Team members also answered a semi-structured set of questions to explain some behaviours and experiences mentioned in their journal entries.

In this study, journaling provided participants with an opportunity to make their experiences, opinions, thoughts, and feelings visible to the researchers. Participants, on a regular basis, recorded significant events that were relevant to the issue being explored (Hood, 2009). Students in our study kept weekly entries and sent the Word files via emails. The corresponding author provided guidelines in the form of prompts to ease their writing process. In the entries, eight engineering students described in detail what important experiences they got, whether these experiences were positive or negative, and how they impacted their task performance and emotions. The data from journals were used to triangulate the data from one-to-one interviews and the focus group discussion.

Data Collection and Analysis

Data collection began with journaling. Participants were invited to write their journal entries over a three-month data collection period. One-to-one interviews were organized at the end of the first and second months and each lasted approximately 60 minutes. The interviews were carried out with eight participants and ended just before the focus group discussion. Notes were taken during the interviews and the focus group discussion. The corresponding author audio-recorded the interviews and the focus group discussion and sent transcripts to participants via emails to provide them with opportunities to validate and amend data. No engineering undergraduates altered their responses. The English language was the preferred means of communication in our study. The focus group discussion lasted approximately 90 minutes. At the end of the three-month period of journaling, the researcher had received 56 entries from eight engineering undergraduates.

In the present study, the inductive coding process (Creswell, 2012) and the thematic analysis method (Braun & Clarke, 2006) were chosen as methods of analysis. The researcher coded for specific research questions and followed a four-step procedure suggested by Le (2011) as in Table 2. Table 3 illustrates how emerging codes were grouped into subcategories and categories in our study.

Table 2
Overview of the data analysis procedure

Step	Focus	Pre-analysis	Steps in analysis
1. Analyzing the journal entries	-Experiences influencing self-efficacy -Effects of these experiences on self-efficacy, i.e. increasing or decreasing it	Reading each journal entry several times	1A. Underlying keywords, phrases, and coding them. 1B. Categorizing the above, grouping them into subcategories by cutting and pasting 1C. Tabulating data of each student.
2. Analyzing one-to-one interviews		-Transcribing data -Reading each transcript several times	2A. Cutting and pasting keywords and phrases into the above subcategories. 2B. Comparing and contrasting data from journal entries
3. Analyzing the focus group discussion		-Transcribing data -Reading the transcript several times	3A. Cutting and pasting keywords and phrases into the above subcategories. 3B. Comparing and contrasting data from participants' journals and interviews.
4. Triangulating findings	Understand how self-efficacy fluctuated under the influence of different experiences	Reviewing all data	-Interrogating all data again for additional or contradictory findings -Refining the content of all sub-categories -Grouping experiences: increasing or decreasing self-efficacy

Table 3
Example of coding hierarchy

Feedback	Contest pressure	Task allocation	Adviser credibility	Comparison with team members
My adviser let me communicate with that team. He told me he is very proud of what I can do (S1).	- We need to do a lot of tasks (S1). - We have only three months. Time seems not to be enough (S5)	The advisor reviewed my task weekly and broke them down into sub-tasks. That made me feel confident and clearer (S5).	The advisor cares about us a lot. He often has meals with us and has organized two sightseeing trips to many areas in Taiwan for us . . . He treats us as his family members (S7).	No one knows what a vacuum pump is. I learned about the vacuum pump and shared it with my team (S3).

Reliability and Validity

In our study, in terms of reliability, the research aims, and research questions were made explicit. The assumptions and theories behind the study were explained. Social Cognitive Theory, self-efficacy theories, and studies of engineering undergraduates which helped to position the current study and form the research questions were critically discussed. The methods of collecting and analysing data were justified and illustrated.

Within-method triangulation and data triangulation helped to increase confidence in the present study's validity. Three types of data instruments; namely one-to-one interview, focus group discussion, and journaling, helped to ensure data accuracy and an in-depth understanding of factors affecting engineering students' contest self-efficacy. Two types of data triangulation, i.e., person and time, were also included to add strength to the research findings. Gathering data from eight engineering students in three months increased data validation across participants and contributed to the robustness of data. Transcripts of interviewing sections were sent to participants for emendation and validation, facilitating the data interpretation and research findings' writing process. In addition, the two researchers discussed emergent themes and findings to make sure analyses emerged from the data.

Participants' privacy and confidentiality were respected and protected in this research. The researchers, at the outset, discussed with the participants how their privacy and confidentiality were addressed. The researchers collected, analyzed, and reported data anonymously. The real names of eight participants and two universities were removed and replaced by pseudonyms. Participants were made to be aware of the need to keep the comments made within the focus group discussion confidential.

FINDINGS

In the present study, the way eight engineering students perceived the day-to-day experiences in the laboratory appeared to affect their sense of self-efficacy. During the first two weeks of the contest preparation period, participating students experienced a low sense of self-efficacy under the influence of perceived lack of knowledge and skills, contest pressure, doubt of team ability, and negative feelings. Roughly half of a month before the contest, as the students draw inspiration from a growth in knowledge and skills, verbal feedback, and positive feelings, their self-efficacy was enhanced. Comparison with team members and trust in the advisor's credibility also strengthened their sense of self-efficacy.

Perceptions of Knowledge and Skills

It appears that the eight students' perceptions of their knowledge and skills had the potential to enhance or lower their self-efficacy. When they joined the team for the first two weeks of the preparation period, all students expressed concern for their low English language proficiency and limited background knowledge of motors and technology. The students used negative words and phrases to describe their experiences and mentioned their confusion about what was required of them which suggested their sense of inefficacy. For example:

> *My English is not good and I have limited technical knowledge of modern motor series and electronic engineering technology. I got lost in my discussion with the team today.* (S6RJ2)

> *I'm one member of the IOT [Internet of Things] team. I'm the only sophomore to join this contest, but I'm doing the most challenging task which no one did before. I seriously lack laboratory experience and technological knowledge. I think the time is not enough for me to reach the goal indicated by the team's schedule.* (S5IT1)

However, in the journal entries written over the last two weeks of the preparation period and in the focus group discussion, some engineering undergraduates reported perceptions of obtaining better English language skills, motor knowledge, and laboratory experience, which seemed to increase their feeling of being able to tackle some particular tasks. For example:

> *The meeting with the guest speaker . . . was very useful. I learned about a range of motors and motor technology. . . We have worked in the laboratory for 3 months and it has given me many skills that can be carried over to the contest. I feel more relaxed now*. (S7RJ15).

> *After three months of working with team members and our adviser, I can express my thoughts in English quite easily now. . . I have practiced my presentation with a team member a few times this week. I have done it quite well, I think. I believe we will deliver this presentation successfully on the contest day.* (S1FG)

Contest Pressure

It appears that during the first week of the three-month period, participating students' perceptions of the contest pressure in terms of the number of tasks, time limit, and scope undermined their sense of self-efficacy. All team members had never joined in any contest and needed to compete against many strong teams worldwide. They reported negative feelings to describe how the contest impacted on them.

> *I was very tired during the first week [of the contest preparation period]. After exciting moments knowing that the team was on the final list, I realized I had a lot of tough tasks ahead. . . I suffered a lot of pressure. I couldn't sleep well for several nights.* (S7IT1)
>
> *My IOT task was too tough. I was confused and felt seriously stressed. I didn't know where to start.* (S5IT1)

Perception of Team Capability

Findings of the study offer evidence that the perception of the team able to do certain tasks affected individual student's perceptions of their ability to do their own tasks. In the first and second week of the preparation period, the students expressed a diminished sense of collective efficacy which lowered their own sense of self-efficacy:

> *I don't think all team members understood what we needed for the contest, what we needed to prepare for the contest. No one has done that before. . .You will lose your belief in yourself.* (S1RJ3)
>
> *The whole team, including me, was down because I think we didn't know what we would do. We haven't found the right direction that can make a beautiful story, beautiful materials, beautiful scripts, how to show ourselves . . . and the IOT issue. . . The whole team was up and down, up and down together. And I myself was in a bad mood at that time. I lost my belief in the team's ability to win in the contest, and I am a part of the team. I thought we couldn't make it! I couldn't make it.* (S4IT1)

However, in the last two weeks, the students mentioned the team's discovery of their "value" and "strengths" which built up individuals' beliefs in the team's contribution and motivated them to achieve their own goals.

> *And finally, we found the value of the team, we learned about our strengths compared to other teams. We strongly believe we have our own value. I think this is the most important thing which has helped us move forward more smoothly. It built up every member's belief in their contribution. Each of us oversees different tasks and we have together achieved our goals step by step.* (S8FG)

Verbal Feedback

In the present study, verbal feedback enhanced participants' sense of self-efficacy, especially within the last month. Findings suggest that students relied on team members and their adviser's verbal feedback, to register task performance as successful or not. Feedback guided engineering undergraduates' interpretations of their competence, that is, the feedback developed the perception of whether they had the required ability to succeed. Interestingly, no team members considered the feedback to be negative.

> *We didn't think we received any negative feedback [from our advisor and team members]. Everything was good but something was better, more suitable. We chose the best thing! And that makes us feel confident in ourselves.* (S7FG)

> *I like the way I am given feedback. . . . We often hold a discussion at the end of the day. We tackle every single issue. I agree with him [S7] that we don't have negative feedback. We try to give constructive feedback to everybody. . . . Every member raises his voice and comments on daily work. . . . So, when we leave the meetings, we feel satisfied with specific and timely feedback we receive from team members and the advisor.* (S8FG)

The eight participants reported receiving more "compliments" from their peers and their advisor within the last month than at other times which boosted their sense of self-efficacy and prepared them well for the contest.

> *The adviser assigned a new task for me a week ago. He let me work as the communicator between the IOT team and the university staff. He told me he is very proud of what I can do. His encouragement motivates me a lot and strengthens my belief that I can do any task well on the contest day.* (S1RJ8)

> *In the third month, I feel more confident with my work. Not only me but the whole team feel the same thing. We nearly finish all the tasks on the schedule. We receive more compliments from our advisor. Of course, he often compliments us, but we have received more good words recently!* (S3FG)

Advisor Credibility

McCroskey and Teven (1999) identified competence, trustworthiness, and goodwill as important dimensions of teacher credibility. Competence refers to a student's perception of the teacher's knowledge and experience, whereas goodwill is the perceived caring resulting from empathy, understanding, and responsiveness. Trustworthiness is seen as the perceived character and honesty of the teacher. In our study, findings suggest that engineering undergraduates seemed to display a robust sense of self-efficacy when learning with an advisor, who they perceived as credible. First, the advisor was perceived to be able to assign tasks in accordance with the students' attributes and to break the tasks down into manageable and achievable sub-tasks which confirmed his knowledge and experience. For example, student 5 said he felt "more confident and satisfied" because he became "clearer about what [he] needed to strive for" after his IOT task was divided into manageable subtasks. Second, the advisor's verbal feedback illustrated his responsiveness and understanding which also instilled a sense of self-efficacy in the students (see *Verbal Feedback* above). Last but not least, some students also mentioned his caring and other good characteristics:

> *The advisor cares about us a lot. He often has meals with us and has organized two sightseeing trips to many areas in Taiwan for us . . . He treats us as his family members.* (S7IT2)

> *I feel warm and safe to learn more in this laboratory with my advisor and my team members. I believe that our advisor can help us to succeed at the contest with his knowledge, ability, and generosity.* (S6IT2)

Comparison with Team Members

In the study, it appears that students' comparison with team members can strengthen their self-efficacy. Observing team members doing the same tasks provided participating students with opportunities to compare their own abilities to that of their team members. High efficacious students formed a need to enrich their knowledge and skills in order to help their team members while those with weaker self-efficacy displayed a willingness to learn from their peers to improve their knowledge and skills. As a result, both types of students felt more efficacious due to the perceptions of successful skill development or task accomplishments. For example, student 3 shared in his interview that he "could learn about vacuum pumps quickly and shared with the team because no one knew what it was". The newly gained knowledge made him think he "could speak well on the contest day". Student 5 said:

> *I fixed a lot of English pronunciation mistakes and learned some new terms by observing a team member deliver his presentations. I learned quite a lot from him. I also recognized that I need to practice my speaking skills a lot to keep up with my team members. I have done it promptly for 2 months. . . I become more confident in my English competence.* (S5RJ9)

Emotions

In this study, the negative or positive feelings associated with the interpretations and internalization of other sources of efficacy-relevant information can enhance or harm engineering students' self-efficacy. For example, in the first two weeks of the three-month period, the feeling of incompetence in motor technology knowledge and English language skills lowered students' self-efficacy beliefs. Some students in their interviews and journal entries mentioned their "tiredness" (S3), "sadness", "pressure" (S7), and a feeling of "lacking comfort and confidence" (S4). In contrast, growth in knowledge and skills, a stronger belief in the team's ability to win the contest, successful task performance brought by verbal feedback, the advisor's credibility, and comparison with team members induced students' positive feelings. For example, the students reported to be "excited" (S2), "motivated" (S3; S1), "confident" (S5; S7), "safe" and "warm" (S6) which strengthened their trust in their competence to do assigned tasks successfully.

DISCUSSION AND CONCLUSION

The present study confirms previous theoretical assumptions (Bandura, 1997, Schunk et al., 2008) and empirical findings (e.g., Fantz et al., 2011; Keefe, 2013) that four sources of self-efficacy information are related to students' self-efficacy beliefs. In addition, the study also supports the role of collective efficacy (Ahlgren &Verner, 2009) and context (Klassen & Klassen, 2018) in mediating engineering students' self-efficacy.

Mastery experiences appear to be a powerful factor affecting the self-efficacy of individual students in the present study since they exerted the most direct experiences on forming self-efficacy (Bandura, 1997; Schunk et al., 2008). At the early stages of the study, some engineering undergraduates displayed a low sense of self-efficacy due to the perceived serious lack of knowledge of motor series, technology, and presentation skills. However, as their knowledge and skills improved over time, participating students' self-efficacy beliefs were strengthened. The process of developing new skills and experiences happened when tasks were practiced and completed. As Bandura (1997) suggested, the greatest potential for a positive change in self-efficacy occurs during this period of skill development. Our study confirms the results of previous studies (e.g. Fantz et al., 2011; Keefe, 2013; Srisupawong et al., 2018) which highlighted the importance of supplying engineering students with a range of opportunities to gain a sense of mastery (see below).

The findings suggest that social persuasion contributed significantly to the development of mastery experiences. Feedback brought individual students the perception that they could succeed or were on the right track. Specific, timely, and constructive verbal comments motivated students to keep attempting mastery. Some researchers (e.g., Keefe, 2013; Mills, 2011) noted the critical role of supplying enough feedback to enable students to quickly absorb the pain of confusion or possible failures and find the courage to try again. Other researchers (e.g., Agricola et al., 2020; Mills, 2011) made it clear that feedback's form, content, quality, and focus can lead to the positive development of self-efficacy. Our study shows that organizing feedback conversations, in which verbal feedback is focused, goal-oriented, timely, and constructive, can have a significant impact on the improvement of engineering students' self-efficacy beliefs.

Consistent with Won et al.'s (2017) assertion, in our study, the perceived credibility of the advisor was associated positively with increased self-efficacy beliefs of the students. This special form of social persuasion interacted closely with other forms of social persuasion (feedback and task allocation and breakdown) in increasing their self-efficacy. The students reported positive emotions and greater effort (a stronger sense of self-efficacy) since they trusted in the qualities of the advisor. The perceived credibility of the advisor likely made his feedback and guidance particularly effective in developing his students' self-efficacy. Owing to the scarcity of research on the relationship between advisor credibility and students' contest self-efficacy, future studies are suggested to support this finding of our study.

Regarding vicarious experiences, it seems that participating students' comparison of their performance relative to their peers' scaffolded input opportunities for them to visualize their current strengths and weaknesses, see their uniqueness and contribution, understand their knowledge and skill gaps, set up improvement goals to reduce the gaps, and gain desired results. The comparison facilitated engineering students' willingness to work and learn together to attain their goals. Our study suggests that social comparison engendered undergraduates' co-construction of knowledge, which consequently led to their improvement of mastery experiences and self-efficacy beliefs.

The findings in the present study also confirmed Bandura's (1997) assertion that emotions and physiological responses do not directly influence students' self-efficacy beliefs. Instead, they are a factor in the interpretation of what that response means. In our study, negative or positive emotional reactions can be interpreted as indicators of incompetence or competence. Research suggests that negative feelings such as fear, boredom, fatigue, and anxiety can harm self-efficacy and lead to poor performance. Positive emotions, however, usually engender self-efficacy beliefs and subsequent success (Martinez et al., 2011). In line with Fantz et al.'s (2011) and Usher and Pajares' (2008) contention, our findings make clear that creating more opportunities for students to gain more senses of mastery and negotiate developmental challenges, increasing the credibility of the advisor, and giving timely, specific and constructive feedback has the potential of triggering positive feelings for engineering students which indirectly engender their contest self-efficacy.

Our study resonates with the assertion of Bandura (1997) and other researchers (Ahlgren & Verner, 2009; Goddard et al, 2004) that collective efficacy can influence self-efficacy. For example, when individual students believed that no one in the team could figure out the way to solve the IOT problem or to produce interesting scripts, they lost the beliefs in their own abilities. It appears that participating students' perception of team ability to succeed or fail in accomplishing some tasks influenced the self-efficacy of some individual students. The finding suggests that collective efficacy beliefs acted as a resource in affecting self-efficacy in our study. However, due to the lack of research into the relationship between collective efficacy and self-efficacy in the field of engineering education, more research is needed to understand its specific nature.

Our findings substantiate the assertion of Bandura (1997) and other researchers (e.g., Chen & Usher, 2013; Srisupawong et al., 2018) that students' self-efficacy fluctuates in accordance with contexts.

The students appeared to have fluctuating self-efficacy in accordance with the context. However, as they gained more mastery experiences a couple of weeks prior to the contest, the impact of contextual factors became less significant, that is, they gained a stronger sense of self-efficacy beliefs.

Our research has limitations that must be acknowledged. First, all data collected are self-reported. Participating students might have felt uncomfortable disclosing certain information which they considered to be sensitive. It is also possible that students could overestimate or underestimate the role of efficacy-relevant information. It would be useful if future qualitative research could employ observation as an additional data tool. In addition, the respect for the teacher seems to play a unique role in Asian cultures (Phan, 2011) and sources of self-efficacy may operate differently in Asian and Western cultures (Klassen, 2004). Therefore, the finding that adviser credibility indirectly bolstered students' contest self-efficacy should be interpreted with caution.

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