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Influence of Context on Item-Specific Self-Efficacy and Competence of Engineering Students*

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Self-efficacy is critical for academic success. Self-efficacy theory suggests that the social setting and problem format can influence self-efficacy. While robust studies assessing students' self-efficacy and its relation to other academic outcomes have been undertaken, little is known about the relation between self-efficacy and competence on specific problems and how problem format and implementation type relate to self-efficacy. 94 conceptual questions in three formats (interpretation, ranking task, and multiple-choice) were developed through an iterative research-based effort. Ten university faculty implemented questions with their students in one of five types (closed-book exam, take-home exam, in-class quiz, homework, and group discussion). In total, 569 individual students responded to 2,006 questions. To capture item-specific self-efficacy (ISSE), students were asked to rate their confidence immediately after they had answered individual questions, on a 10-point scale. It was found that students with similar performance self-reported a wide variance of self-efficacy and that many student answers lacked correspondence between self-efficacy and performance. Results of multivariate analysis of variance (MANOVA) revealed that student performance differed according to question format and implementation. Students performed best on interpretation questions and they had the highest ISSE and percentage correctness for problems completed in groups. The findings support that interactive learning can contribute to student competence and self-efficacy.

Keywords: self-efficacy; students' competence; problem format; implementation type; engineering education

1. Introduction

Self-efficacy is "the belief in one's capabilities to organize and execute the course of action required to produce given attainments" [1, p. 3]. Students' self-efficacy beliefs relate to academic outcomes at multiple levels and are critical to overall academic achievement. Students' self-efficacy beliefs in learning and educational performance are frequently addressed in content areas such as mathematics [2, 3], medical science [4, 5], psychology [6] and engineering [7–9]. Students' item-specific self-efficacy (problem-based self-efficacy) has been measured in relation to individual problems in many formats and disciplines. For example, ranking task exercises in physics [10] and mechanics of materials [11] frequently include a self-efficacy scale and the Mathematics Self-Efficacy Scale [12] assesses self-efficacy related to specific mathematics problems. However, there is no research that investigates the relation between the problem format and students' item-specific self-efficacy (ISSE).

In Bandura's theory, self-efficacy beliefs are developed from four principal sources: 1) enactive mastery experiences that serve as indicators of capability, 2) vicarious experiences that are shaped by the perception of the outcomes experienced by others, 3) verbal persuasion that is created by the social influences that one possesses certain capabilities and 4) physiological and affective states from which people partly judge their capableness, strength and vulnerability to dysfunction [1]. The social context of the learning environment can affect an individual's self-efficacy beliefs, as noted in Bandura's four factors that influence these beliefs. When students' efficacy beliefs in problem solving are assessed in relation to problem format, it is important to consider the context problems are presented in, as the context of the problem can influence both the efficacy beliefs and correctness of student responses [13, 14]. Although many experts in the field of engineering education confirm that competence in solving problems (correctness of responses) and related student efficacy beliefs are crucial, some questions remain unanswered. Questions such as how do problem format and implementation environment relate to ISSE and competence, and how do these two factors interact?

The present study investigates how students' efficacy beliefs relate to responses to conceptual engineering problems with differing problem formats and implementation contexts. Problems are all short answer types that require less than five minutes to solve and include ranking tasks, conceptual multiple choice questions, and interpretation (open-response) questions. Implementation contexts include in- and out-of-class, group and individual, and homework, quiz and exam.

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2. Literature review

Self-efficacy refers to perceived capabilities for executing tasks or performing actions at designated levels [1]. Efficacy beliefs operate as a key factor in a generative system of human competence. There is much evidence to support Bandura's argument that self-efficacy beliefs can affect virtually every aspect of people's lives [15–18], their thoughts, feelings, and actions. In addition, self-efficacy is a critical determinant of how individuals regulate their thinking and behavior [19]. As Bandura claims, different people with similar skills or the same person under different circumstances, may perform poorly, adequately or extraordinarily, depending on fluctuations in their beliefs of personal efficacy. In other words, "while skills can be easily over-ruled by self-doubt in a way that even highly talented individuals make poor use of their capabilities under circumstances that undermine their belief in themselves, a resilient sense of efficacy enables individuals to do extraordinary things by productive use of their skills in the face of overwhelming obstacles" [1, p. 37].

The influence of self-efficacy on learning and performance has been widely applied and tested in educational settings [20–23]. Within an educational context, self-efficacy is frequently described in terms of academic self-efficacy which defines a student's judgments about her ability to successfully attain educational goals [24]. Examining academic performance while considering the underlying role of self-efficacy can contribute to a broader understanding of how self-efficacy operates while students solve problems. Indeed, knowledge is traditionally judged to exist if the person being evaluated simply answers a question correctly. This judgement can be flawed if a correct response is provided by a student who lacks self-efficacy. The potential trap is that the student may have a high level of self-efficacy in the incorrect response, which means that the student may behave in accordance with such flawed beliefs in the future, leading to errors sometimes with potentially negative consequences [25]. Recently in an extensive review of research on the relationship between academic self-efficacy and university students' academic performance [26], Honicke and Broadbent (2016) identified 59 studies of published, peer-reviewed journal articles and unpublished theses/dissertations from 2003 to 2015. Findings from these previous studies provided overwhelming support for a positive relationship between academic self-efficacy and academic performance. This relationship suggests that students who hold stronger beliefs about their ability to perform well academically are more likely to do so than students who do not. While Honicke and Broadbent confirm the importance high levels of academic self-efficacy play in positively influencing academic performance, they also bring to light additional variables that affect this relationship. One of the factors that could considerably mediate the relationship of overall academic self-efficacy and academic performance is competence and problem solving self-efficacy [27]. The current study examines the relationship between ISSE, or students' ratings that they can successfully solve a problem, and the competence (correctness of their responses).

In theory, self-efficacy is hypothesized to influence behaviors and environments and, in turn, to be affected by them. Bandura contended that "beliefs of personal efficacy do not operate as a dispositional determinants independent of contextual factors as some situations require greater self-regulatory skill and more arduous performance than others" [1, p. 14]. Bandura makes the example of public speaking in which the level and strength of personal efficacy will differ depending on many conditional factors including the subject matter, whether the speech is extemporaneous or from notes, and the evaluative standards of the audiences. Contextual factors vary broadly depending on the situation. In the case of public speaking it depends on what might be considered the topic (or subject matter) and the individual's previous experience and knowledge with that subject matter, the material resources available (notes), and the interpretation of the speaker of the audiences' background and potential to evaluate the speaker (evaluative standards). These same contextual factors could be applied to problem implementation. The topic is the content that is being asked about in a problem, the resources available are the items that students are allowed to utilize when solving the problem, including textual resources, such as notes and textbooks, and human resources, such as peers, and the social conditions in which the problem is solved, including the evaluative standards of others solving the problem.

In an educational setting, problem solving involves selecting the most efficient method to satisfy learning goals by overcoming classroom obstacles [28]. The body of literature regarding efficacy beliefs in problem solving has been considered from two perspectives, that of the teacher [29, 30] and that of the student [31]. The teacher's problem solving ability and level of subjective self-efficacy is considered as a critical prerequisite for student success as it is assumed to be the most important tool for conveying material to the students. This present study is concerned with the second perspective, which is the relationship between students' self-efficacy and problem format and implementation, both contextual factors. This type of analysis strongly resonates with Bandura's argument that "efficacy beliefs should be measured in terms of particularized judgements of capability that may vary across realms of activity, under different levels of task demands within a given activity domain, and under different situational circumstances'' [1, p. 42].

3. Research objectives

Bandura noted that ''it is no more informative to speak of self-efficacy in general terms than to speak of nonspecific social behavior'' [1, p. 14]. While the literature is rich with studies assessing students' self-efficacy beliefs using aggregate measurements, there is little, if any, insight into the interaction of competence in problem solving and efficacy beliefs among students at a problem-based level. This paper addresses this gap in literature and considers the role of contextual factors in a problem-based setting. In this setting, context is referred to as nature of the problem and implementation. For example, when exposed to different question formats or various implementation types, students with the same level of competence could demonstrate differing levels of self-efficacy specific to a problem. Evaluation of underlying mechanisms for student's efficacy beliefs in solving specific conceptual problems will shed light on the mediating contextual factors in the relationship of self-efficacy and academic performance.

The following research questions are addressed:

- What is the relationship between student ISSE and competence?
- How do different question formats relate to student competence and ISSE?
- How does implementation of the question relate to student competence and ISSE?

4. Method

4.1 Data acquisition

The present article builds on the work of Abadi et al. (2016) [7], which discussed the iterative development of robust conceptual questions regarding traffic signal systems and the adoption of those questions by Transportation Engineering faculty at 10 different universities. Based on an examination of traffic signal system misconceptions held by student and practicing engineers [32], total of 94 conceptual questions were developed. Developed questions were considered to be conceptual questions because they did not require calculation or extensive analysis, and could all be answered correctly in a short amount of time using conceptual knowledge in the content area. The six question topic areas included yellow change intervals (19 questions), red clearance intervals (18 questions), cycle length (14 questions), effective green time (15 questions), coordinated signals (13 questions) and actuated signals (15 questions). The curriculum developed for each topic area included the following three formats of conceptual questions:

- Interpretation questions in which a quote is presented, and students are asked to describe in their own words if the quote is correct or not, and why,
- Ranking tasks, in which 4 to 5 figures are presented and students are asked to place the figures in a particular order based on some inherent element of the information provided in each figure, and
- Multiple choice questions, with one or more correct answers and several incorrect distractors. Distractors are robust misconceptions that were determined from a previously published study [32].

Ten university faculty from various Civil Engineering departments agreed to use the conceptual questions in their classrooms. Faculty were asked to select their desired topic areas (could be more than one topic) and implement the questions with their students in one of five ways: as an exam (closed-book or take-home), as a quiz, as a homework assignment, or as in-class formative feedback (group discussion). All participating faculty were employed as public university instructors in the U.S.

In total, 730 individual students responded to 3604 questions in this experiment. Two iterations of data cleaning were conducted prior to detailed analysis. First, any question without a recorded answer or an ISSE score was removed from the dataset. This resulted in the removal of 493 partial question responses and a final dataset containing 569 individual students. On the second step, for those individual students who had responded to more than one question format, one set of responses (a single format) was randomly selected. This was done in order to remove any between group correlations. This resulted in removal of 1105 questions. In final data set, an average ISSE score and competence (correctness) was calculated for each of the 569 individual students. Students' demographics were not recorded as part of data collection process.

4.2 Self-efficacy measurement

A standard practice of measuring self-efficacy strength is to employ a unipolar structure on a 100-point scale, ranging in 10-unit intervals from zero (cannot do) through intermediate degrees of assurance, 50 (moderately certain can do) to complete assurance 100 (certain can do). Based on the theory, it is also possible to retain the same scale structure and descriptors but use single unit intervals ranging from zero to 10. However, scales that use only a few steps should not be used because they are less sensitive and reliable [1].

In this study, to capture ISSE, students were asked to rate their ISSE immediately after they had answered each individual question, on a 10-point scale ranging from 1 (basically guessed) to 10 (very sure). This method resembles the self-efficacy scale proposed by Bandura and adopted in other investigations of self-efficacy [6, 33, 34].

4.3 Statistical analysis

The data in this present study was obtained through a multivariate design experiment. As it was mentioned earlier, two dependent variables, ISSE and competence were recorded for each individual student. The interaction of these two dependent variables (research objectives—question 1) was analyzed by visualizing the data and using the Pearson correlation. Two factors were manipulated to observe their relation with ISSE and competence: question format with 3 levels (interpretation, ranking task and multiple-choice) and implementation type with 5 levels (closed-book exam, take-home exam, in-class quiz, homework, and group discussion). To find possible main effects (research objectives—questions 1 and 2), the two dependent variables were analyzed in a series of multivariate analysis of variance (MANOVA) with the question format and implementation type as the between subject factors. This was followed by post hoc pairwise comparisons using Tukey HSD adjustments. Analyses were conducted using SPSS version 23 and R version 3.0.3.

5. Result

5.1 Interaction of ISSE and competence

Students' competence on conceptual engineering problems and its interaction with ISSE is investigated. To evaluate this relationship, the ISSE scores are plotted against the competence (measured as percentage of correct answers) for each student (Fig. 1).

The distribution of student responses by ISSE (M = 6.75 and SD = 2.04) and the competence (M = 57.21 and SD = 37.95) can be divided into four regions which necessitates additional scrutiny. Quadrant 1 includes students who demonstrate better performance in answering conceptual questions but lack ISSE ($r = -0.069$, $n = 101$, $p = 0.490$). Quadrant 2 includes students with a high competence and ISSE solving conceptual problems ($r = 0.224$, $n = 196$, $p = 0.002$). Quadrant 3 includes

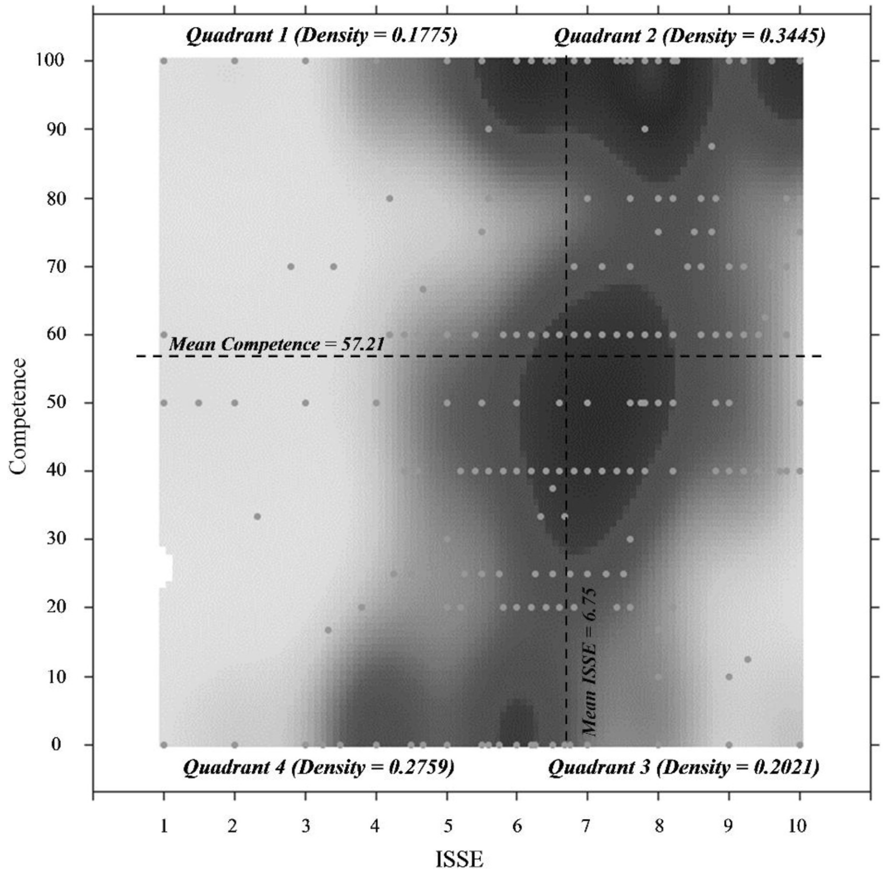

Fig. 1. Interaction of competence and ISSE.

students with high ISSE but lower levels of correctness solving conceptual questions (r = –0.093, n = 115, p = 0.325) and Quadrant 4 includes students who demonstrated low levels of ISSE and correctness solving conceptual problem solving (r = 0.132, n = 157, p = 0.100). Looking into correlations between ISSE and competence in each of the quadrants demonstrates that while students in Quadrants 1, 3 and 4 are not capable of accurately mapping their efficacy beliefs with their actual performance, students in Quadrant 2 (the one with highest density and the best performance) are more successful in gauging these two variables.

Figure 1 illustrates that while the distribution of ISSE by correct percentage is horizontally symmetric, it is asymmetric vertically. Indeed, inspection of the ISSE and competence distribution shows that 52.19% of students (n = 297) had a correct percentage of more than 50 and 47.81% of them (n = 272) had a correct percentage of less than 50. However, 76.45% of students (n = 435) reported an average ISSE of 5.5 or higher, while just 23.55% (n = 134) reported an average ISSE below 5.5.

5.2 Contextual factors

5.2.1 Question format

Table 1 presents descriptive statistics for students' performance by question format. MANOVA is performed to test whether or not the question format affects ISSE and competence. MANOVA results show a main effect of question format (F (4, 1130) = 5.285, p < 0.0005; Wilk's Λ = 0.964, partial η^2 = 0.018). It is found that question format has a statistically significant effect on both ISSE (F (2, 566) = 5.817, p = 0.003; partial η^2 = 0.020) and competence (F (2, 566) = 6.845, p = 0.001; partial η^2 = 0.024).

Looking at pairwise comparisons, results of Tukey HSD post hoc test reveal that ISSE scores are significantly higher for interpretation questions when compared to ranking tasks (p = 0.002) and multiple-choice question (p = 0.026). Pairwise comparison post hoc tests on competence reveal that rates of correct responses are significantly lower for ranking tasks when compared to multiple-choice questions (p = 0.004) and interpretation questions (p = 0.006).

5.2.2 Implementation type

Table 2 presents descriptive statistics for students' performance by implementation type. MANOVA results indicate that there is a main effect of implementation type (F (8, 1126) = 6.970, p < 0.0005; Wilk's Λ = 0.908, partial η^2 = 0.047). Implementation type has a statistically significant effect on both ISSE (F (4, 564) = 6.255, p < 0.0005; partial η^2 = 0.042) and competence (F (4, 564) = 7.087, p < 0.0005; partial η^2 = 0.048).

Tukey HSD post hoc tests reveal that ISSE scores are significantly higher for group discussions when compared to closed-book exams (p = 0.004) and in-class quizzes (p = 0.043). ISSE scores are also significantly higher for take-home exams compared to closed-book exams (p < 0.0005) and in-class quizzes (p = 0.015). Pairwise comparison post hoc tests on competence reveal that rates of correct responses are significantly higher for group discussions when compared to homework (p < 0.0005) and in-class quizzes (p = 0.020). It is also found that these rates are significantly lower for homework compared to closed-book exams (p < 0.0005), take-home exams (p = 0.001) and in-class quizzes (p = 0.002).

6. Discussion

6.1 Interaction of ISSE and competence

Figure 1 presents evidence in support of Bandura's argument that different people with similar skills may perform poorly, adequately or extraordinarily,

Table 1. Mean and standard deviation values for the dependent variables of each question format

Dependent Variable	Interpretation (N = 82)		Ranking Task (N = 171)		Multiple-Choice (N = 316)	
	M	SD	M	SD	M	SD
ISSE	7.39	2.06	6.47	2.07	6.74	1.99
Competence	64.27	47.56	48.60	36.35	60.05	35.22

Table 2. Mean and standard deviation values for the dependent variables of each implementation type

Dependent Variable	Closed-Book Exam (N = 138)		Take-Home Exam (N = 84)		In-Class Quiz (N = 230)		Homework (N = 88)		Group Discussion (N = 29)	
	M	SD	M	SD	M	SD	M	SD	M	SD
ISSE	6.29	2.25	7.44	1.92	6.64	2.11	6.80	1.48	7.74	1.33
Competence	62.32	43.90	61.49	29.95	57.27	38.67	39.77	31.28	73.02	21.33

depending on fluctuations in their beliefs of personal efficacy. Indeed, each horizontal line on this graph represents individuals with equivalent average question performance but with highly variable efficacy beliefs. Ideally, students would recognize when they are incorrect and have lower self-efficacy on problems they do not understand. This, arguably, is an important facet of professional engineering practice; that it is very important to know when you are right or wrong. It is suggested that an educational setting should strive to promote this kind of awareness. For example, one might expect that students would express high efficacy beliefs when they have robust conceptual knowledge (Quadrant 2 in Fig. 1), and low efficacy beliefs when they demonstrate weak conceptual knowledge (Quadrant 4 in Fig. 1). Students should be able to distinguish between what they know and do not know in the self-reported efficacy. However, there are situations where poor calibration occurs in the data. Here, calibration refers to how well self-efficacy correlates to actual performance on corresponding tasks [19]. When students judge that they are capable of performing a task but do not perform it very well (Quadrant 3 in Fig. 1), or when they judge that they are incapable of performing a task but then perform it very well (Quadrant 1 in Fig. 1), they are poorly calibrated due to the lack of correspondence between ISSE and performance. Students who underestimate what they can do may shy away from active engagement and be reluctant to attempt a task thereby delaying skill acquisition [19].

This failure in calibration is clearly demonstrated by the unequal distribution of ISSE and competence. Ideally, one might anticipate higher concentrations of responses in Quadrants 2 and 4 and lower concentrations in Quadrants 1 and 3. However, in the dataset examined, 37.96% of all students (n = 216—sum of Quadrants 1 and 3) are misjudging their power to produce an effect in academic terms. The asymmetry of ISSE distribution about the vertical axis in Fig. 1 is another observation supporting item-specific calibration errors of engineering students. While the distribution of correct response percentage shows that students are almost equally divided into two sections of higher (above 50 percent of correct responses) and lower competence (below 50 percent of correct responses), the distribution of ISSE clearly indicates that students tend to demonstrate poor judgment when asked about their item-specific efficacy beliefs. Students appear to have overly high ISSE, despite the fact that they might not possess the correct underlying conceptual knowledge.

As students engage and progress through knowledge and skill acquisition in a new content area, they should initially present in Quadrant 4 advancing towards and ultimately terminating in Quadrant 2. Student responses in Quadrant 1 require emphasis on increasing their ISSE beliefs while students presenting in Quadrant 3 need to have a more realistic belief related to their current performance and simultaneously emphasizing improvement in their competency. These transitions could be promoted through a constructive learning process with attention to problem format and implementation.

6.2 Contextual factors

6.2.1 Question format

Based on the percentage of correct answers and ISSE scores, as well as pairwise comparison tests, students performed best on interpretation questions. Moreover, students performed better on multiple-choice questions than ranking tasks. In theory, the incongruence between students' self-efficacy and actual performance can arise when students lack task familiarity and do not fully understand what is required to execute a task successfully [19]. This fact is not limited to educational endeavors. For example, studies with infants have shown that when a new action system such as crawling or walking become available, infants require a period of experience with the new skill to make accurate judgments about possibilities for success or failure [35].

While in an academic setting students have been extensively exposed to interpretation and multiple-choice questions, ranking tasks remain comparatively novel. Additionally, the participating instructors have had little to no previous practical experience implementing ranking tasks in a classroom environment, although they have previously used multiple-choice and interpretation questions prior to their participation in this project. Once problem solving skills are developed and routinized in recurring situations, students behave in accordance with what they believe they can or cannot do without giving the matter much further thought [1]. Furthermore, in responding to ranking tasks, students need to combine different skills in order to perform this task. The complexity of this synthesis could have directly influenced students' ISSE ratings and competence. Bandura contended that "solving problems typically require applying multiple cognitive operations and even if the operations are readily recognizable, judgement of cognitive capabilities for a given activity is complicated if some of the operations are thoroughly mastered while others are only partially understood" [1, p. 65].

6.2.2 Implementation type

While students had performed better on closed-book exams compared to in-class quizzes and homework, they stated lower levels of ISSE respectively. This demonstrates that anticipated results and contextual anxieties could influence efficacy beliefs. Exams are usually weighed heavier in the overall grade of students' performance and therefore, they are coupled with higher levels of anxieties [36]. An item-specific measure of self-efficacy confirms that while students might be well prepared for exams, they feel less confident in their responses. The results are different in a take-home exam setting, where students performed better and they were more confident in their performance.

The highest level of efficacy beliefs and performance are evident in problems completed as a group. In theory, self-efficacy often refers to one's perceived capabilities, but many educational (and professional) situations require that students work in teams to accomplish a task. Collective self-efficacy is defined 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" [1, p. 477]. Prior research on self-efficacy in a collaborative environment suggests that team context, task complexity, and individual characteristics impact learner efficacy beliefs [37]. Such that, collective self-efficacy is not simply the average of individuals' self-efficacy but rather refers to what the members believe the group can accomplish by working together [19]. This is evident in the present study, where the highest rate of competence and the highest level of self-efficacy intersect during group discussions. Consequently, working as a group not only considerably improved the ability to accomplish necessary tasks but also resulted in higher levels of ISSE.

6.3 Implications for teaching

The development of ISSE is, to the knowledge of the authors, never an explicit outcome of a class even in the presence of a vast body of research that suggests self-efficacy development is a critical element of academic success. The four principals of self-efficacy development (enactive mastery experiences, vicarious experiences, verbal persuasion and physiological and affective states) may provide hints at how to accomplish this.

Problem solving in a general form can be categorized as a mastery experience as students feel more efficacious when they feel prepared to correctly solve problems and less efficacious when they feel unable to do so. However, looking at problem solving in a conceptual context, one can observe the influence of the other three sources of efficacy beliefs as well. While problem solving ability affects the relationship between competence and ISSE, it does not operate as a dispositional factor. This paper's investigation into the influence of contextual factors on students' efficacy beliefs provides evidence that students with similar skills self-report a wide variance of ISSE and perform differently according to question format and question implementation.

The findings presented herein related to question format could be associated largely with mastery experiences and to a smaller extent physiological and affective states. Enactive mastery experiences are the most influential source of efficacy information because they provide the most authentic evidence of whether one can ultimately be successful at a given task. Here, "successes build a robust belief in one's personal efficacy and failure undermine it" [1, p. 80]. Indeed, in mastery experiences past performance accomplishments and previous attainment help students to develop efficacy beliefs.

In the dataset examined, students performed best on traditional interpretation questions. This dataset includes university students who likely have a long history of encountering and attaining success with interpretation questions. These two factors may have contributed to students having higher efficacy beliefs and better problem performance. This is further evidenced by the comparison of ranking tasks and multiple-choice questions, in which multiple-choice questions were associated with higher ISSE and higher rate of correct answers. Previous experience with these types of problems were likely achieved through previous mastery experiences.

Physiological and affective states could also justify the difference in students' performance by problem format. As mentioned previously, solving problems typically requires applying multiple cognitive operations and students' judgment about their power to produce a desirable effect is dependent on their underlying cognitive capabilities. This is a complicated process, as is the case of approaching conceptual engineering problems in a novel context (ranking tasks) requiring a combination of multiple skills. Self-efficacy beliefs serve as a filter through which new information is processed and therefore, those who lack confidence in their cognitive capabilities may falsely interpret their anxiety as a sign of incompetence.

The findings related to implementation context are even more complex, because they seem to touch on all four principle sources of efficacy beliefs. For example, group work in a class setting can be characterized by complex social dynamics that are dependent both on the nature and difficulty of the problem as well as the group dynamics. As such, in addition to mastery experiences, vicarious experiences and verbal persuasion likely played a role. Through vicarious experiences, students gauge their capabilities in relation to the performance of others.

This can occur in a group discussion in which students may observe a classmate succeed at a challenging conceptual task and then may be convinced that they can achieve at a similar level. In a verbal persuasion experience, support from others (parents, teachers and peers) whom a student trusts can also increase a student's efficacy beliefs. This can also be facilitated by group discussions in which students can explain concepts to each other in order to solve problems. In a group discussion students can collectively reinforce each other's beliefs that they have the correct answer. This is a unique attribute of group discussion that is not inherent in other implementation types.

Moreover, in theory, integration rules that individuals use when weighting and interpreting efficacy-relevant information may be divided into four categories: (1) additive (the more sources available, the more efficacy beliefs are enhanced), (2) relative (one source is stronger than another), (3) multiplicative (two sources present an interactive effect) and (4) configurative (the strength of one source depends on the presence of others). The underlying mechanism for each of these integration rules depends largely on personal and contextual factors [38]. For the case of group discussion, sources of ISSE appear to have an additive and multiplicative interaction, making group discussion the best implementation type for promoting ISSE and competence. However, comparing closed-book exams with take-home exams demonstrates the fact that physiological and affective states can relatively mask the influence of other sources. In take-home exams not only do students have higher rate of correct answers, but they also possess higher levels of ISSE as compared to closed-book exams.

Comparing homework questions with a take-home exam questions may shed further light on the configurative integration of self-efficacy principles. Both cases seem to be influenced by mastery experience as students most probably have experienced previous attainments in either implementation type. However, since exams typically represent a larger portion of the cumulative grade for a course, students who are internally motivated by grades are emotionally engaged to achieve at a higher level. Therefore, these students may expend more time and energy on the problems in a take-home exam when compared to homework problems. In other words, when students are incentivized differently they perform differently. Higher competence and higher ISSE in take-home exams may be a tangible result.

In a typical classroom, students may not initially possess conceptual understanding or may demonstrate low ISSE for solving conceptual questions (Quadrant 4 in Fig. 1). Through the adoption of a constructive learning process, affected by contextual factors, students will gain new information and will move toward success. Indeed, as their skills become more refined, their competence and ISSE should increase (Quadrant 2 in Fig. 1). Classroom reform efforts are largely focused on increasing the level and quality of active learning. Michelene Chi, a noted researcher in this area, developed the ICAP hypothesis, which suggests Interactive, Constructive, Active, and Passive Learning activities are decreasingly effective [39]. An example of passive learning is taking notes without any substantial cognitive engagement in that process. In contrast, an example of interactive learning is groups of students working on problems together that are harder than they can solve individually. The results of the present study confirm that in an interactive learning setting, students not only develop competence but also gain higher self-efficacy beliefs.

7. Limitations

The present study has a number of limitations. Students' demographics (such as gender, experience (years at school) or ethnicity) were not collected as part of data collection process, making it impossible to look at these covariates as between subject factors. It would be useful for future studies to examine whether the influence of question format and implementation type would vary among different demographic cohorts. Furthermore, the current study used four principals of self-efficacy development and their integration rules to discuss parts of findings. While these elements shaped a robust framework to analyze the results, they were not directly measured as part of this study. Pursuing this study with direct measurement of four principals of self-efficacy would also be a worthy research objective.

8. Conclusion

This paper investigated the self-efficacy beliefs and competence that students demonstrate in their responses to conceptual engineering problems. The present study used a 10-point scale to record the self-reported ISSE strength of students and used the correctness of responses as a measure of competence. Since self-efficacy theory has yet to be applied to item-specific conceptual questions, this study is unique in showing how a well-accepted theoretical construct can work in a conceptual engineering problem-based context. This study pursued three research objectives. Those objectives and a summary of the research findings are documented in Table 3.

The interaction of competence and ISSE was

Table 3. Summary of research findings

Objective	Findings on ISSE* and competence**
(1) ISSE vs. Competence	• Students with similar competence self-reported a wide variance of ISSE. • Many student answers lacked correspondence between ISSE and competence (poor calibration).
(2) Influence of Question Format	• Question format significantly affected ISSE and competence. • Students performed best on interpretation questions (both ISSE and competence). • Students performed better on multiple-choice questions than ranking tasks (both ISSE and competence)
(3) Influence of Implementation Type	• Implementation type significantly affected ISSE and competence. • Students performed more competent on close-booked exams compared to in-class quizzes and homework, but they stated lower levels of ISSE respectively. • Students performed better on take-home exams than closed-book exams (both ISSE and competence). • The highest level of ISSE and competence is achieved through group discussions.

* Item-Specific Self-Efficacy. ** Correctness of responses.

investigated as the first objective and it was confirmed that students with similar skills self-report a wide variance of ISSE. It was also suggested that a considerable percentage of all students are poorly calibrated because of the lack of correspondence between ISSE and performance. Indeed, almost 38% of all students misjudged their power in producing academic effects. To understand how instructors might tackle this problem, the role of contextual factors was investigated as the second and third objectives. In theory, self-efficacy is not a dispositional factor but it is varied within different contexts. One of the factors that could govern the relationship between self-efficacy and competence is problem solving. This study demonstrated that problem solving and conceptual understanding could be influenced by the nature of problem format (objective 2) and problem implementation (objective 3). Finally, considering contextual factors, the influence of self-efficacy principle sources on students' interpretation of their efficacy beliefs and subsequent competence was investigated. It is undeniable that the association among problem format, problem implementation and self-efficacy beliefs would be mediated by sources of self-efficacy beliefs. The overall findings of the current study support Bandura's theory of self-efficacy in an academic setting and shed further light on the interaction of self-efficacy and competence in solving conceptual engineering problems.

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