Investigating Pre-Service Science Teachers' Self-Efficacy Beliefs for Teaching Science Through Engineering Design Processes

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ARTICLE INFO	ABSTRACT
	The school system in Oman faces a problem in educating students in integrated science, technology, engineering and mathematics activities. This statement, in part, stems from science teachers' preparation programs. This study was aimed to close a research gap in Oman by investigating science pre-service (trainee/student) teachers' self-efficacy beliefs for teaching science by using engineering design processes. A self-efficacy beliefs for teaching as engineering design questionnaire was developed and utilized for measuring science trainee teachers' self-efficacy beliefs for teaching science by engineering design methods. A descriptive approach with quantitative data collection was used as a design of the study. A sample of 73 students at Sultan Qaboos University participated voluntarily. The results showed that student teachers believed themselves to be highly successful in teaching science. BSc program trainee teachers had higher perceptions of themselves as highly successful in teaching science with regard to personal self-efficacy beliefs and in two scales in outcome expectations for science teaching in the new manner than did trainee teachers with a teacher qualification diploma. Regarding gender and major, there was no statistically significant difference in trainee teachers' self-efficacy beliefs. Contributions to research and future perspectives of the study findings on improving science teaching and learning are discussed. **Keywords:** pre-service science teachers, self-efficacy beliefs, engineering design process, Sultanate of Oman

INTRODUCTION

Over the last few decades, Oman has experienced a massive change in its education system, including curriculum reforms and teaching/learning processes. This reform includes using such new curricula as Cambridge in science and mathematics, and integrating the science, technology, engineering, and mathematics (STEM) education program designed by Rolls-Royce UK as an interdisciplinary approach based on real-world applications (Oman Educational Portal, 2019). This was done because students were not achieving high academic scores. For example, in the trends in international mathematics and science study (TIMSS) 2019, the average science score of eighth-grade Omani students was 457, significantly lower than the average of 500, with Oman ranking 30th of the 64 participating countries (Mullis et al., 2020). Eighth-grade students reported their teachers' emphasis on science investigations in half the lessons or more, with an average score of 458, significantly lower than the TIMSS average of 492 for highlighting science investigations. TIMSS 2019 also showed that eighth-grade Omani students' attitudes towards science were on average 454, lower than the international average of 524. Some studies have suggested that low student

achievement reflects student effort, social context, and the teachers' role in the school (Abou-Assali, 2014). One study assumed that the teacher's instruction methods affect students' outcomes (Shahat et al., 2022a). Research on teaching and learning provides broad evidence that learning and interest-development are more effective when a student is actively engaged in the learning process rather than merely receiving knowledge (Sezgin Selcuk et al., 2011). In most countries, considerable attention has recently been given to applying next generation science standards (NGSS), linked to integrating STEM education. The concept of STEM education has spread worldwide (Zaher & Damaj, 2018). Since 2017, Oman has been using STEM as an enrichment program for students (Oman Educational Portal, 2019).

Therefore, Oman's current vision of education focuses on an effective school that provides instructional quality for each learner (Oman-2040, 2020). Accordingly, from the beginning of 2018, the STEM education program was implemented as enrichment activities by the Ministry of Education in Oman (Oman Educational Portal, 2019). Its goals are to make learning more enjoyable, connected and relevant for the students' future success, and subsequently for Omani society. However, the currently applied science curriculum lacks

integration, so providing STEM-based curricula as formal curricula together with preparing science teachers in the proper application of these curricula is essential. Thus, finding effective teaching strategies and models for developing pre- and in-service teachers' quality of instruction is important in improving achievement and learning processes. For this, it is necessary to provide practical and applied school training to equip distinguished science teachers with a high level of professional knowledge and expertise, and then measure their influence on students' learning outcomes (Oman-2040, 2020). To reach the STEM program's aims, it is necessary to address both the inadequate number of teachers skilled in education of these STEM subjects, and the quality of instruction by, and the science teacher's commitment to, developing a systematic scientific approach based on engineering design skill methods.

Teachers' actions in the classroom are generally affected by their self-efficacy beliefs (Bandura, 1989). Hoy et al. (2009) clarified that teachers' beliefs play a crucial role as cognitive filters that guide their perception and actions in the classroom. These beliefs influence their practice in classroom situations (Shahat et al., 2022b). Research has revealed the importance of teachers' beliefs in the concept of learning and teaching, the curriculum and its content, their role in the classroom and the students' impact on their planning for instruction (Kitsantas & Baylor, 2001), curriculum implementation (Cronin-Jones, 1991), classroom management (Gurcay, 2015), teaching strategies (Hoy et al., 2009), and assessment (Shahat et al., 2022b).

If we accept that the TIMSS results reflect the actual level of Omani students' achievement in science, there is a need to investigate the low results (Shahat et al., 2022a, 2022b). One way to do so is to study in depth the pre- and in-service teachers' beliefs, especially those regarding the teaching process (Smolleck et al., 2006). The current study's researchers acknowledge no recent attempt in Arab countries to explore student teachers' self-efficacy beliefs for teaching science by using engineering design processes. Thus, this study examined trainee teachers' self-efficacy in teaching science in this manner. It is the first to deal with all these aspects. It has the potential to give an overview of the current situation of trainee science teachers. It will show the relationship between these beliefs and demographic variables such as the students' gender, major and preparation program. It should lead to the educational success of trainee science teachers. It is based on the goal that improved education can achieve academic success. Consequently, this will influence their students' success in STEM programs in the future, which is of high importance for Oman.

SCIENCE TEACHER EDUCATION IN OMAN

Bachelor Program of Science Teacher Education

This program aims to provide the educational field with science teachers who have scientific knowledge and are qualified to teach general sciences in basic education schools (grades 5-10) and biology, physics and chemistry in post-basic education schools (grades 11-12). The science teachers' program at Sultan Qaboos University is designed to be

completed in four years (eight semesters) (Al Barwani & Bailey, 2016).

The program comprises three parts: a specialized component 60%, an educational component 30%, and a cultural component 10% of the total credit hours (Public and Private Universities in Oman, 2021). It includes a focused academic discipline of the courses at the College of Science, which provides the candidates with specialized scientific knowledge and a deep understanding of the enquiring nature of science. Moreover, professional preparation at the College of Education enables students to practice their work as 'distinguished' teachers.

There is cooperation among faculties in integrating the Cambridge science curricula, which are currently implemented in Oman with the educational courses (Shahat et al., 2022a). All these courses focus on science, mathematics, technology and psychology, and on the foundation and leadership role of education. During the preparation period of the program, the student-teacher is exposed to the experience of field training through which he or she learns to experiment with the effectiveness of the teaching skills they have learned (Shahat et al., 2022a).

In 2016, the BSc at Sultam Qaboos University was recognized by the National Science Teachers Association (NSTA) and accredited by the National Council Accreditation of Teacher Education, which is now known as the Council for the Accreditation of Educator Preparation. This accreditation gives the science teacher program in Oman and the region a high international-quality standard, which has been recognized in the quality of teaching and learning of science education in Omani schools, resulting from the new trends in the discipline (Al-Balushi et al., 2020b).

Teacher Qualification Diploma

There is a parallel program called the teacher qualification diploma (TQD) with the aim of preparing qualified teachers for teaching in two semesters after receiving their BSc from arts, science and technical colleges. This program focuses on pedagogical knowledge field training in public schools (Shahat et al., 2022a).

THEORETICAL BACKGROUND

Teaching Science Through Engineering Design-Based Activities

Considerable attention has been given to applying NGSS (Malkawi & Rababah, 2018), according to which achieving a high-quality science education requires developing students' skills in engineering design (Banko, 2013). Evidence has shown that active learning enhances student performance (Freeman et al., 2014) and literature reviews on teaching and learning have demonstrated that teachers' pedagogical knowledge of integrated STEM education activities, focused on scientific concepts, affects student learning, attitudes and engineering habits of mind (Guzey et al., 2016; Hudson et al., 2015).

Using engineering design-based activities in the classroom helps students to strengthen knowledge of science, technology and mathematics (Thibaut et al., 2018), involves an authentic

context (English & King, 2015) and works cooperatively to solve real problems (Dumas et al., 2016). Engineering design activities are highly related to communication, as protocols have to be written, arguments have to be developed, and group discussions occur (Hoeg & Bencze, 2017). They also help test hypotheses, show multiple representations, provide numerous solutions (Li et al., 2016), communicate with social processes and foster motivation for learning (Gero & Danino, 2016). Yesilyurt et al. (2021) indicated that mastery of cognitive content and pedagogy were important sources for trainee teachers' engineering teaching efficacy.

Engineering design methods provide critical foundational ties across STEM disciplines, allowing students to comprehend how numerous concepts, techniques, and tools can be applied to complicated problems with multiple solutions (English, 2017). With these features, engineering design seems a promising means to support STEM learning. In addition, teachers acquire basic information on engineering (Felix & Harris, 2010). As a result, schools are encouraged to support the integration of such knowledge and abilities with the practices needed to engage in scientific inquiry and engineering design (NRC, 2012). However, without offering high-quality instruction by science teachers in the classroom, it will be impossible to reach the goals (Shahat et al., 2022b).

There are three main models for engineering design as instructional models for teaching STEM programs, including learning by design (Koehler & Mishra, 2005), design-based research (Anderson & Shattuck, 2012), and design-based modelling (Penner et al., 1998). Engineering design can be defined as "an activity that involves the construction of a physical product that solves a human problem" (Marulcu & Barnett, 2013, p. 1828). Marulcu and Barnett (2013) identified the steps of engineering design that we used in developing our questionnaire, as follows:

1. identifying a problem;
2. researching possible solutions;
3. picking the best solution;
4. building a prototype;
5. testing the prototype; and
6. repeating any steps needed to improve the design.

Engineering design is not yet standard practice in many science classrooms. In part, this happens in Oman because science teachers might lack guidance or training in designing investigations in ways that facilitate students' practising and learning to enquire and think critically, mathematically and computationally about evidence and their design and investigation (Ambusaidi & Al-Balushi, 2015). This is in line with the findings of a neighbouring country with a culture similar to that of Oman (e.g., Shahat et al., 2017).

Considering the above perspectives, particularly the standards of NGSS (NRC, 2012) and the high expectations of the Sultan Qaboos University and Ministry of Education in Oman (MoE, 2020), this study is focused on student teachers' self-efficacy beliefs for teaching science with engineering design methods.

Self-Efficacy Beliefs for Teaching Science

Bandura (1989) has linked self-efficacy within observational learning in social cognitive theory. Bandura (1986) defined self-efficacy as

> "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances" (p. 103).

Christian (2017) defined self-efficacy for teaching as

> "teachers' belief in their own ability to foster learning with instructional tactics, is one predictor of classroom effectiveness" (p. 14).

Bandura (1997a, 1997b) identified four sources for self-efficacy:

1. Mastery of experiences interpreted as successful if they raise confidence. However, experiences are interpreted as unsuccessful if they lower confidence (Bandura, 1997b).

2. Vicarious experiences are weaker than mastery of experience in creating self-efficacy beliefs; moreover, when teachers are uncertain about their own abilities or when they have limited prior experience, they become more sensitive to self-efficacy (Bandura, 1997b).

3. Social persuasion means verbal and non-verbal judgments of others. Negative persuasions of teachers can work to defeat and weaken self-efficacy beliefs (Bandura, 1986).

4. Physiological arousal concerning mastery of experiences such as anxiety, stress, and mood states (Bandura, 1986).

Bandura (1986) identified four phases of observational learning:

1. Attention to the required skill, which is affected by the observer's perception on similarity to the model, the competence of the model, and status (Smolleck et al., 2006).

2. Retention requires memory of the skill acquired during mental or physical practices (Christian, 2017).

3. Replication tests the observer's ability to practise the skill (Britner & Pajares, 2006).

4. An external or internal reason to imitate the model (Britner & Pajares, 2006). Self-efficacy affects academic performance by influencing several behavioural and psychological processes (Bandura, 1989).

A metanalysis study indicates that teachers' self-efficacy beliefs influence their commitment to the teaching profession (Shahat et al., 2022a). Teachers with firm self-efficacy beliefs have a positive impact on teaching experiences (Al-Balushi et al., 2020a), instructional quality in the classroom (Holzberger et al., 2013) and students' learning outcomes (Caprara et al., 2006). A science teacher who believes that he can succeed in science learning activities will persevere and be guided by physiological indices that promote confidence as he meets obstacles and works hard to complete his or her activities successfully. In contrast, a teacher who does not believe he can

succeed in science learning activities will avoid them and will not do his best if he cannot avoid them (Britner & Pajares, 2006). The influence of teachers' demographic characteristics, such as gender and teaching experience (Shahat et al., 2022a) and course of study (Basith et al., 2020), on these beliefs has been investigated. Srikoom and Faikhamta (2018) revealed that gender and teaching experience influence self-efficacy, beliefs, and attitude about STEM education. Another recent study showed that student teachers who possess STEM teaching experience have higher levels of STEM self-efficacy in terms of cognitive concept, affective attitude, and equipped skills (Chen et al., 2021). Using a self-reported instrument, Kang et al. (2018) explored elementary teachers' understanding of the NGSS science and engineering practices. They found teachers engaging their students in engineering design activities, but could not explain how they could involve them in engineering activities. On the basis of the low efficacy beliefs, Hammack and Ivey (2017) suggested enhancing the knowledge and skills needed for engineering design.

Chen et al. (2021) revealed that trainee teachers who had STEM teaching experience expressed STEM interests or participated in STEM-related activities and had great levels of STEM self-efficacy in terms of cognitive idea, emotional attitude and equipped skills. Considering teachers' self-efficacy and concerns about STEM education, Geng et al. (2019) showed that teachers need professional development, pedagogical assistance and curricular tools to apply STEM education in the classroom effectively. A study by Haatainen et al. (2021) demonstrated that teachers' opinions on integrated education and self-efficacy were linked to their experiences with integrated activities and teamwork. In her study, Webb (2015) concluded that mastery of experiences and cultivating a growth attitude through embracing the engineering design process were primarily responsible for self-efficacy increases.

As a first step in measuring self-efficacy beliefs, several researchers have tried to develop instruments to measure them with trainee science teachers (Smolleck et al., 2006; Tschannen-Moran & Hoy, 2001). One of the instruments used, teaching science as inquiry (TSI), was designed on the basis of Bandura's (1986) social cognitive theory and the work of others (Smolleck et al., 2006). TSI also considers the five features of classroom inquiry mentioned above, stated by the NSES (NSTA, 2020). Our study followed the Friday Institute for Educational Innovation (FIEI, 2012) that defines personal self-efficacy as meaning self-efficacy and confidence related to teaching the specific STEM subject; whereas it defines an outcome expectation as a degree to which the respondent believes, in general, actions of teachers can impact student-learning in the specific STEM subject. To date, no study has focused on measuring the Omani student teachers' self-efficacy beliefs for teaching science as engineering design. The present study's findings may help reveal the quality of preparation programs for science teachers at Sultan Qaboos University and its influence on course development and their performance as in-service science teachers at schools. This can be applied to similar situations in other colleges and universities in Arab countries and globally.

Table 1. Sample statistics

Variable		BSc (n=32)	TQD (n=41)
Speciality	Biology	8	20
	Physics	10	3
	Chemistry	14	18
Gender	Female	18	36
	Male	14	5

Research Aims and Questions

The following goals are addressed in this study:

1. Developing an instrument under Oman conditions on teachers' self-efficacy beliefs for teaching science by using engineering design processes.

2. Investigating the actual situation of teachers' self-efficacy beliefs for teaching science by using these methods.

3. Testing the impact of demographic variables (gender, major, and preparation program) on the participating pre-service science teachers' beliefs.

From the presented theoretical background and the goals of this study, the leading research questions (RQs) were:

1. **RQ1:** What is the level of teachers' beliefs related to their efficacy for teaching science by using engineering design processes in the Sultan Qaboos University?

2. **RQ2:** Which demographic characteristics (gender, major, preparation program) have an impact on teachers' self-efficacy beliefs for teaching science by using engineering design processes?

METHODOLOGY

Participants and Settings

A sample of 73 student teachers (~23 years old) from the 4th year from the College of Education, Sultan Qaboos University in Oman, participated in this study. It included student teachers joining the BSc (n=41, **Table 1**, 87.3% of total enrolled students) and TQD (n=32, 64% of total enrolled students) programs at Sultan Qaboos University. All science student teachers participated voluntarily. The sample was selected with official permission from the educational authorities at Sultan Qaboos University through a funded research project focusing on student teachers at Sultan Qaboos University. A descriptive approach with quantitative data collection was used as the study design (Jason & Glenwick, 2016). Relevant demographic student teachers' characteristics were considered, such as gender, major and preparation programs.

Instrumentation

The instrument's self-efficacy beliefs for teaching as engineering design questionnaire (SEBTEDQ) was based on a standardized instrument 'T-STEM survey' (FIEI, 2012) and Marulcu and Barnett's (2013) steps of engineering design and the work of Smolleck et al. (2006) on self-efficacy beliefs for teaching science. We considered in the adaptation the cultural differences, education settings and Arabic language in Oman.

Table 2. Features, dimensions, and items examples of SEBTEDQ. Combined data from BSc and TQD programs

Engineering design model	Personal self-efficacy (PS) example item	Outcome expectancy (OE) example item
Identify the problem	I leave the opportunity for students to identify problems associated with their engineering designs.	I expect students to identify problems associated with their engineering designs.
Finding solutions	I encourage students to collect appropriate data on engineering problems.	Students analyse data and information related to scientific problems.
Planning	I discuss with students the mechanism of evaluating solutions to solve scientific problems.	Students innovate mechanisms to evaluate solutions to solve scientific problems.
Production and testing	I offer students appropriate opportunities to turn forms into testable products.	Students are able to create testable products.
Communicate	I encourage students to present forms to other groups.	Students present forms to other groups.
Improvement	I direct students to benefit from feedback on product development.	Students are busy studying nutrition owing to product development.

Table 3. Range of mean values for each category of the scale. Combined data from BSc and TQD programs

Level of perception	Range of mean value
Very high	4.21-5.00
High	3.41-4.20
Moderate	2.61-3.40
Low	1.81-2.60
Very low	1.00-1.80

The SEBTEDQ was translated and retranslated between Arabic and English by six independent professional translators.

Content validity was considered by comparing the instrument and literature by expert rating in Oman. The experts were asked to judge the correctness and relations of the items to each dimension. Cohen kappa was acceptable with range values between 0.65-0.79. The SEBTEDQ instrument contained for PS=37 items and for OE=31 items used to measure trainee teachers' self-efficacy regarding the teaching of science by using engineering design processes (**Table 2**).

Data Analysis

To evaluate the inter-rater agreement between evaluators, Cohen's kappa (κ) was used. The correlation analyses and confirmatory factor analysis (CFA) were used to determine the adapted/developed tests (Field, 2009). Items were coded from too big=5 to very few=1. The coding was reversed for negatively worded items (Aiken, 1997). Mean scores were estimated to answer the RQ1. To answer the RQ2, analyses of variance (MANOVA) were used to investigate the effect of demographic variables (gender, major, and preparation program) on trainee science teachers' self-efficacy beliefs for teaching science by

using engineering design processes. To answer RQ1, the mean value of each item and domain was calculated and then classified into one of five categories: very high beliefs, high beliefs, moderate beliefs, low beliefs and very low beliefs, as shown in **Table 3**. The range of the means was determined according to the following formula (Al-Qamish & Kharbasha, 2009): interval (the highest minus the lowest value [5-1]) divided by the number of options [5]; 4÷5=0.80]; this increment (0.80) was added to the minimum value (1) and the result (1.80) was repeatedly added to the increment until the maximum value of 5.0 was reached (**Table 3**).

Ethical Statement

The study met the requirements of the Human Science Ethics Committee of the Sultan Qaboos University at the time the data was collected, and no ethical review was needed. We complied with data protection legislation and related instructions, and we requested an informed consent from the participants.

RESULTS

This section reports the CFA and reliability of the instrument as well as the analysis of the data collected and responds to the two research questions.

Descriptive Statistics

The results of quality criteria (**Table 4**) revealed acceptable reliabilities: Cronbach's alpha≥0.65 (Griethuijsen et al., 2014) for the two dimensions (PS and OE) and the five steps of

Table 4. Reliabilities of the components of SEBTEDQ. Combined data from BSc and TQD programs

Dimension	Scale	Cronbach's alpha	Number of accepted items	Excluded items
PS	Identify the problem	0.72	7	
	Finding solutions	0.75	6	1
	Planning	0.84	7	
	Production and testing	0.79	4	1
	Communicate	0.79	7	
	Improvement	0.73	5	1
Whole scale		0.93	37	3
OE	Identify the problem	0.81	7	
	Finding solutions	0.80	4	1
	Planning	0.80	6	
	Production and testing	0.75	4	1
	Communicate	0.68	6	
	Improvement	0.77	4	1
Whole scale		0.92	31	3
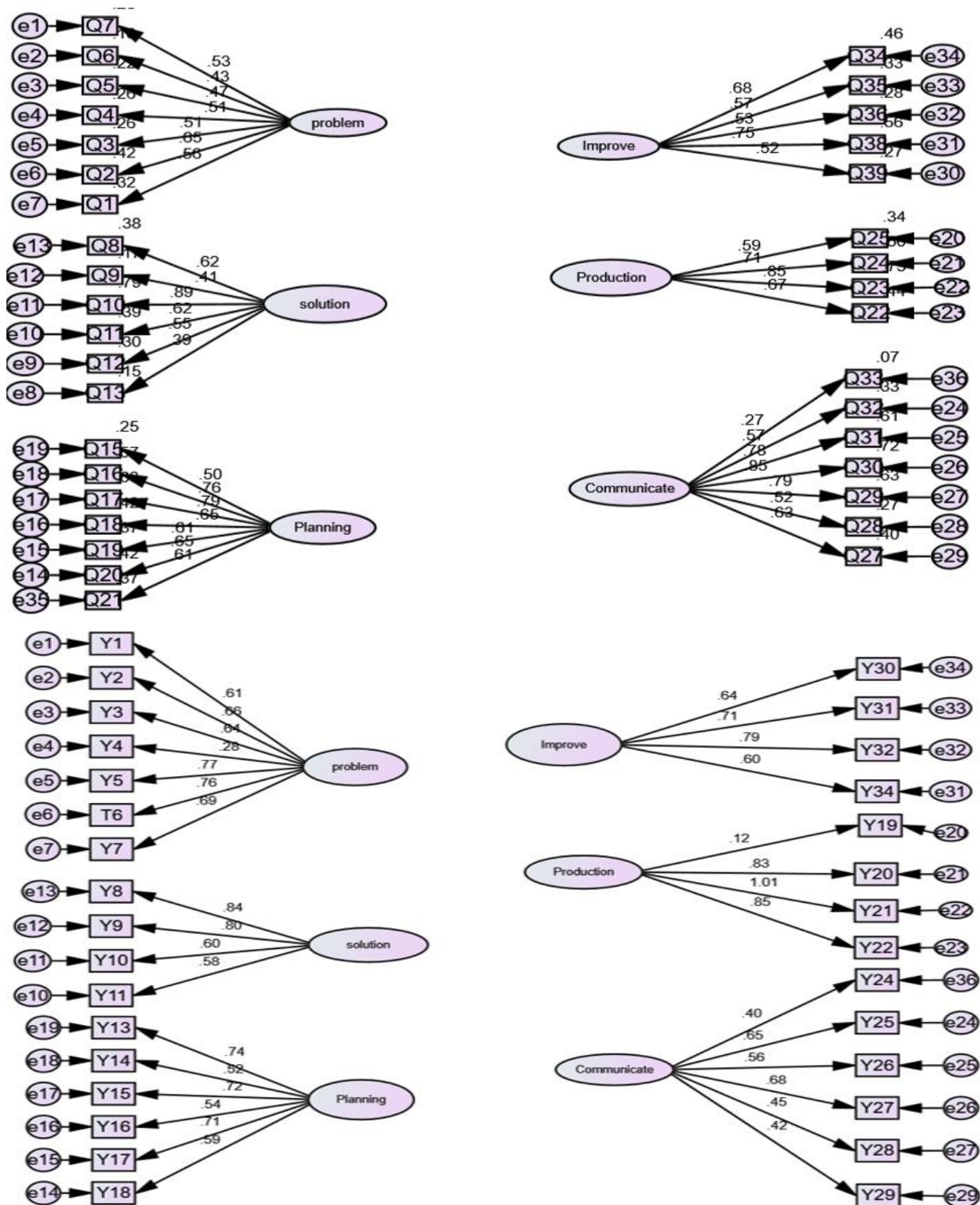
Figure 1. Factor model of components of the two dimensions of teachers' personal self-efficacy beliefs

SEBTEDQ in both dimensions. Bivariate correlations between components of trainee teachers' self-efficacy beliefs for teaching science methodically were tested. Correlations between the components revealed coefficients within a range of values (0.45<r<0.70) for personal self-efficacy beliefs, and within a range of values (0.22<r<0.77) for outcome expectations. The results of CFA confirmed five-factor model for each scale with a general factor model. Intercorrelations between factors were allowed, with coefficients as shown in **Figure 1**.

Response to RQ1:* What is the level of trainee teachers' beliefs related to their efficacy for teaching science by using engineering design processes*?

As shown in **Table 5**, from the PS dimension, the responses to SEBTEDQ indicated the teachers believed themselves successful, with a high level in teaching science by using engineering design processes (M=4.02; SD=0.46). They also perceived themselves as being successful with a high level in

teaching science with engineering design-based methods in the dimension of OE (M=3.93; SD=0.45). **Table 5** illustrates that teachers perceived themselves as moderately and highly productive in all five steps of SEBTEDQ (ranged for PS from M=3.96 to 4.06; for OE from 3.84 to 4.09, in the 'frequently' range), suggesting that most of them have SEBTEDQ in the range from 'big' to 'too big'.

Table 5. Descriptive statistics for scales of SEBTEDQ. Combined data from BSc and TQD programs

Scale/item	Mean	SD	LB
I leave the opportunity for students to identify problems associated with their engineering designs.	4.03	0.72	High
I encourage the students to ask questions related to scientific problems.	4.37	0.63	Very high
I instruct the students to explore scientific problems related to daily life.	4.21	0.84	Very high
I provide general and meaningful experiences to allow them to explore scientific problems.	4.00	0.97	High
I offer the possibility to students to identify the criteria and factors for solving scientific problems	3.86	0.75	High
I help students to revise scientific problems and extract criteria and factors for solving them.	4.05	0.76	High
Feeling confident enough to welcome students' questions about scientific problems.	4.37	0.73	Very high
Identify the problem	**4.12**	**0.47**	**High**
I encourage students to collect appropriate data on engineering problems.	4.26	0.74	Very high
I provide students the information that supports to find out engineering problems.	4.00	0.83	High
I provide opportunity for students to write down their ideas about possible solutions to the engineering problems.	4.32	0.74	Very high
I support unfamiliar solutions to engineering problems.	4.08	0.79	High
I understand very well the concepts of engineering design to teach it effectively	3.99	0.82	High
I have the ability to train students to inquiry about engineering problems.	3.75	0.76	High
Finding solutions	**4.06**	**0.52**	**High**
I discuss with students the mechanism of evaluating solutions to solve scientific problems.	3.88	0.74	High
I have the necessary skills to guide students in adequate planning to solve scientific problems.	3.78	0.82	High
I Provide students with opportunities to be critical decision-makers upon planning to solve scientific problems.	3.88	0.86	High
I have necessary skills to train students to use diagrams and illustrations while planning to solve scientific problems	3.90	0.80	High
I can train students to use diagrams and mind maps to collect the raised solutions.	4.19	0.86	High
I pay attention to training students in selection mechanism for the appropriate solution from the proposed solution.	4.03	0.74	High
I believe that I can train students to use models while planning to solve scientific problems.	4.03	0.83	High
Planning	**3.95**	**0.57**	**High**
I offer students appropriate opportunities to turn forms into testable products.	3.90	0.77	High
I believe that I can explain success criteria in solving scientific problems.	4.11	0.76	High
I have the necessary skills to train students on the product testing mechanism.	3.85	0.90	High
I am constantly improving my practice of training students to produce and test solutions to scientific problems.	4.21	0.83	High
Production and testing	**4.01**	**0.64**	**High**
I can invite my colleagues to evaluate my performance in teaching engineering design.	4.19	0.81	High
I'm pretty sure of my ability to answer the questions of the students about engineering design.	3.92	0.84	High
I encourage students to exchange ideas and information related to scientific problems	4.29	0.71	Very high
I provide the opportunity to discuss previous knowledge and experience related to scientific problems.	4.29	0.77	Very high
I encourage students to present forms to other groups.	4.48	0.64	Very high
I do not know what to do to rekindle the students' attention to scientific and engineering challenges.	4.07	0.77	High
I can invite my colleagues to evaluate my performance in teaching engineering design.	3.00	1.21	Moderate
Communicate	**4.03**	**0.55**	**High**
I direct students to benefit from feedback on product development.	4.25	0.72	Very high
I know what I shall do to increase students' interest in developing scientific designs.	3.75	0.92	High
I offer the opportunities for students to discuss problems related to the product.	4.16	0.92	High
I suspect whether I have the necessary skills to teach engineering design.	3.79	0.70	High
I set out–with the students–the major points for developing engineering solutions.	3.88	0.88	High
Improvement	**3.96**	**0.58**	**High**
PS	**4.02**	**0.46**	**High**
I expect students to identify problems associated with their engineering designs.	3.88	0.74	High
I expect that students can take the initiative to ask questions related to scientific problems.	3.88	0.78	High
Students are busy in exploring the scientific problems related to daily life.	3.89	0.87	High
It is possible to overcome inadequate scientific background to identify students' scientific problem through good teaching.	3.93	0.90	High
Students are looking for factors and criteria for solving scientific problems.	3.90	0.76	High
Students can choose questions related to scientific problems they want to investigate.	3.79	0.88	High
Students are busy asking questions related to scientific problems.	3.81	0.72	High
Identify the problem	**3.86**	**0.55**	**High**
Students analyze data and information related to scientific problems.	3.90	0.71	High

Table 5 (Continued). Descriptive statistics for scales of SEBTEDQ. Combined data from BSc and TQD programs

Scale/item	Mean	SD	LB
Students are looking for information that supports the exploration of scientific problems.	4.07	0.80	High
Students are busy writing down their ideas about possible solutions to scientific problems.	3.99	0.77	High
Students can extract the concepts related to scientific problems.	3.92	0.81	High
Finding solutions	**3.96**	**0.61**	**High**
Students innovate mechanisms to evaluate solutions to solve scientific problems.	3.88	0.83	High
The teacher is generally responsible-in general- for teaching students the planning for solving scientific problems	3.85	0.86	High
Students can take critical decisions when planning to solve scientific problems.	3.68	0.91	High
There is a close relationship between students' learning of the planning mechanism to solve scientific problems and the efficiency of their teachers in teaching them.	4.03	0.92	High
Students can master how to use the diagrams and mind maps to collect the proposed solutions	3.78	0.94	High
Students can use models while planning to solve scientific problems.	3.96	0.82	High
Planning	**3.86**	**0.62**	**High**
Students are able to create testable products.	4.00	0.97	High
When students do better than usual at producing solutions to scientific problems, it is usually because the teacher puts in extra effort.	3.99	0.79	High
The minimal learning of the students in the product testing process in general can be attributed to their teachers.	3.93	0.85	High
I invite students to create possible solutions to scientific problems and test them.	3.88	0.91	High
Production and testing	**3.94**	**0.67**	**High**
The extra effort that the teacher makes in teaching engineering design has a limited effect on student learning.	3.37	1.12	Moderate
When the learning of the student in engineering design is greater than expected, this is due to a teacher using more effective teaching strategies.	3.86	0.82	High
Students come up with new ideas and information related to scientific problems.	3.97	0.74	High
When the student's progress with low achievement is more than expected in presenting solutions to scientific problems, that is usually due to the extra attention that the teacher provides.	3.90	0.83	High
Students present forms to other groups.	4.08	0.92	High
If parent notices that his son is showing an interest in engineering design problems, credit goes to his teacher.	3.86	0.78	High
Communicate	**3.84**	**0.54**	**High**
Students are busy studying nutrition owing to product development.	3.79	0.83	High
I asked the students to pay attention to developing the engineering designs.	4.19	0.75	High
Students are discussing problems related to the product.	4.10	0.80	High
If the students' learning in the mechanism of developing engineering designs is less than expected, it is most likely due to ineffective teaching strategies.	4.29	0.69	Very high
Improvement	**4.09**	**0.59**	**High**
OE	**3.93**	**0.45**	**High**

Note. SD: Standard deviation; LB: Level of belief; n=73

Response to RQ2: What demographic characteristics (gender, major, and preparation program) affect student teachers' self-efficacy beliefs for teaching science by using engineering design processes?

Gender Differences

The results in **Table 6** showed no statistically significant gender differences between the mean scores for teachers on the PS dimension of the SEBTEDQ scale. The MANOVA results, $F_{(1, 71)}=0.66$, $p> 0.05$, also revealed that males and females did not statistically significantly differ on their personal self-efficacy beliefs for teaching science by using the new methodology. The results also showed no statistically significant gender differences between the mean scores of teachers on the OE dimension of the SEBTEDQ scale. The MANOVA results, $F_{(1, 71)}=1.52$, $p> 0.05$, revealed that male and female teachers' outcome expectancy beliefs for teaching science by the new method did not statistically significantly differ from male pre-service teachers.

Table 6. Mean, standard deviation, and MANOVA for SEBTEDQ scale by gender. Combined data from BSc and TQD programs

Scale	Gender	N	M	SD	F	df	P
Identify the problem	Female	54	4.13	0.48	0.05	1, 71	0.81
	Male	19	4.10	0.45			
Finding solutions	Female	54	4.05	0.54	0.14	1, 71	0.70
	Male	19	4.10	0.47			
Planning	Female	54	3.93	0.59	0.35	1, 71	0.55
	Male	19	4.02	0.53			
Production and testing	Female	54	3.94	0.65	2.39	1, 71	0.12
	Male	19	4.21	0.58			
Communicate	Female	54	4.00	0.56	0.42	1, 71	0.51
	Male	19	4.10	0.53			
Improvement	Female	54	3.93	0.59	0.69	1, 71	0.40
	Male	19	4.06	0.54			

Table 6 (Continued). Mean, standard deviation, and MANOVA for SEBTEDQ scale by gender. Combined data from BSc and TQD programs

Scale	Gender	N	M	SD	F	df	P
PS	Female	54	4.00	0.48	0.66	1, 71	0.42
	Male	19	4.10	0.40			
Identify the Problem	Female	54	3.83	0.60	0.61	1, 71	0.43
	Male	19	3.95	0.38			
Finding solutions	Female	54	3.92	0.63	1.27	1, 71	0.26
	Male	19	4.10	0.55			
Planning	Female	54	3.78	0.61	3.70	1, 71	0.06
	Male	19	4.09	0.60			
Production and testing	Female	54	3.92	0.68	0.23	1, 71	0.63
	Male	19	4.01	0.65			
Communicate	Female	54	3.81	0.52	0.65	1, 71	0.42
	Male	19	3.92	0.60			
Improvement	Female	54	4.07	0.62	0.19	1, 71	0.66
	Male	19	4.14	0.52			
OE	Female	54	3.89	0.470	1.52	1, 71	0.22
	Male	19	4.04	0.392			

Preparation Program

Analysis of MANOVA showed a significant effect of the preparation program on trainee teachers' self-efficacy beliefs in engineering designs, Wilk's lambda=0.63, F=2.32, p<0.05, in one or some subscales. **Table 7** showed a significant effect of the preparation program on the PS dimension and most of their scales of the SEBTEDQ: for whole PS, $F_{(1, 71)}=7.34$, p<0.0. However, it showed no significant effect of preparation program for OE, $F_{(1, 71)}=3.19$, p>0.05). Nevertheless, the results showed statistically significant preparation program differences between the mean scores of pre-service teachers on two scales of OE dimension: for identify the problem, $F_{(1, 71)}=5.75$, p<0.05; for finding solutions, $F_{(1, 71)}=7.29$, p<0.05.

Major Differences

MANOVA results in **Table 8** showed no significant effect of major on the two dimensions of the SEBTEDQ and also each scale: for PS, $F_{(2, 70)}=0.77$, p>0.05; for OE, $F_{(2, 70)}=0.26$, p>0.05.

Table 7. Differences between BSc and TQD trainee teachers' self-efficacy beliefs in engineering designs

Scale	Program	N	M	SD	df	F	P
Identify the problem	TQD	41	4.07	0.49	1, 71	1.21	0.27
	BSc	32	4.19	0.44			
Finding solutions	TQD	41	3.95	0.54	1, 71	4.75	0.03*
	BSc	32	4.21	0.46			
Planning	TQD	41	3.80	0.56	1, 71	6.46	0.01*
	BSc	32	4.14	0.55			
Production and testing	TQD	41	3.84	0.66	1, 71	7.69	0.01*
	BSc	32	4.24	0.53			
Communicate	TQD	41	3.84	0.57	1, 71	12.62	0.00*
	BSc	32	4.28	0.43			
Improvement	TQD	41	3.90	0.58	1, 71	1.15	0.29
	BSc	32	4.05	0.57			
PS	TQD	41	3.90	0.48	1, 71	7.34	0.01*
	BSc	32	4.19	0.37			
Identify the Problem	TQD	41	3.73	0.54	1, 71	5.75	0.02*
	BSc	32	4.04	0.53			
Finding solutions	TQD	41	3.80	0.61	1, 71	7.29	0.01*
	BSc	32	4.17	0.55			
Planning	TQD	41	3.74	0.57	1, 71	3.50	0.06
	BSc	32	4.01	0.66			
Production and testing	TQD	41	3.95	0.66	1, 71	.00	0.97
	BSc	32	3.94	0.69			
Communicate	TQD	41	3.85	0.54	1, 71	.04	0.84
	BSc	32	3.82	0.55			
Improvement	TQD	41	4.00	0.51	1, 71	2.28	0.13
	BSc	32	4.21	0.67			
OE	TQD	41	3.84	0.44	1, 71	3.19	0.07
	BSc	32	4.03	0.44			

Note. *Significant at 0.05 level

Table 8. MANOVA for the effect of major on trainee teachers' self-efficacy beliefs in engineering designs. Combined data from BSc and TQD programs

Scale	Specialty	N	M	SD	df	F	P
Identify the problem	Biology	28	4.13	0.48	2, 70	0.25	0.77
	Physics	13	4.04	0.54			
	Chemistry	32	4.15	0.45			
Finding solutions	Biology	28	4.06	0.48	2, 70	0.00	1.00
	Physics	13	4.06	0.51			
	Chemistry	32	4.06	0.57			
Planning	Biology	28	3.84	0.52	2, 70	1.30	0.27
	Physics	13	3.90	0.48			
	Chemistry	32	4.07	0.64			
Production and testing	Biology	28	4.00	0.63	2, 70	0.74	0.47
	Physics	13	3.84	0.78			
	Chemistry	32	4.10	0.59			
Communicate	Biology	28	3.94	0.55	2, 70	1.52	0.22
	Physics	13	3.91	0.62			
	Chemistry	32	4.16	0.52			
Improvement	Biology	28	3.96	0.58	2, 70	0.76	0.47
	Physics	13	3.80	0.41			
	Chemistry	32	4.03	0.63			
PS	Biology	28	3.99	0.43	2, 70	0.77	0.46
	Physics	13	3.92	0.47			
	Chemistry	32	4.09	0.48			
Identify the problem	Biology	28	3.87	0.49	2, 70	0.15	0.86
	Physics	13	3.93	0.52			
	Chemistry	32	3.83	0.62			
Finding solutions	Biology	28	3.92	0.61	2, 70	0.29	0.74
	Physics	13	3.90	0.64			
	Chemistry	32	4.03	0.61			
Planning	Biology	28	4.00	0.48	2, 70	1.09	0.34
	Physics	13	3.79	0.68			
	Chemistry	32	3.77	0.70			
Production and testing	Biology	28	4.00	0.69	2, 70	0.23	0.79
	Physics	13	3.84	0.71			
	Chemistry	32	3.94	0.64			
Communicate	Biology	28	3.97	0.50	2, 70	1.25	0.29
	Physics	13	3.76	0.63			
	Chemistry	32	3.76	0.53			
Improvement	Biology	28	4.07	0.44	2, 70	0.55	0.57
	Physics	13	3.96	0.69			
	Chemistry	32	4.16	0.67			
OE	Biology	28	3.97	0.39	2, 70	0.26	0.77
	Physics	13	3.86	0.47			
	Chemistry	32	3.91	0.50			

DISCUSSION

The initiative of this study was to investigate trainee science teachers' self-efficacy beliefs for teaching science with engineering design methods at Sultan Qaboos University. For RQ1, the findings indicated that teachers' self-efficacy for teaching science this way was high; they believed themselves as highly successful in teaching science by using engineering design processes. We argue that the knowledge, skills, and dispositions that the participants experienced during their preparation programs contributed to these high self-efficacy beliefs. One of the important courses in the BSc and TQD programs was a science methods course, which exposed the teachers to the topic of teaching science by an engineering design approach (College of Education, Sultan Qaboos University, 2021). Furthermore, these science methods course discussed different engineering design processes (e.g.,

identifying the problem, planning solutions, finding best solutions, production, and testing, communicating results and improving solutions) when covering other science teaching methods and related topics such as enquiry-based learning, problem solving, STEM education, project-based learning, science learning cycle, and NGSS.

Participants were also given the opportunity to plan and deliver a science lesson in the micro-teaching section of the science methods course. Each student had to plan and teach a science lesson for 15-20 minutes to their peers and then reflect on how to improve their performance. We argue that this direct exposure to the topic of engineering design, its related processes of planning and teaching a lesson as engineering design, enhanced the participants' self-efficacy beliefs and helped them consider themselves as highly successful in teaching science by this approach. All these confirm the high quality of the BSc program at Sultan Qaboos University that

was recognized by NSTA, which has been noticeable in the quality of teaching and learning of science education (Al-Balushi et al., 2020b).

Previous research reported that individuals' experience of specific topics enhanced their self-efficacy of these topics (Chen et al., 2021; Haatainen et al., 2021; Srikoom & Faikhamta, 2018; Webb, 2015). More specifically, previous research indicated that science teachers' self-efficacy in STEM education and teaching with engineering design was associated with their experience in teaching science using these approaches (Chen et al., 2021), and this teaching experience influenced their self-efficacy, beliefs, and attitude about STEM education (Srikoom & Faikhamta, 2018). This could explain the high self-efficacy level of the student teachers of the current study who experienced teaching science using an engineering design model in their micro-teaching session. Additionally, previous research reported that acquiring sufficient knowledge about engineering design is an essential factor for teaching science by using engineering design (Hammack & Ivey, 2017), and this is in alignment with the content of the teaching methods courses which devoted certain weeks to read and discuss different topics related to STEM education and engineering design, and the related science and engineering practices in the NGSS. Student teachers were also practicing integrating the engineering design model and STEM education into the Omani national science curriculum they were teaching in the micro-teaching session. This integration practice is an important characteristic of STEM education and engineering design curriculum (Roehrig et al., 2021) and is associated with high self-efficacy in teaching integrated activities (Haatainen et al., 2021).

For RQ2, the current study's findings also demonstrated that BSc participants had significantly higher self-efficacy beliefs than TQD participants. The differences in these two programs could help in the interpretation of this result. The science teaching methods course expands for two semesters in the BSc program. In contrast, it is only for one semester in the TQD program, limiting the knowledge, skills and dispositions that students of this program are exposed to. Therefore, participants in the BSc program had more opportunities to experience the processes of engineering design than the participants of the TQD program. For instance, the BSc participants watched different videos from the internet, including YouTube, during their lectures showing elementary and secondary school students' planning and implementation of varying engineering design ideas, mainly in the United States of America. Another essential engineering design experience that the BSc participants went through was a take-home mid-exam to design a science lesson by using the engineering design cycle. Since engineering design was not one of the pedagogical themes found in the science textbooks in Oman, this take-home experience allowed them to apply what they learned about teaching science in the manner of engineering design teaching and modify the textbook activities to suit the engineering design cycle.

The experience factor that differentiated the BSc program from the TQD one could explain the BSc student teacher's higher self-efficacy and be in alignment with the previous research, which showed that different experiences in teaching

science using STEM education and engineering design positively influenced science teachers' self-efficacy, beliefs, and attitude about these approaches (Chen et al., 2021; Srikoom & Faikhamta, 2018).

On the basis of the study's findings, our main argument is that the type of the program (i.e., BSc vs. TQD) was the only source of difference in self-efficacy beliefs for teaching science by using engineering design processes. Participants' gender and study major (i.e., biology, chemistry, physics) did not affect their self-efficacy beliefs for teaching science methodically. There is empirical evidence for the lack of effect of gender (Shahat et al., 2022a) on Omani teachers' self-efficacy in teaching science as enquiry. However, the study's finding contrasts with other studies demonstrating the impact of this major variable on an individual's self-efficacy (e.g., Basith et al., 2020). We argue that since both of our programs had male and female students and representatives of different specializations, gender and major variables did not significantly affect participants' self-efficacy beliefs for teaching science.

The study's result is similar to other studies' results (e.g., Yenice, 2009). A possible argument is that all males and females had taken the same credit hours and courses, which means no variability in their perception of teaching science (Bursal, 2010). These findings indicated clearly that the types of pedagogical experience of engineering design that the teachers went through, regardless of their gender or major, were an important defining element of their preparation program to enhance their self-efficacy beliefs for this sort of teaching.

Limitation and Conclusion

The findings from this research seem to provide some indications for investigating trainee science teachers' self-efficacy beliefs for teaching science by approaches used in engineering design. However, it is essential to note that the purposive sampling method was used in this study, so the findings may reflect similar student science teacher performance in the other colleges or institutions of science teacher preparation programs in Oman.

The data collection was carried out at a single point in time in Oman by using a cross-sectional design. From the importance of professional engineering development, possible further research would be to conduct a training intervention study focusing on enhancing the trainee teachers' engineering design processes. Another limitation in this study is that the teachers' self-efficacy beliefs were assessed by a self-reporting measure. We recommend conducting a future study using qualitative methods such as observations and interviews.

The questionnaire was valid and reliable for measuring the Omani science teachers' self-efficacy beliefs in engineering design-based activities. The results showed a high level of their own competence in their teaching using the engineering design processes in the two SEBTEDQ subscales. The results also revealed the influence of teachers' preparation program on their self-efficacy beliefs of teaching science by using engineering design processes as indicated by the survey using SEBTEDQ.

Finally, criticising the current research is not meant to minimise the outcomes of the self-efficacy beliefs for teaching science by using engineering design processes at X university but rather to provide a context for increasing the validity and reliability of the results in this study. Although the validity of SEBTEDQ was derived and enhanced from an extensive review of literature in science education, reliability could be improved more in final fieldwork by increasing the size of the research sample with in-service science teachers and supervisors.

Implications for Research and Teaching

The current study's findings indicate that exposing trainee science teachers to different types of experience regarding the teaching of science by using engineering design processes helped enhance their related self-efficacy beliefs. The results also show that the program that implemented more types of engineering design experiences had a better chance of strengthening students' self-efficacy. This finding was evident in the outperformance of BSc students over TQD students who had fewer opportunities to experience teaching science with engineering design-based methods. Other science teacher-preparing programs could implement some of these types of engineering design experiences such as

1. discussing the topic of engineering design thoroughly;
2. linking this topic to other major science education topics such as STEM education and NGSS;
3. discussing different pedagogical methods for teaching science as engineering design;
4. reflecting on different videos and scenarios that illustrate teaching science as an engineering design in real classrooms;
5. encouraging trainee science teachers to generate many ideas to implement engineering designs in science classrooms;
6. training these teachers to modify textbook activities to suit the engineering design; and
7. requesting them to design and teach different engineering design science lessons by different pedagogical methods.

This study contributes to the research literature on self-efficacy in engineering design by investigating the actual level of self-efficacy between BSc and TQD programs at Sultan Qaboos University and the influences of gender, major, and preparation program on science student teachers. One contribution of this study is its demonstration of the excellent quality of utilising the Arabic version of the SEBTEDQ in Oman. The SEBTEDQ could foster the assessment of pre- and in-service science teachers' competence in teaching science lessons by using engineering design using SEBTEDQ in elementary, lower, and upper secondary schools in Oman and possibly, in other countries.

An additional theoretical aim of this study is the detailed description of the two subscales of SEBTEDQ, which can be used as a single diagnostic scale for education officials in Oman to identify further strengths and weaknesses in pre- and in-service science teacher training programs regarding engineering design processes. This may help science teachers, or teachers in general, to meet their STEM training needs, and

influence teacher training and help establish teachers' confidence to teach effectively using engineering design methods. Another added value of the study is that the findings showed that TQD trainee science teachers might need more training to enhance their engineering design skills and improve their classroom practice. This is important for achieving good classroom interactions and, subsequently, ensuring the good quality of science instruction in Omani science classes.

The contribution of this study is that it shows how instrument items can be successfully developed and applied to the Arab language and culture. Another contribution of the study's results to science education literature is showing possible variable influence achieving highly effective STEM teachers by developing a sustainable and successful preparation program for university science student teachers. This way may make a big difference in building a solid and stable economy and will foster the future excellence and competitiveness of the economy in any country.

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