Teaching Strategies Employed by Academics in STEM Education: A Qualitative Inquiry

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Abstract. Science, Technology, Engineering and Mathematics (STEM) education needs a teaching workforce that is knowledgeable and skillful. Previous studies have reported the effectiveness of the delivery of the STEM education using the outcome-based education approach. Yet, the implementation of STEM education has been equally criticized. This study is a qualitative inquiry using the grounded theory approach to identify the teaching strategies employed by academics involved in STEM education in a leading private university in Malaysia. In particular, the inquiry focusses on the outcome-based education and its implementation in STEM education. Eight academics involved in STEM education from a private university in Malaysia were recruited using a purposive sampling procedure. In-depth interviews were conducted using semi-structured questions. The findings suggest that the participants are apprehensive of using outcome-based education in implementing STEM education and would require more training on this approach. The data yielded teaching strategies and challenges faced by STEM academics in the implementation of outcome-based education.

1 Introduction

Science, Technology, Engineering and Mathematics (STEM) education has a potential to give a great impact to the worldwide education system [1], especially in engineering education [2, 3]. STEM education is defined as a pedagogy that involves multidisciplinary field of learning [1, 4, 5, 6], as it provides learners with purposeful and comprehensive real-life learning experience [1, 4]. Moreover, the main objectives are based on students' abilities to perform and apply the learnt skills in an integrated way [1] as well as to bridge the gap between learners, knowledge providers and industrial demands [3, 4, 7].

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Furthermore, past studies have emphasized the need for STEM education and STEM skills that should be mastered [8] by engineering students who will be future engineers [3, 9]. This due to the higher requirements for graduates in STEM education [10] needed with multi-skilled, innovative and competitive [11] in this advanced global industry.

However, in order to meet the demands of the industry, STEM education faces significant challenges [2] in producing a suitable workforce. This is because academics face complication in choosing appropriate teaching strategies [1, 2, 3, 11] in engineering education. Hence, the effectiveness of the implementation of STEM education is still questionable [1]. The Engineering Accreditation Council (EAC) in Malaysia and Board of Engineers Malaysia (BEM), which was accepted as the 13th signatory of the Washington Accord, have shifted the focus of engineering education system using outcome-based education (OBE) in all higher education institutions [7, 12]. OBE is an educational theory which focuses on the outcomes (goals) of education system and emphasizes active learners with critical thinking, reasoning skills and action skills [7, 14] which is in line with the objectives of STEM education approach. Furthermore, OBE is used as a dominant guide for the development of instructional framework in STEM disciplines [3].

This paper discusses a case study in one of the leading private higher education institutions in Malaysia on the teaching strategies employed by its academics in STEM education using OBE practice and the problems encountered by the academics through the implementation in the engineering education.

2 Literature review

2.1 STEM education

STEM education is an integrated teaching approach which plays a critical role in the modern educational curriculum [1]. The main goal of STEM education is to produce an effective, multi-skilled workforce for the society. However, there are a few challenges faced in STEM education due to its lack of specific strategies to be effectively implemented [1, 2, 3, 11]. A meta-analysis has been done on STEM education show that problem-based learning is the strategy mostly used at the secondary school level and it focuses on students' ability to invent and innovate learning [1]. However, the researchers have suggested that there is a need to find other suitable teaching strategies that will be able to cater students in tertiary education. Furthermore, instructional practices were also found to play a role in improving the STEM education [13].

Besides, it was concluded that STEM education has expanded in the 21st century and detailed activity description on instructional strategies research needs to be done as they would be helpful for academics to innovate their lesson plans [4]. Furthermore, pre-service chemistry and mathematics teachers were found to be ready to accept and adopt the STEM education concept and keener to learn the effective instructions to be implemented in their teaching [5]. However, in childhood education, teachers lacked instructional resources although they showed significant interest [6]. As for middle school teachers, they believe that incorporating STEM in teaching encourages learning and helps to build confidence in students [9].

2.2 Outcome-based education

OBE is a learning model which has been favored and implemented in many countries [7]. The main focus of the OBE approach is to enable learners to produce the output of learning. In other words, it is a results-oriented approach [9]. Therefore, at the end of the lesson,

students should be able to perform the knowledge that they have gained in the classroom and should be able to employ it in real life learning. OBE focuses on students' outcome and this allows academics to track students' problems and helps to create innovation in course instruction [14].

Results from another a study on creating outcome-based competency model in engineering training reported that OBE was effective as the management was able to select experts of their field by measuring them through constructive training evaluation based on outcome [14]. Furthermore, the Washington Accord and the BEM insisted on the importance of OBE in all engineering education systems in higher education institutions [7, 12]. In Malaysia, the OBE and e-learning approaches in engineering education showed a significant impact on students' performance [7].

2.3 Teaching strategies in STEM education

Teaching strategies are an important factor in producing good quality education and concerns the academics as well as the higher education institutions recently [15]. Traditional teaching style is outdated especially when it comes to engineering education [16]. Therefore, pedagogy in the classroom needs to be reformed in 21st century education [16]. A study on instructional techniques in STEM education especially on digital information or E-learning reviewed that it will trigger an active role of students in the classroom [17, 18].

Higher education institutions that practices interactive or active learning apart from traditional teaching resulted in better students' outcomes and they have encouraged more new pedagogy implementation in-response to it [19]. A research on factor influencing teacher's instructional practices resulted on academics attitudes and their knowledge on teaching context [20]. However, they have suggested that future research should be done on factors influencing teacher's instructional practices together academics opinions on implementing the integrated STEM education by using in-depth interview [20].

3 Methodology

This research is a qualitative single exploratory case study, using the social constructivist grounded theory approach. A case study approach is suitably used when the study involves a specific setting [21]. This approach was selected as it only focused on a particular group of contexts, the engineering academics in a private university in Malaysia, specifically Universiti Tunku Abdul Rahman (UTAR). A single case study is an ideal method to use to gain rich data and deeper insights on the particular group of setting [22] to explore the teaching strategies used by the STEM academics. Although the findings cannot be generalized to other studies due to the differences in context [23], this research can be referred to by other researchers [24].

This study uses Charmaz's social constructivist grounded theory approach because it explores the respondents' experiences and develops subjective meanings from the participants' view of an issue [23]. The constructivist grounded theory encourages innovation, develops new understandings, concepts, and creates new theoretical interpretations based on their research [25]. The method of analysis focuses on reflexivity and relativity provides several additional steps for researchers to further critically analyze and examine their construction research process [26]. Thus, its flexible guidelines and interpretive nature are the reasons why the social constructionist approach is appropriate to be used in this study since it aims to explore the teaching strategies practiced by STEM academics.

3.1 Sampling method

The selected participants for this study were academics from two engineering schools of UTAR, Malaysia. Purposive sampling was used to recruit the samples for this study. Eight STEM academics with engineering expertise and different levels of teaching experiences were selected.

3.2 Instrumentation

Semi- structured in-depth interview using the grounded theory approach was used as an instrument for data collection in this study. Intensive interviewing method using grounded theory is useful for the qualitative research due to its nature which enables the researchers to have the freedom to explore and immediately prompt or mold the questions according to the participants' understanding, response, and needs [25, 27, 28]. Furthermore, in-depth interview helps the researchers gain detailed information [22] on the teaching strategies used by the academics in STEM education.

First, icebreaker questions were asked at the beginning of the interview to create rapport between the interviewer and the interviewee [30]. The participants were asked to briefly describe their job scope. Then, a central question was imposed on the participants regarding their teaching strategies in STEM education. Probing questions were used to elicit extensive information [29]. Then, a concluding question was asked to the participants to summarize the whole interview. This approach is supported by [29, 31]. Thereafter, at the end of the interview session, suggestions to improve their teaching strategies were asked.

3.3 Data collection

After obtaining ethical clearance from the institution, email invitations were sent to the selected participants. Appointments for interview sessions were fixed according to the available time slots of those willing to participate in this research. Before the interview session, the participants were asked to fill out consent forms which contained information on the purpose and benefits of their contributions to the study. Besides, participants were also asked to fill out the Personal Data Protection Act 2010 form, which was to make sure that their information would be kept confidential.

The interviews were audio recorded after obtaining participant consent. Four out of eight respondents declined to be audio recorded. Thus, for the respondents who declined audio-recording, extensive notes were taken by the researcher and verified by the respondents. Field notes were taken for all interview sessions. A token of appreciation was given to each respondent after the interview. Finally, the interviews were transcribed verbatim for analysis.

3.4 Data analysis

The grounded theory coding method was used to analyze the collected data. The main purpose of using the grounded theory coding method was to analytically analyze the collected data from in-depth interviews. Furthermore, it helps to develop the link and categorize and cluster the information from the collected data [31] and generate a theory based on the central focus of the study [25]. In this study, one inter-coder assisted the researchers to code the raw data. This will help to justify the validity and reliability of the data coded by the researchers and will reduce the biasness among the coders [25, 34]. Data analysis involves of several systematic steps that is open coding, axial coding and selective

coding. NVivo Pro 11 was used to systematically categorize the nodes and ease the coding steps for the coders. The coders were required to familiarize themselves with the transcripts first before beginning to code. Then, they were required to code any possible codes that are related to teaching strategies. The coders were required to perform axial coding by grouping the open codes into a major group. Then, selective coding was used to determine the significant teaching strategies which were applied in STEM education. Some irrelevant codes were eliminated while performing the selective coding.

4 Findings and discussion

The findings show that the eight STEM academics employed several teaching strategies using the OBE approach. Interactive learning, case study, adaptive teaching and e-learning are used mainly in STEM engineering education. The results show that all eight (100%) participants employ interactive learning as their dominant teaching strategy while conducting their lesson. Apart from interactive learning, four (50%) participants infuse case study as a teaching strategy in their classrooms. Two (25%) participants make use of E-learning and another two (25%) participants apply adaptive teaching. The table below shows the number and percentage of the teaching strategies applied in STEM education.

Table 1. Number and percentage (%) of STEM academics' Teaching strategies using OBE approach

Teaching strategies applied	No of participants/Percentage (%)
Interactive learning	8 (100%)
Case study	4 (50%)
E-learning	2 (25%)
Adaptive teaching	2 (25%)

4.1 Teaching strategies

4.1.1 Interactive learning

The results show that interactive learning is mostly used by the STEM academics while conducting the classes, as the findings show that all eight participants used this teaching strategy. Based on the participants' opinion, interactive learning incorporates discussion in the classroom, group activities, facilitation and two-way communication between the educator and the students. Below are some opinions given by the participants:

> '…I try to make it interactive and I also try to get them to do some sort of activities at the beginning of the semester. So, I discuss with them...' (P1)

> '…I will divide them according to their assignment groups. After that, they have competitions to gain bonus coursework marks; quite interesting to see the active participation actually create a kind of interactive way for the class …' (P2)

Thus, interactive learning in this context was defined as active classroom, whereby every student's participation in the classroom becomes focused. Besides, a past study found that most students enjoyed interactive classroom and they find the learning environment

more challenging, lively and fun to learn [34]. Therefore, this method of teaching needs to be applied during lessons so that students are able to interact with their workplace colleagues later on. Furthermore, the participants have emphasized that by using interactive learning, students will be able to learn and understand lessons better as compared to one-on-one learning. Similarly, a past study found that students would when they actively participate, they learn at their best [35]. Besides, via interactive learning, the participants suggest that they are able to identify the students' input level and this serves as a guideline for the educators to know whether they need to give more explanations and exercises, or if they should proceed to the following lesson. Furthermore, P6 and P5 commented:

> '...I prefer interactive learning, because when you interact with the student, you can make sure that the student understands…' (P6)

> '… I will ask the students questions to measure their understanding…' (P5)

> '…I value interaction because each student is different and each should be treated differently. It is never uniform so that can begin the interaction, yes…' (P8)

Moreover, [30] in their study stated that students are able to improve their classroom performance if they actively participate in classroom activities.

i. Case study

The second most-applied teaching strategy is case study. According to the participants, using case studies as a teaching strategy means giving a real-life situation to students and asking them to find a solution.

> '…give them real life situations…' (P3)

> '…I will show them by giving a scenario or situation in which I also had the experience, for example the construction line…I will then share my experience with them …' (P6)

The participants further opined that case study includes hands-on learning and field trips, which are very much applicable to STEM education and needed by STEM students. This is because at the end of the case study teaching strategy, students should be able to handle the given case and find a solution for it [37]. P3 emphasized that as engineering students, they should be able to handle the hands-on works apart from gaining knowledge from the book. Besides, P6 mentioned that field trips are needed by engineering students so that they can gain knowledge about how big machinery works. The following are the opinions of P3, P6 and P7.

> '…For science field and engineering, you need to do a lot of hands-on works. I think hands-on works are very important for engineering students, not just gaining knowledge from the books. If their hands-on knowledge is poor, that is very bad…' (P3)

> '…I just bring them to the training center…I like to bring them to that place so they can see how big the machinery is.' (P6)

'…I try to talk about something industry-related...' (P7)

Using the case study strategy, learners can put the theories that they have learnt to practice [38]. This will sharpen their thinking and decision-making skills. By applying case studies in teaching, students will be more encouraged to learn the lessons as they can practice real life problem-solving in the classroom [39]. Hence, practicing case study in the classroom will be very beneficial to engineering students as it enables them to be more experienced in handling problems encountered in their future working life.

4.1.2 Adaptive teaching

Adaptive teaching method is emphasized by the participants because as academics, they should be able to adapt their teaching to students' level of understanding [40]. As academics, they should focus on students' understanding of a particular lesson. However, if students were unable to understand the concepts of a particular topic, instructors should be able to change the teaching method or way of teaching delivery according to the students' needs and the current needs of education [41]. In other words, adaptive teaching is based on students' responsive guidance [42]. The participants place emphasis on adapting new teaching methods such as flipped classroom, whereby students are required to do presentations in the classroom. The educator listens and gives feedback to them during the particular lesson. P1 and P2 emphasize on the use of adaptive teaching in their lessons.

'…have to be adaptable to gauge what is their level of understanding…So if you see their responses are not so good as if they are not getting it, then you need to elaborate more and give more examples…'(P1)

'…I am very keen to attend in-house training courses on related teaching, so that I can learn from these…I have attended a lot of training courses, I have learnt a lot…So I incorporate some methods, but not all. For example, I learn about the flipped classroom, so I used that for one of the topics...' (P2)

4.1.3 E-learning

E-learning is one of the many important components in STEM education. In this digital era, most delivery of lessons have shifted towards integrating technology in the classroom. The findings show that students were attracted by the use of ICT tools in the teaching and learning process. For example, P2 and P7 stated the following:

'…in terms of e-learning, of course now as we know, electronic or web learning is very common and especially for this new generation students…So actually, we incorporate our contents into e-learning so that the students have more options and more methods to actually capture the knowledge that you want to deliver to them…" (P2)

'…to have more interactive ICT tools to let them be more interested…' (P7)

E-learning has become a feasible substitute for traditional methods since application of e-learning facilitates teaching and learning [43, 44].

> '…I'll find some videos related to that subject, and then show them how it happens in the real industry…" (P7)

According to the participants, engineering education always needs to be updated with technological application as both academics and students are required to use and familiarize themselves with new machines, tools and software's in engineering. There are numerous engineering laboratories in each branch of engineering departments which utilize direct and indirect use of network computing [45]. Therefore, emphasis on teaching delivery using technology will also be of great interest in order to reach the goals of STEM education, to enable learners to be skillful in using technology.

4.2 Challenges and suggestions by participants

This study reveals several challenges faced by academics in implementation teaching strategies in the classroom. First, although the academics have tried their best in implementation the OBE approach in STEM education, they emphasize the need to create more awareness on the OBE approach and teaching strategies to senior lecturers and new lecturers. This is because there are some lecturers, especially the new lecturers, who are still struggling to identify suitable teaching strategies. Therefore, attending a training course on the OBE approach will enable them to vary their teaching strategies and to apply proper and effective teaching strategies in STEM education. Below are the participants' views, stating that they require more training.

> '…the training courses provide lecturers with better perspectives to enable them to better update their knowledge. Based on this, they can share in their class…' (P2)

> '…especially in terms of OBE training, try to ensure every single new staff member attend these training…At least they will have awareness of this concept and will know how to implement in their teaching… we will try to promote whenever we have a OBE related training…' (P2)

> '…I attended the training in which the instructor taught us how to use it. Then we can deliver better to students...' (P3)

> '…I would like to know how to get good and relevant sources of teaching…' (P5)

The results also show that the participants face difficulties in bringing their students for site visits. This is because they have limited teaching periods as they need to rush to complete the syllabus. Further, there are also limited facilities to bring a huge number of students for a site visit.

> '…you have limited time…you have only 14 weeks of teaching…as I mentioned, sometimes students need more time and they are all so pressured because of taking so many subjects…' (P1)

> '…since we have limitations in going to the site, the students cannot see everything.' (P6)

> '…we don't have the chance to go to the site…' (P6)

'…And then we lack those safety boots, helmets, all the PPEs, Personal Protection Equipment…Another thing is transportation to go to the site…' (P6)

However, the participants believe that every STEM-related course should provide an opportunity for the educators to bring students for a site-visit so that they have a glimpse of how the real working industry is like and learn to adapt in real life situations.

3 Conclusion

In conclusion, this study finds that interactive learning and case study are the most-used teaching strategies by STEM academics, followed by adaptive teaching and E-learning teaching strategies. Besides, the academics are very passionate about using these teaching strategies and the OBE approach as they believe these can achieve the objective of STEM education, which is to produce a caliber workforce. The participants believe interactive learning would be the best choice to be implemented in STEM education. However, the academics find that the implemation is still scarce. Therefore, they emphasize the need for training on OBE-based teaching approach, so that educators can vary their teaching strategies in the classroom and also be a guide for new STEM educators.

This study has filled in the knowledge gap on teaching strategies using OBE in STEM education. Most researches to date have been done separately on OBE and STEM education. There are very few studies which emphasis the implementation of OBE in STEM education. This study will be beneficial to new STEM academics as they can use these teaching strategies in their lessons. From the suggestions given by the STEM academics in this study, the teaching portfolio for lecturers can be improved in order to produce an excellent workforce for the industry. Although the findings from this study cannot be generalized to all institutions, it can be used as a guide for academics to employ OBE in their teaching.

There are several limitations in this study. Firstly, this is a case study in a private institution and it is difficult to generalize the findings to represent all the other public and private universities. Suggested future researches would be for researchers to collect larger and broader data on teaching strategies in STEM education, for example, data to represent every state in Malaysia. Further, both qualitative and quantitative methods should be incorporated if it involves a broader population.

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