Heliyon 9 (2023) e14531

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Contextual variation on teachers' conceptions of ICT-enhanced teaching in engineering education

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ARTICLE INFO

Keywords:
ICT
TPACK
Engineering teaching
Phenomenography and conceptions

ABSTRACT

Due to the COVID-19 epidemic, higher education all over the world is increasingly reliant on the use of Information and Communication Technology (ICT), which creates several opportunities and problems, especially in the field of engineering education. One of the significant aspects that needs to be bought to the academic attention is how teachers' use of ICT in engineering education has been transformed due to this pandemic. Therefore, the purpose of this study was to investigate views, and practices that define varying conceptions of engineering university teachers' use of ICT in their teaching. Phenomenography, an emerging research approach in engineering education was used as a theoretical and methodological underpinning. A cohort of 14 teachers was selected from two universities in Bangladesh to participate in a semi-structured in-depth interview. The findings revealed five qualitatively different categories of description such as: imparting information, transmitting structured knowledge, offering guided learning, engaging students toward practice and engaging students toward innovation. Relationships among the categories of description revealed four dimensions of variation such as: purpose of using ICT in engineering teaching, role of a teacher, role of a student and TPACK components. The study further found that ICT-usage underpins teacher's pedagogical approach to teaching engineering subjects and therefore provides useful information for university policy makers, teachers and curriculum designers toward quality teaching and learning. A quantitative investigation to determine the impact of the pedagogical approaches to teaching underpinned by ICT-use in engineering education is recommended.

1. Introduction

The outbreak of the deadly coronavirus disease which originated from Wuhan, China on December 31, 2019 is continuing to spread amongst people and affect education systems across the globe. This has led to a shift in the way teaching is approached in many universities, for example, from face to face to online [1] or hybrid pedagogy [2] in order to curb rapid transmission and effectively handle the existing cases of the novel disease. Due to this outbreak, the way of using Information and Communication Technology (ICT) in global education has shifted enormously [3,4]. In another perspective (before COVID-19), a significant amount of studies have provided evidence of theoretical and practical implications of using ICT in improving education for sustainable development [[5–7]].

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https://doi.org/10.1016/j.heliyon.2023.e14531
Received 21 August 2022; Received in revised form 6 March 2023; Accepted 10 March 2023
Available online 17 March 2023

UNESCO [8] defined education for sustainable development as "a learning process or approach to teaching based on ideals and principles that prepare people of all walks of life to plan for, cope with and find solutions for issues that threaten the sustainability of our planet" [9, p.3]. Considering this, ICT plays a significant role towards achieving the Sustainable Development Goal Number Four (SDG No.4) [9,10]. Due to the COVID-19 pandemic, when 87% of the educational institutions around the world had closed [11], the SDG No.4 mainly depended on how effectively ICT is integrated in their education system. Therefore, many researchers have drawn attention to the opportunities ICT can offer in teaching and learning especially towards encountering the challenges posed by COVID-19 [4,12].

In a general perspective, ICT-enhanced teaching promotes diverse teaching and learning experiences in higher education which indicates a linkage with SDG [10,13–15]. For instance, affordable and easily accessible ICT tools such as desktop computers, laptops, smartphones and iPads connected to high speed internet have been used in many educational settings for offering myriad educational experiences through self-paced learning [16,16], Online learning [1,17,17] and blended learning [18,19]. Teachers have been able to communicate with students anytime, anywhere and even reuse lecture slides [20,21]. The existing teachers' instructional approaches have been enhanced and in some cases, more specifically, due to COVID-19 effect, new pedagogies have emerged [2,11,22].

Context-specific research reports that ICT-enhanced teaching practices, such as face to face, blended and online, are context dependent [23–25]. The way of using ICT in teaching may vary due to contextual factors, such as but not limited to, socio-economic location [23] and disciplinary variation [26]. Previous studies reported that there is relationship between technology-use and discipline/subject being taught [6,27,28]. Therefore, contextual variation has influence on ways of using ICT in teaching. It is therefore expected that, teachers in developing countries may use ICT differently than that of developed countries with differences across the various disciplines. Engineering education (EE) is another area of higher education which has bestowed the benefit of using technology in its teaching and learning [29,30]. This study, therefore, aims to investigate different ways of using ICT in EE in Bangladesh. Investigating ICT-enhanced teaching at two novel contexts in this study, that is, engineering education (applied hard discipline) and Bangladesh (context of a developing country) certainly provides useful knowledge that extends the prior literature. Thus, engineering teachers' experiences of ICT in teaching engineering subjects uncovered a new and better understanding of teaching in EE.

2. Bangladesh context

The University Grant Commission (UGC) indicates three categories of universities in Bangladesh as public, private and international. Recent data (2020–2021) prepared by UGC shows rise in the number of public universities to 46, private to 107 and international to two, that makes total to 155 universities. 44 universities out of 155 offer many principal branches of engineering disciplines in Bangladesh [31]. In 1997, the Government of Bangladesh (GoB) recognized ICT as one of the contributors to the country's development and formulated the first ICT policy in 2002. In Bangladesh, ICT is considered an important tool for matching international standards through modern and updated education systems. Teachers are expected to be properly qualified, skilled and committed for quality education and development of skilled human resource [32]. Thus, the use of ICT is extended to almost every level of educational program. However, recent data indicates that the unemployment rate is at 4.37% of which 46% are university graduates [33]. Further, the desire to match the international standards is still far from reach, though in 2018/2019 the provisional GDP was at stunning rate of 8.15% [34]. Since then, there has been a staggering GDP drop at a rate of 5.2% as per the Trading Economics report in 2020. Additionally, pressure has been exerted on tertiary education systems in relation to the economy needs of Bangladesh [35], implying that the quality of learning outcome does not fully match certain economic needs. The good news is that the use of technology impacts on students' learning in less developed regions, such as, South Asia in general [36], and Bangladesh [37] in particular. Quality teaching leads to quality learning [38–40]. ICT-use in teaching can improve the quality of learning outcome [41] in order to meet a nation's changing economic needs. Teachers in EE of Bangladesh, like in many other Asian countries, predominantly undertake practice teacher-centered approaches where students are expected to listen to lectures with no, or in some cases very limited, opportunities for engagement in the teaching and learning process [42]. Due to the COVID-19 pandemic, teachers' understanding, and their ways of practicing teaching have been shifted from traditional face-to-face delivery to an ICT-enhanced online or blended approach. Therefore, in the context of developing countries such as Bangladesh, how engineering teachers' conceived ICT-enhanced teaching in EE is an emerging issue for foreseeing their ways of using ICT in their teaching practices. Prior literature reported that teachers' conceptions of teaching are directly linked with their teaching practices [43]. Svenson [44] clarified the term 'conception' as one that signifies the relation between people and aspect of the surrounding world [45]. The purpose of this study, therefore, is to identify teachers' perceived understanding (conceptions) towards ICT-enhanced teaching in EE in Bangladesh. To meet this purpose, phenomenographic inquiry, which is a second order perspective with interest in EE, was used to investigate different views, practices and experiences that define varying conceptions of university engineering teachers' use of ICT in their teaching. This translated into a research question: '*What are the qualitatively different ways engineering university teachers in Bangladesh conceive of ICT enhanced teaching?*'

3. Literature review

In phenomenography, teachers' perceptions, views, beliefs, practices, and experiences are translated as one word known as 'conception'. Marton and Booth [46] perceived conception as the awareness or ways of experiencing a particular phenomenon. 'Conception' is the unit of description in phenomenography [48, p. 335]. Kember [47], in his review paper identified two broad teaching conceptions as teacher-centered and student-centered. A number of studies show that teachers' conceptions of teaching guides their teaching approaches and further controls students' ways of learning [43,47,48]. Similarly, teachers' understanding of

ICT-use in teaching determines their approach to teaching with influence on students' learning [49]. However, technology alone may not lead to achieving the desired learning outcomes [50–52]. Most importantly, its impact on student's learning may also depend on the nature of subject, discipline and the way it is used [6,27,28]. Thus, engineering student's learning outcomes can be affected by teachers' perceived views of ICT enhanced teaching within their various engineering disciplines.

Many phenomenographic ICT related studies in the area of teaching have contributed new knowledge, insights and pedagogies toward enhancing student learning at university level. For instance, Tsai and Tsai [53] reported quality technology integration into lesson plans which is believed to be one of the ways that could improve teaching practices in EE. However, no evidence was found about the relationships among pedagogy, ICT and subject in their study. Timsal et al. [36] found no disconnect in students' learning process as a result of the parallel use of technology alongside institutional offering contrary to Landgrebe's view [54]. In support of, and addition to Timsal et al. [36] assertion, students' use of ICT to acquire knowledge and skills beyond their major subject area required more investigation. Results have been reported in this study with accountability for, and justification of, the alternative infrastructure developed by students alongside institutional offerings. In their study, Hodgson and Shah [55] reported that technological limitations affect teachers' conceptions and their teaching approaches. However, this evidence was not directly linked with EE rather it was focused on socio-economic aspects affecting other disciplines such as law, health science and administration. Degago and Kaino [56] informed that the categorization of a greater number of instructors in student-centered conception in their finding was an attempt made so far to change instructors' conceptions of teaching towards student-centered learning in higher education. In order to promote from teacher-centered teaching approach to student-centered teaching approach in EE of Bangladesh and the likewise contexts, first is to identify what different ways teachers conceive ICT-enhanced teaching.

Generally, phenomenographic studies are scanty in Bangladesh and even across higher education compared to other research methods [57]. For further improvement, the engineering education community needs to focus and engage in purposeful and reflective qualitative research methodology practices such as phenomenography [58]. According to the researchers' knowledge, the available literature has not revealed any phenomenographic discovery creating space for teachers' experience on ICT-enhanced teaching within engineering disciplines. Therefore, the present study discovered important relationship between ICT-use, subject and pedagogy in engineering education using phenomenographic research design.

4. Method

The methodological underpinning of this research was guided by the phenomenographic research approach that is qualitative in nature. In case of qualitative research, many research designs have been used and the most fundamental are phenomenology, phenomenography, ethnography and grounded theory, however, new qualitative research approaches have also emerged, such as, narrative inquiry, life history etcetera [59]. Phenomenology is concerned with conceiving the meaning of the different experiences people go through in order to discover their essence [60]. The patterns of behaviour and experiences of defined cultural groups are unveiled through grounded theory and ethnography. The phenomenographic research approach, contrary to other qualitative research approaches, was most suitable to investigate this study because it provides qualitatively different categories that are collective experience of participants (Phenomenography) rather than individual (Phenomenology). The phenomenographic research design is important in understanding people's varying experiences toward reality, their differences in perceiving similar phenomena and variations in their derived experiences as conceptions [61]. Moreover, phenomenography, rooted in a set of studies of learning from the 1970s, focuses on uncovering qualitatively different ways people experience, conceptualize or understand phenomena [62,63]. In phenomenography, the conception of a particular phenomenon is captured by participants' collective understanding in a limited number of categories of description [62]. Phenomenography is innovation-focused [57], and leads to insights that can provide solutions connected to empirical research associated with a cognitive viewpoint [64] hence, generates high quality results [65]. It investigates the relationship between subject and phenomenon in a non-dualistic manner [66], with interest in higher education towards improving student learning, discovering variations in teaching approaches, simulating both methodological and theoretical developments [57]. Its findings are represented in the form of categories of description [[62,67]]. Categories of description and their relationships constitute outcome space as the final result [62,67,68]. In recent years, engineering education research, phenomenographic research approach has contributed significantly [69]. In the present study, phenomenography was selected to explore engineering university teachers' conceptions of ICT enhanced teaching. Therefore, the phenomenographic research approach was most relevant and suitably qualitative methodological underpinning to investigate the above stated research question (What are the qualitatively different ways engineering university teachers in Bangladesh conceive of ICT enhanced teaching?) It was further used to determine study sample, collect data and perform analysis. The quality issue was satisfactorily addressed through a joint analysis exercise. Advanced analysis of unstructured phenomenographic data was considered, taking into account participants' perspectives as close as possible with reflective personal contributions. Ethically, this study followed the procedure approved by the Committee for Advanced Studies and Research of the Islamic University of Technology, Bangladesh.

4.1. Participants

In phenomenography, study participants can be selected through purposive or convenient sampling methods [61]. In phenomenography, participants' experiences are determined by differences in disciplinary fields, age, teaching experiences and gender [70]. In terms of participant selection (sample size), Trigwell [71] suggested 15–20 interviewees for this research method and reported that a minimum of 10–15 individuals might give the reasonable variation in any study. However, the final sample may depend upon the achievement of data saturation [72]. In the previous studies, small sample size of up to twelve participants or even smaller have been used [19]. Therefore, a cohort of 14 teachers were selected purposively with an aim to maintain considerable variation among them by following recommendations from prior phenomenographic research. The fourteen participants were sufficient enough to provide the needed data because of their distribution across all the six targeted engineering departments. Nonetheless, due to COVID-19 pandemic restrictions on travelling into, out of, and within, Bangladesh in 2020, the research was not able to include more than the two engineering and technology universities, which represented other similar universities in the country. A number of phenomenographic studies in the SSCI indexed journals were conducted selecting participants from one university [19]. Table 1 shows the participant selection matrix which comprises of two (2) female and twelve male experienced teachers, across six departments (CSE, TVE, EEE, CEE, MPE and CS) of two universities (U1 and U2) in Bangladesh. It is important to acknowledge that due to the male-dominated nature of the engineering profession, there were relatively few female participants. Pilot interviews were conducted as recommended by many scholars [66,73]. Participants' relevant experience towards the investigated phenomena is an important aspect for discovering categories of description in phenomenographic research [66]. Therefore, participants were selected based on their current or past teaching experiences using technology. Ability to speak in English was useful for expressing participants' understanding in the semi-structure interviews freely and deeply (see Table 1).

4.2. Interviews

The general focus of qualitative inquiry is describing, understanding and clarifying human experiences leading to collecting of a series of intense, full and saturated description of the aspect under investigation. Interviews is one of the techniques commonly used to study small homogeneous samples [[74], p. 162]. More specifically, the *semi-structured interview* is the most dominant data collection technique in phenomenographic research approach [[62,70]]. A large number of prior phenomenographic studies conducted were exclusively based on *semi-structured interviews* such as [28,69,74]. A semi-structured interview in this research allows participants to provide in-depth understanding towards investigated phenomena. It allows interviewees to express their feelings, experience and understand more freely and elaborately. Therefore, in this study semi-structured in-depth interviews were administered to engineering university teachers with an aim of illuminating their teaching experiences using ICT. There were basically three main topics that triggered the following questions: (a) What does ICT enhanced teaching mean to engineering university teachers? (b) Why do engineering university teachers use ICT in their teaching? (c) How do engineering university teachers use ICT in their teaching? For example, (a) meaning of ICT enhanced teaching [What], (b) reasons for ICT enhanced teaching [Why] and (c) ways or methods of conducting teaching using ICT [How]. The three questions were followed by a series of unstructured follow-up questions aimed at illuminating participants' experiences of using ICT in their teaching, for example, "Would you show that with an example please?", "could you highlight more on (specific point) please?", depending on the level of details revealed by the interviewee in response to questions. This was important in obtaining quality data for better results. The interviews were audio recorded and lasted between 30 and 50 min per participant. The researcher (first author) started conducting the interviews from January 2020 until the end of 2020.

4.3. Analysis

Data analysis started after data collection was completed [66]. The purpose was to discern participants' interview data through sorting, interpretation and representation [65,66,75]. Marton [76] explained that "phenomenographic analysis is not a measurement procedure but one of discovery" [81, p.16]. Marton [67] informed that phenomenographic data analysis does not depend on one specific technique. For instance, the five-step [74] and seven-step [75,77] analysis procedures have been followed in the previous related studies. In the present study, the researcher followed the seven-step phenomenographic analysis process that were: *first, familiarization:* reading the transcript iteratively to familiarize with data. *Second, compilation:* categorizing participants' statement basing on similarities and differences. *Third, condensation*: distinguishing relevant statements from irrelevant ones in the categories. *Fourth, preliminary grouping*: limited numbers of categories of description are constructed. *Fifth, comparison of the categories*: involves careful identification of differences in the categories of description. *Sixth, naming the categories*: categories are named according to their

Table 1
Participants selection matrix.

University (U1 and U2)	Teacher-Id (01–14)	Fluency in English	Department	Experience (Years)	Gender
U1	P01	Fluent	CSE	8	Male
	P02	Fluent	CSE	2	Female
	P03	Fluent	TVE	4	Male
	P04	Fluent	TVE	10	Male
	P05	Fluent	EEE	5	Male
	P06	Fluent	EEE	2	Male
	P07	Fluent	EEE	17	Male
	P08	Fluent	CEE	5	Male
	P09	Fluent	MPE	10	Male
	P10	Fluent	CSE	5	Male
	P11	Fluent	CSE	12	Male
U2	P12	Fluent	CS	17	Male
	P13	Fluent	CS	21	Female
	P14	Fluent	CS	12	Male

meanings. *Seventh, category arrangement/outcome space:* explains the nature of occurrence or hierarchical arrangement of the named categories. In the present study, the researcher followed the seven-step phenomenographic analysis process to discover teachers' conceptions of ICT enhanced teaching because the procedure is independent of its counterpart, familiar in many phenomenographic studies, easy to understand and apply. Firstly, the recorded data was transcribed to form a data pool which appeared ambiguous and less meaningful. The transcripts were read again in order to gain familiarity. Statements with similar meanings in relation to the interview questions were sorted based on similarities and differences. More transcript reading with reference to the raw interview data was undertaken to eliminate irrelevant data while focusing on broad meanings. A limited number of qualitatively different preliminary categories of description were identified. Each category consisted of participants' views with similar meaning relating to the central meaning of ICT enhanced teaching. Dimensions of variation were discovered to demonstrate further understanding of the different conceptions of ICT enhanced teaching. The structural relationships between qualitatively different categories of description constitute the outcome space of the study as the final result.

5. Findings

The main aim of conducting this study was to investigate engineering university teachers' conceptions of ICT enhanced teaching. The empirical data revealed five categories of description along with four key dimensions of variation. University engineering teachers use ICT in teaching for:

A: imparting information.
B: transmitting structured knowledge.
C: offering guided learning.
D: engaging students toward practice.
E: engaging students toward innovation.

Each of the categories are discussed along with the supporting evidence from the interview data (quotation). At the end of each quotation, an identifiable rubric (PXX = participant number, UY=University Number) is inserted so that the interviewees' identities could remain anonymous, and the transcripts' sources could be tracked.

Category A: Imparting information

In Category 'A', use of technology in engineering teaching, is conceived as a means of presenting subject content to students. In this regard, three broad intentions were seen in this category. First, teachers use of ICT for conveying information to students for saving their time. For example, through sending content files to students prior to class session. One of the participants envisaged:

> … it could be up to open presentation or sending materials to students ahead of lecture time. ICT gives me the opportunity to have a wider coverage of syllabus pretty much quicker and be able to meet other requirements. P08–U1

Some participants comprehend ICT-use in teaching as a means of acquiring available information for teaching their students. Teachers with this view do not only depend on textbooks from the library but also internet for acquiring information for teaching by using technology. One of the teachers informed:

> I am, you can even say, a learner. Each year, I learn from the various cloud-based online sites like Massachusetts Institute of Technology (MIT), and this makes my class different. In my class, I tell my students that all my lectures are not only from the text books but also the internet as well. P12–U2

Moreover, others believed ICT is used in teaching for posting class assignments and results for students. Teachers in this subscale use ICT tools for transferring assignment information to the learners. Smartphones, computers, and Google classrooms are commonly used in these circumstances. For instance, a participant stated:

> Actually, I'm using Google Classroom to deliver assignments and feedback to students. They don't need paper and pen to produce the answers and then spend money on these things but rather receive notifications from me, of what they need to do. P06–U1

Category 'A' represents teachers' views on ICT use in teaching as a means of presenting a body of subjects' contents to the learners. This category generally focuses on accessing and presenting information to students whereas students' learning is limitedly emphasized.

Category B: Transmitting structured knowledge

In this category, the use of ICT in engineering teaching is viewed for transmitting structured knowledge to the students. Teachers focus on delivering simplified and organized content in a way that is easy for students to understand and remember. For instance, ICT facilitates delivery of meaningful contents to the students during teaching. A teacher stated:

> ICT basically supports teaching for preparing and delivering contents. Teaching itself involves so many things from preparation, planning, to delivery. So, I think anything that I do in teaching using technology, kind of like, assists that teaching process. P03–U1

> I think I will be specific to you in my view on this based on the course I teach now. I mean the outcome of every class is an image produced and therefore, I need to focus on color, texture, and image shade well. P12–U2

In related views, appropriate presentations of complicated diagrams are seen easily accomplished through ICT. The ideas relating to the features and functionalities of diagrams are represented more clearly by simulation. For instance, one participant points out:

> … drawing human blood circulation system using a marker pen or chalk on a board is complicated right? From my experience, I feel students get it much easier when diagrams are represented through technology. P14–U2

Moreover, another group of participants conceived that ICT is used in teaching to organize and deliver content for easy follow up by the students by using a Learning Management System (LMS) and Google Drive and the like. Presentation slides are prepared by summarizing huge amounts of content in order for students to make sense out of the classes. For illustration purposes, one of the participants affirmed:

> I design a separate presentation slide which is kept in the Google Classroom or Google Drive for students to access, that contain summary of the main points of class for clarity because students will not really coordinate the concepts easily. P14–U2

Therefore, the concept of ICT enhanced teaching in category B is transmitting structured knowledge to students for ease students' learning.

Category C: Offering guided learning

Offering guided learning is an intermediary category in which good communication relationships with students is established. Teachers interact with students in order to attain good teaching habits. For example, students are seen not getting scared or worried of making mistakes during their learning processes and provide immediate responses to teaching when good communication is established. One participant asserted:

> … I maintain them in control in order to attain good teaching habit. It is the reason I need to communicate with them and understand what they are doing (progress). P13–U2

In another concept, ICT enhanced teaching is sharing teaching responsibility. ICT-enhanced teaching in this regard facilitates students advancing their learning towards teachers' guided activities. For example, the following comment shows how students are advancing their learning after completing teachers' instructions:

> I request my students to demonstrate how a related activity in my previous example applies in their next learning … being an activity for the next class is just to see if they've got an idea. P12–U2

Therefore, the concept of teaching in category 'C', is offering guided learning which is teacher centered. Teacher's focus is on establishing an interactive class within their control. Students' engagement in active learning is seen only when teachers requested them to respond otherwise, they remain passive.

Category D: Engaging students toward practice

The use of ICT in Category D is viewed as promoting students' active engagement in their learning and offering independent learning. Students are seen to be engaged in their own learning through self-motivation. They apply ICT in their learning activities freely while receiving instruction from the teacher. A group of participants in this category conceived ICT enhanced teaching as guiding students to acquire necessary information they need. For example, during their late night studies in which there is a limited intervention of the teacher, one of the participants states:

> … … so, the information has to be in a server somewhere else where the students are passionate to access because their late night studies require help for information [to complete their tasks/assignments]. P13–U2

ICT is used in engineering teaching for improving problem solving skills. Students' engagement in critical thinking activities provide diverse solutions to engineering problems, for example, students assume independent responsibilities in their own learning toward solving course related problems. One of them presumed:

> From our field point of view (CSE), every day we have new tools, so I give my students problems to find solutions using new tools. Nowadays, knowledge cannot be limited to oneself. P13–U2

The concept of ICT-enhanced teaching in this category, unlike other three categories (A, B and C), is to promote students' active engagement in their own learning freely. That is, students are actively involved in, and take responsibility for, their own learning processes toward solving course related problems. In contrast, in Category C, students' engagement is guided and controlled by the teachers.

Category E: Engaging students toward innovation

In this category, ICT-enhanced teaching is understood to create space for engaging engineering students toward innovation.

Creative and imaginative practices by students are seen in this category that is linked with professional practice (engineering practice). For example, students privileged to source information the way they need and therefore, teachers do not start to teach from scratch. ICT enhanced teaching leads students towards their own interest and facilitate to come up with innovative ideas. A participant envisages:

Table 2
Dimensions of variation and their illustrative quotations.

Dimension	Quotation from interview data
Purpose of using ICT in engineering teaching	Category-A: "… I give lecture by PowerPoint and at the end of it, I ask students to download the content files from Google class for study purposes." P10–U1 Category-B: "… for each animation, there is mathematics/geometry done at the back of the scene that learners need to be served along so that they understand and hopefully perform better in the context of rotation and transportation." P13–U2 Category-C: "… so whenever students browse many different things, they may get important information from other view-points which exposes them to how people think on the topic which they (discuss) with me and I arrange connections between such points of view within the teaching content in slides, as methods known vary from person to person." P10–U1 Category-D: "As we are in a sea of information, especially in the use of the internet, I mean, am there to guide students to proper information from these technologies and proper guide on how to use them. You know, without technology, I would not be able to optimize their time or channel the use of this technology to proper ends." P05–U1 Category-E: "I always tell my students to just try to understand 20% in class and then look for the remaining 80% through PDF books, topics, news, and every major thing I direct them to read or practice. In my view this will make the learner to become the teacher or even better because I don't think that I know everything. I think I know something as well as my student, together then, we make it 100%." P09–U1
Role of teacher	Category-A: "… it could be up to open presentation or sending materials to students ahead of lecture time. ICT gives me the opportunity to have a wider coverage of syllabus and be able to meet other requirements." P08–U1 Category-B: "ICT basically supports teaching for preparing and delivering contents. Teaching itself involves so many things from preparation, planning, to delivery. So, I think anything that I do in teaching using technology, kind of like, assists that teaching process." P03–U1 Category-C: "Through simulation program, I find it easier to explain lines of codes from an output point of view. I later request students to demonstrate a few of such programs based on the previously shared examples." P11–U1 Category-D: "Previously, knowledge was only for the teachers, so if I write something in the Google address bar now and my student does the same, the results would equally be the same. So, for me, the 24 h in a day is limited for teaching and learning, coupled with other activities and therefore, if I include my students in the learning process, the 24 h will become multiple of the number of students involved in acquiring skills and knowledge. This makes the learning environment knowledge and skill rich." P07–U1 Category-E: "… you may be trained as a public administrator but tomorrow you are a network administrator because during reading that public administration course you had to go into contact with all that information." P05–U1
Role of student	Category-A: "See up there in the bookshelves, I have a couple of books, but I cannot see whether you have got any of your own. But the truth now is, you might be having a thousand PDF books in your SD card of your Smartphone right, and as I struggle with my two small shelves of books, technology has given you every book that I don't have therefore you can have access to as many copies of books as you may need." P09–U1 Category-B: "Diagrams were drawn on white piece of paper and then shown and given to us to visualize but with the advent of technology, now I don't see myself wasting time to draw complex diagrams on pieces of paper for students. Students receive graphs and other images opened in a picture editor, PDF reader, Microsoft word and PowerPoint for their easy learning." P02–U1 Category-C: "Before I involve any ICT platform in my instruction, I need to know how to properly use it, so that, I can also effectively guide my students on how to use for organizing their materials I give." P04–U1 Category-D: "Of course, as a teacher you have got to show perfect by giving guidelines, but the students sometimes end up going six steps ahead using computer and internet. What is the ultimate objective?" P09–U1 Category-E: "Much of the technology talked about here were invented and designed by electrical engineers, which is important to let students know. In order to improve for the future, in a way that community's benefit, I guide my students in applying ideas toward creating new and better products." P07–U1
TPACK components	Category-A: "I always use presentation slides and whatever goes more than two hundred slides, no problem because they (students) have their copies, all they need is to put in some concentration in order to pass their exams" P07–U1 Category-B: "Well, I think that ICT actually helps teachers more because some of the contents presented in the slides or in other related ICT tools are self-explanatory. Students just get ready made things to read, sit for examination to express their understanding." P02–U1 Category-C: "… maybe you expect 60% output from what you discuss with students (Content and Knowledge) which will be impossible to attain if you did not guide them well, yes, some students can manage but they really need some guidance because we do not just teach anyhow (Pedagogy), we have some syllabus to follow. Based on this syllabus we tell them what to do." P05–U1 Category-D: "Whenever students browse (technology) many different things, they may get important information from other viewpoints (Learning Style). This gives them the exposure of how people think on the topic (Content) and therefore do not only depend on my views alone (Knowledge) as methods known vary from person to person (Learning approach)." P10–U1 Category-E: "I will allow students to teach themselves (Knowledge Creation) because some students will like to exhibit their knowhow or they understand something that they would like to teach their fellow students (Learning Style/Pedagogy). So, I give them the opportunity to work in groups so as to share (Technology) what they understand (Content Knowledge)." P05–U1

> Some students bring very important arrangements and agreements in what I give them because they searched through and found other things related to my instructions and I do think that technology draws their learning interests from all directions and when considered, may lead to producing their best because it's in the direction of their interest. P06–U1

In this category, unlike the Category D, ICT use in engineering teaching is extended from individual growth (Category D) to departmental growth (Category E). Students are seen to engage different forms of ICT supported research activities that promote not only individual growth but also departmental growth. Students' practices in ICT supported learning allows them to develop new ideas, for instance, when approaching class tasks/assignments in ways that is easy for them to remember and apply. One of the participants informs:

> Technology provides numerous services to the users but the best of all can be realized based on relevance of application and my main aim as a teacher is to influence, encourage and supervise students or do research on teaching and learning to support this department [al] grow[th]. P08–U1

In addition, students' ICT practices lead to community development through creating new knowledge beyond their main subject areas. Digital libraries aid in providing new learning experiences to learners toward encountering various disciplinary challenges in engineering education within institutions. For instance:

> Much of the technology talked about here were invented and designed by electrical engineers, which is important to let students know. In order to improve for the future, in a way that communities [other engineering fields] benefit, I guide my students in applying ideas toward creating new and better products. P07–U1

ICT provides access to variety of learning activities beyond the institutional boundary. Authoring software is seen commonly used by students to construct knowledge for solving global challenges in engineering education. Thus, engineering university students are seen preparing for an expanded future career with innovative intentions. A participant remarked:

> A lot is expected of ICT in relation to improving the capacity and capability of students' learning outcomes not only within their subjects of specialization but also other knowledge areas for a sustainable globe. P09–U1

In brief, engineering university teachers' conceptions of ICT enhanced teaching emerged in five qualitatively different categories of description such as: imparting information, transmitting structured knowledge, offering guided learning, engaging students toward practice and engaging students toward innovation, of which, engaging students toward innovation.

5.1. Relationships among categories of description

In order to discover relationships among the five categories (A to E), and to present the variations (how qualitative different ways the categories are deviated from each other), four dimensions of variation were discovered. Four dimensions of variation among categories of description underpinned pedagogy in engineering teaching are outlined in Table 2.

5.1.1. First dimension: purpose of ICT in engineering teaching

ICT is used for two purposes in Categories 'A' and 'B', that is, for accessing, presenting information, and transmitting structure knowledge respectively. Students use it for receiving that information and knowledge. Communication between teachers and students is established in the intermediary category 'C'. While in category 'D' and 'E', active learning space for problem solving and wider active learning space for innovation is created respectively. Engineering students acquire expertise knowledge and skills beyond their main subject areas in the Category E. Therefore, the purpose of ICT in engineering teaching is for accessing and re-organizing available information for teaching and building good communication relationship in the lower categories, 'A' 'B' and 'C'. In the upper categories (D and E), it is used to create active and innovative learning space for the students (see Table 2).

5.1.2. Second dimension: role of teacher in ICT enhanced teaching

In categories 'A' and 'B', the role of teacher is to deliver information to the students. The second dimension emerged as a result of the relationship between categories 'B' and 'C'. In category 'C', teaching is interactive but in a controlled way. Teacher's role remains central to conveying content information and creating of space for students to respond/react to teaching in 'C'; however, this role advanced to entirely creating learning environments and guiding students in their learning activities within and beyond their subject requirements in categories 'D' to 'E' respectively (see Table 2).

5.1.3. Third dimension: role of student in ICT enhanced teaching

Students are passive recipients (receiving information and knowledge) in categories 'A' and 'B', whereas students are seen a little active (controlled) and passive most of the time in category 'C'. In category 'D', students engage in active learning through myriads of ICT tools. The teaching focus expands from creating an interactive class apparent in category 'C' to entirely student engagement into active learning in category 'D'. Therefore, students are seen active by using a myriad of ICT resources and devices that support their learning in their subject matter in category 'D' whereas, their engagement is extended from subject meters to industrial innovation in Category E (see Table 2).

5.1.4. Fourth dimension: TPACK components

The dimension represents expansion in a way TPACK components are used in the five categories of description. TPACK components are compact and more applied in the higher-level categories. In category 'A', teaching and learning is mainly focused on Technology and Content (TC) components. Teachers use technology to access and transmit subject content to the learners. Therefore, not all TPACK components are fully present. In Category 'B', the teaching and learning process is not only about the Technologies used and Contents accessed but also Knowledge passed (TCK). Category 'C' is Technology and Content Knowledge focused while Pedagogy is moderately present. Technological, Pedagogical and Content Knowledge (TPACK) is present in category 'D' and applied at advanced level in Category 'E', that is beyond institutional boundaries (see Table 2). Table 3 provides an overview of university teachers' responses to the ICT-use in their teaching.

Table 3 represents the pedagogical implications that were revealed from the relationship between categories of description and dimensions of variation. The main objective of this relationship in Table 3 is to present how each category is deviated from each other when a particular dimension is considered. For instance, the first dimension of variation [purpose of ICT in engineering teaching], expanded from category 'A' to 'B', 'C', 'D' and 'E' respectively. The purpose of ICT in engineering teaching is limited and moderate in categories 'A' and 'B' respectively whereas significant in category 'C', more significant in 'D' and most significant in 'E' respectively. In the second variation, teachers' role shifted from active in categories ['A', 'B'] to partially facilitators in category 'C', and full facilitators in categories 'D' and 'E'. Simultaneously, in third variation, students' involvement became reverse direction (students passive in categories ['A', 'B'] and most active in categories ['D', 'E']. In the case of TPACK components (fourth category), teachers' and students' ways of applying it varies from Category A (least applied) to Category E (more advance). Therefore, the double arrow symbol indicates the intensity of each category deviated bidirectional, that is, the features (characteristics) of each category moves from Category A (lower order) to Category E (higher order) and vice versa.

Table 4 shows the relationships based on referential and structural components of phenomenographic research [62,63]. The referential and structural aspects of the study discerned two broad orientations. The five qualitatively different categories of description varied from teacher-centered/content oriented to student-centered/industry oriented. Student-centered conceptions further expanded into a student-centered/activity-oriented and student-centered/industry-oriented continuum. Categories 'A' and 'B' are structurally placed under teacher-centered orientation whereas categories 'D' and 'E' were placed under student-centered orientation (see Table 4). Meanwhile Category C bridge two broad continuum teacher-centered (Categories A, B) to student-centered (Categories D, E).

Overall, Table 4 provides evidence for engineering university teachers' practice of ICT enhanced teaching in Bangladesh, which is expanding towards student-centered learning.

6. Discussion

The aim of this study was to investigate engineering university teachers' conceptions of ICT enhanced teaching. The findings revealed five qualitatively different categories of description: imparting information; transmitting structured knowledge; offering guided learning; engaging students toward practice; and engaging students toward innovation. The categories of description represent different characteristics of engineering university teachers' conceptions of ICT enhanced teaching. Categories of description 'A' and 'B' are considered less complex ways of teaching because in category 'A', the teachers' focus is on accessing and delivering syllabus information and in category 'B', the emphasis is on delivery of content knowledge more effectively. Category 'C' (offering guided learning) is an intermediary category, linking categories 'A' and 'B' to 'D' and 'E'. Teachers create interactive environments for building good relationships with students through communication which relates to the finding by Kember [47]. In his study [47], identified student-teacher interaction as intermediary category between teacher-centered and student-centered orientations. This intermediary category was found important in predicting demonstration results by students before they were advised. However, this result was later contradicted by Samueeowicz and Bain [78]. Categories 'A', 'B' and 'D', that is, imparting information, transmitting structured knowledge and engaging students toward practice relate to findings by Kember and Kwan [56,79]. However, category 'E' (engaging students toward innovation) is a new knowledge in engineering education. Recently a quantitative study conducted by Lin et al. [80] investigated pre-service technology teachers' cognitive structures and how they construct engineering design in technology

Table 3
University teachers' response to ICT-use in teaching.

Dimension of Variations	Categories of Description				
	Expansion				
	Category A	**Category B**	**Category C**	**Category D**	**Category E**
Purpose of ICT use in engineering teaching	Limited	Moderate	Significant	More significant	Most significant
Role of teacher	Provide information (active)	Provide knowledge (active)	Both active & facilitator	Facilitator	Facilitator
Role of student	Passive	Passive	Partially passive & active	Active	Active
TPACK Components	Least applied	Less applied	Moderate application	Acceptable application	Advanced application

Table 4
Outcome space of conceptions of ICT enhanced teaching.

Referential aspect (What aspect)		Structural aspect (How aspect)			
Categories of description		Teacher-centered/ content oriented	Teacher-centered/ activity oriented	Student centered/activity oriented	Student centered/ industry oriented
A	Teaching as imparting information	A			
B	Teaching as transmitting structured knowledge	B			
C	Teaching as offering guided learning		C		
D	Teaching as engaging students toward practice			D	
E	Teaching as engaging students toward innovation				E

learning activities. The study recommends that teachers' pedagogical engineering design thinking in relation to technology is necessary for achieving better learning experiences. On that account, phenomenographic research design leads to insights connected to empirical research associated with cognitive viewpoints. The present study discovered five pedagogical approaches to ICT enhanced teaching which may enhance the practices of engineering design. Cropley [81] informed that there are three creative engineering problem solving approaches, they are forward incrementation, redirection and re-initiation, henceforth, new engineering problems require new technological solutions (re-initiation), yet little support is provided for creative students. In the present study, engineering students use ICT tools for creative learning activities toward innovation apparent in category 'E' (engaging students toward innovation). In category 'D', creative ideas developed and practiced by students through ICT extends previous literature by the attained ability to acquire necessary information needed for learning (forward increment) and improve their problem solving skills (re-direction). Further, the easy follow up of content information, attainment of good teaching habit and sharing of teaching responsibility in category 'B' and 'C' respectively outstretch the existing related discoveries. Nevertheless, category 'E' emanates four levels of new knowledge as developing teaching knowledge and skills (engineer teachers), contributing to departmental/disciplinary growth, contributing to community development (beyond departmental boundary) and responding to global industry-related challenges (beyond institutional boundary) that extends the prior phenomenographic investigation.

In order to identify relationships, four dimensions of variation among the five categories of description emerged: purpose of ICT in engineering teaching, role of teacher, role of student and TPACK components. The second and third dimensions of variation (role of teacher) and (role of student) have been reported in the previous studies, for example, see, [28,56,56]. The fourth dimension, that is, TPACK components, is a novel dimension. A few aspects of first dimension 'purpose of ICT in engineering teaching' was identified in the prior phenomenographic studies such as [28]. However, this study identified a novel fourth dimension that shows ICT is used in EE for advanced application of technological pedagogical content knowledge in five categories in a systematic way (from lower level to higher level). This is an innovation and adds new knowledge in exiting phenomenographic studies.

The relationship between engineering university teachers' conceptions of ICT enhanced teaching and using ICT for teaching engineering subjects was discovered in this study. Lecturers with teacher-centered conceptions of ICT enhanced teaching are found more likely to teach engineering subjects within a limited scope of knowledge noticeable in categories 'A', 'B'. Students are mostly passive and, in few cases, found to be active in category 'C' where teachers controlled the teaching practices. On the other hand, teachers with student-centered conceptions of ICT enhanced teaching are found more likely to teach engineering subjects with a wider scope of knowledge apparent in the last two categories; 'engaging students toward practice' and 'engaging students toward innovation.' Teachers in this category gave the impression of unlimited interest in using ICT for teaching engineering subjects. This discovery relates to the technological limitations found affecting teaching approaches in the various knowledge fields such as science, arts, health science, law and administrative science in a Pakistani context [82]. However, the disciplinary context in this study is engineering with special focus on exploring ICT-enhanced teaching in a developing country context (Bangladesh). Despite technological limitation, teachers in EE may incorporate technology in myriad ways (five ways) in their teaching. Therefore, the findings of this study such as five categories of description (five pedagogical approach in ICT-enhanced teaching); the relationship between five categories (dimension of variation) is a novel initiative that can be applied in EE of a similar contexts toward improving students' learning.

7. Conclusion

The study is qualitative, conducted using phenomenographic research approach. Its purpose was to explore engineering university teachers' conceptions of ICT enhanced teaching. In-depth semi-structured interviews were used to gather data through audio/video recording. Five qualitatively different teachers' conceptions emerged, out of which, the first four were found relating with previous findings, meanwhile the last (teaching as engaging students toward innovation) was a new innovation. Four dimensions of variation were identified among the categories of description, where the fourth (TPACK components) has not been found in the available literature. The conceptions in the study were consistent with the teacher-centered and student-centered continuum, where the first two are teacher-centered and the last two are student-centered. However, one intermediate category (C) bridges both the broad continuum.

The findings may improve university engineering teachers' further understanding of teaching through incorporating technology into their teaching approaches. It provides useful knowledge that will be useful for improving teachers' internal believes (conceptions) towards using technology in teaching EE. Thus, the findings could be utilized for improving effectiveness of a professional development program (PDP) in EE. Ho, Watkins, and Kelly [83] reported that a PDP will not be effective until teachers' change their conceptions, that is, if teachers conceived that ICT may not be useful for improving their teaching, then organizing a PDP in ICT-enhanced teaching may not be an effective one for those particular teachers. Besides, it may also help curriculum designers in decision making to select engineering courses, subjects, and contents of relevance. However, some limitations were found that relate to context, interview data, sampling, and outcome space. For example, the sample size of 14 participants was small and the findings were context dependent. However, a significant number of prior phenomenographic studies conducted have been based on smaller sample sizes than this study. For example, Ho, Watkins, and Kelly [83] conducted interviews with 12 academics to learn more about their conceptual shift strategy for enhancing teaching and learning. González [19] conducted interviews with seven educators to learn more about their views on online instruction and other similar studies provided useful outcomes with smaller sample than this study. Therefore, the sample size of 14 participants in phenomenographic approach provides useful knowledge that will be useful for EE of likewise (similar to Bangladesh) contexts. Besides, prior literature also provides evidence that a significant number of high-quality articles published in SSCI journals were based on interview data. Thus, these limitations may not have adverse influence on drawing conclusion for enhancing EE of Bangladesh. This study recommends advanced application of TPACK components to enhance engineering knowledge and skills for addressing global engineering challenges. Considering these limitations, nationwide mixed methods research with a larger sample might be conducted with an aim of generalizing the findings. Additionally, a quantitative investigation to determine the impact of the pedagogical approaches to teaching is recommended to widen the understanding and implication of ICT-use in engineering education. Another study could be conducted to investigate 'how teachers' work experience influences their practices of ICT implementation in teaching engineering education. Besides, students' conceptions of ICT-enhanced learning in engineering education is another emerging area in developing countries that need to be investigated in near future.

Data availability statement interview data and transcripts are available from the first author and the corresponding author upon reasonable request.

Author contribution statement

Mboka Khalid, MSc: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Md Shahadat Hossain Khan, Ph. D; Sue Gregory, PhD: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. It is an outcome from a MSc thesis (OIC full funded scholarship) that was conducted at TVE department, IUT.

Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no competing interests.

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