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Exploring Teaching and Learning Physics in Engineering Institutions of Kathmandu District

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Abstract

Being a physics educator for the last two decades, the first author of this paper observed some disturbing scenarios in the educational landscape of diploma in engineering in physics theory portion. Students' academic achievements in the physics final examination conducted by Council for Technical Education and Vocational Training (CTEVT) indicated that many failed to fulfill the minimum requirements to pass the final exam or gain good grades. In addition, most students could not apply the physics principles in real-world contexts. The purpose of this study was to explore teaching and learning practices in physics theory classrooms of Kathmandu district-based diploma in engineering schools affiliated to CTEVT. The study employed a qualitative research design and was underpinned by the social constructivist learning theory. Ethnography as a research method was employed in which participant observation and unstructured interviews were used as the research tools. A purposeful sampling was carried out to conduct the research in which nine students from two engineering institutions were taken as the research participants. Data analysis was carried out by coding the raw data primarily employing N-vivo coding thus creating several categories and finally developing three major themes. The findings indicated that the classroom dialogue didn't support the social constructivist epistemology. Thus, the findings lead to the conclusion that traditional teacher-centric practices were prevalent at those engineering institutions that might be responsible for the poor academic achievements of students.

Keywords: Diploma in engineering, CTEVT, ethnography, social constructivist epistemology, teacher centric, inquiry-based learning

Introduction

Teaching is the process of imparting knowledge from teacher to student. It is defined as blending several elements into the procedure by which a teacher determines and applies the teaching methodology (Munna & Kalam, 2021). On the other hand, learning is a key consideration that a teacher must consider when training children. Learning can be seen as a permanent change since it is brought about in students by a teacher through strategies such as strengthening certain abilities, changing attitudes, or understanding specific scientific laws that function within a learning environment (Sequeria, 2012). To be considered an active learner, a student must anticipate being treated as an adult learner who can influence the learning environment in some way, such as by asking questions and getting clarification on their doubts.

Physics is essential for understanding the intricacy of modern technology and is necessary for a country's technological development. This field of science has greatly influenced many technologies that are shaping current life and has contributed to the understanding of several phenomena that are encountered every day (Erinosho, 2013). The Council for Technical Education and Vocational Training (CTEVT) curriculum 2021 mandates physics teaching and learning to impart knowledge of various physical concepts that may be applied in each subject domain in technical schools including engineering, health sciences, agricultural science, and forestry. For instance, civil engineering students explore the elastic behavior of structures like buildings, bridges, towers, hydropower dams, and other structures using the laws of elasticity of physics. Likewise, electrical engineering students design a transformer, generator, and dynamo using the principles of Faraday's laws of electromagnetic induction. The ideas of optics and optical devices are used by ophthalmology students to address the issues of short- and long-sightedness, anomalies in combination with vision disorders, relating to human eyes (Paudyal et al., 2021). Thus, it may be claimed that physics and society are intertwined. In the modern world, it is impossible to separate oneself from physics.

From the anthropological perspective, the culture of a human group or society is made up of knowledge, language, customs, and materials that are passed down from one generation to the next (Saldana, 2011). A culture is a shared knowledge and practices of a bounded group of people and is concerned with the people's way of living. The culture of teaching and learning inside physics theory classrooms comprises the elaboration of scientific principles thus employing hypothetico-deductive relationships between various physical quantities and numerical problems concerning different principles/ concepts. During the first author's involvement in teaching physics in an engineering school, he dealt with the chapters/ topics based on the metaphor, ‘curriculum as a content or subject matter’ (Schubert, 1982, p. 5). In doing so, he employed lecture-based teaching to explain and derive the formula for projectile motion, the principle of conservation of linear momentum, total internal reflection of light, nuclear fission, and so forth. In this sense, science education has prioritized imparting secure and accepted knowledge while excluding contradictory information, opposing viewpoints, conflicts, and ethical considerations (Long, 2012).

During the first author’s several years of teaching in an engineering school and other higher secondary schools, he noticed that physics lessons were dominated by traditional chalk-and-talk instructions (Angel et al., 2002) and a culture of transmission-based teaching approaches (Acharya, 2016) and exam-centric teaching and learning practices were prevalent inside physics classrooms in many institutions across Nepal. Many of his students claimed physics was a difficult subject as they were seen struggling with numerous issues across the curriculum that were often categorized as lacking clear examples and requiring a considerable degree of mathematical manipulation. In addition, students’ performance policies encouraged teachers to employ unconventional pedagogical techniques to enhance students’ academic achievement thus creating a competitive, hectic, and tense environment (Mackatieni, 2017) in the classroom culture of physics learning.

The academic result published by CTEVT in January 2022 disclosed the following scenarios. We here present the academic result of an engineering institution. In the electrical and electronics stream, 9 out of 10 failed the final physics exam held in 2021. Likewise, in civil engineering stream, 13 out of 40 failed in the exam. In the electrical engineering stream, 12 out of 18 students failed to accomplish the pass marks. In another engineering school, 22 out of 47 students failed to achieve the pass marks in the final exam of physics conducted in December 2021 (CTEVT results, 2022).

Based on above published results, it could be seen that students were not able to perform well in physics final examinations that made us think seriously to explore and investigate teaching and learning inside physics classrooms of engineering educational institutions affiliated to CTEVT.

The purpose of the study was to explore teaching and learning practices inside physics theory classrooms of engineering institutions of Kathmandu district. This study was guided by the following overarching research question:

1. How do teaching and learning occur inside physics classrooms of engineering institutions?

Literature Review

In this section, we have reviewed some of the recent research in the field of physics education which helped us to allocate the research gap between those studies and this research study.

Iwuanyanwu (2022) conducted research in a university undergraduate physics classroom. The purpose of this study was to investigate the factors that influence students' self-efficacy to solve mathematical physics related problems. The finding was that didactic instructional approaches along with other variables influenced students self-efficacy. Research conducted by Uden et al. (2022) on active online learning in physics showed that students' perspectives changed during the post-implementation phase of the active online learning programme. Kanyesigye et al. (2022) conducted a research on impact of problem-based learning on students performance in physics classrooms as well as conceptual understanding and attitude together with teachers' effective instruction. The results showed that students who were subjected to problem-based learning gained improved learning as compared to those who were guided through traditional pedagogical practices.

Ogedbo and Ramnarain (2022) conducted a research to investigate the effects of employing interactive simulation technology as a guided inquiry strategy to improve learners conceptual knowledge in electrostatic. The finding of this study was the simulation techniques provided learning opportunities that influenced learners' development of metacognitive skills and information transfer. Similarly, Gysin and Rovelli (2021) conducted a research on learning physics lessons. The researchers employed the use of knowledge features (momentum, force, kinetic energy, etc.) and context features (movement of a cable car) during the transfer process in physics learning especially regarding the topic of energy in mechanics. The finding was that knowledge pieces in the chapter on mechanical energy could be transferred to real-life situations using different context features.

Following empirical reviews, a significant gap between these studies and our research was discovered. These studies were focused on different pedagogical approaches in physics education but were not concerned with how students in engineering institutions learn physics especially the 10+3 pattern of higher education in the engineering field. Moreover, these studies were conducted in foreign institutions and didn't reflect teaching and learning patterns in the context of Nepal. In addition, no research has been conducted on teaching and learning physics in the context of the Nepalese educational landscape. The purpose of this study was to fill that gap and to explore the teaching and learning practices in engineering institutions of Kathmandu. This will further reflect the pattern of teaching and learning in physics classrooms of other technical schools affiliated with CTEVT.

Methods and Procedures

Research Method and Design

A qualitative research method was employed to investigate a problem and gain an in-depth understanding of a central phenomenon (Creswell, 2012). In qualitative research, a central phenomenon is the fundamental notion, idea, or process that is being studied. Ethnography as a research design was employed in the study. An ethnography is a written representation of a culture. It carries quite serious and moral responsibilities for the images of others inscribed in writing and is most assuredly not neutral (Van Maanen, 1988). In addition to this, ethnography is the study of social life through observation and documentation to portray a group's culture. With ethnography as a research method, the first author of this study unpacked the culture of participants and settings first through participant observation which is the main method of ethnography (O'reilly, 2005), and then conducted interviews with the research participants.

Research Site and Participants

Two diploma-level engineering schools affiliated to CTEVT were selected for the study. Institution A comprised civil, electrical, electronics, computer, and architecture engineering courses while Institution B comprised electrical, electronics, and computer engineering courses. Both were the oldest engineering schools in Nepal. The research study was mainly focused on the first-year diploma in engineering students from electrical, electronics, and computer engineering as physics was being taught only in the first year of the engineering course. The participant observation was carried out within these streams in the two engineering schools.

Purposeful sampling technique was employed for the selection of the research participants from the two engineering schools. In Institution A, there were 20 students in that specific class whereas in Institution B, there were 30 students in the class where participant observations were carried out. Altogether, nine research participants were selected for the interview process out of which four participants P1, P2, P3, and P4 were from Institution A and participants P5, P6, P7, P8, and P9 were from Institution B. The research participants were the first-year engineering students of both the institutions.

Data Collection Approaches

Two methods of data collection were employed in this research study. The first one was participant observation which is the main method of ethnography (O'Reilly, 2005) in which the first author was involved in the participant observation in the physics theory classes of the two engineering schools. The participant observation was based on the teaching and learning practices of ‘Optics’ in Institution A whereas ‘mechanics’ in Institution B. Multiple classes were observed during the first semester of study in those institutions. Likewise, multiple rounds of unstructured and open-ended interviews were conducted with those nine participants. The interviews were conducted both face-to-face and online platforms such as Zoom and Google Meet.

Data Analysis Approach and Strategies

The data in this research was qualitative in nature. Data analysis is a central step in qualitative research. The analysis of qualitative data ensures the outcomes of the research (Flick, 2014). First, the data from participant observation and interviews were transcribed. The data analysis process started with the exploration of data to obtain a general sense of data, memoing ideas, thinking about the organization of the data, and considering whether the researcher needs more data (Creswell, 2012). In this sense, the first author developed a multitude of codes, which is “a short word or phrase that symbolically assigns a summative, salient, essence-capturing and/or evocative attribute for a portion of language-based or visual data” (Saldana, 2016, p.4) from the field note excerpts and the interviews transcripts primarily employing in-vivo coding. Then several categories were developed from the coded data. Code books for participant observations and interviews were created for more in-depth analysis. Three major themes were developed from the ethnography of physics theory classrooms.

Results

The field note excerpts, the observer’s comments, and personal reflections as well as the interview transcripts were meticulously analyzed, and the findings from those investigations revealed the following elements. This section covers every element that contributes to the total.

Lecture-based Teaching

During the participant observation session of multiple classes, the first author noticed that the chief pedagogical approach in teaching and learning physics was lecture-based. In institution A, the teacher was delivering lectures on the unit ‘optics’ in which teaching and learning were guided by several chapters such as principle of reversibility of light, real and apparent depth, total internal reflection, reflection at spherical surfaces and so forth. Likewise, in institution B, the teaching and learning of physics were based on the unit mechanics in which topics such as characteristics of simple harmonic motion, time period of simple pendulum, rotations of rigid bodies, angular momentum, law of conservation of angular momentum, etc. were covered.

The researcher talked with the participants about physics pedagogy in the theory classrooms. All of the participants mentioned that the teachers explained the topics/ theory and derived formulas and occasionally provided some examples related to the topics. When the first author of this research was a student at the intermediate level of science in 1991-1993, he felt that his teacher's instructional approaches were guided by the lecture-based instructions in which they used to derive the formula and unilaterally explain the theory, and students in those time either had to copy the teacher's write up or carefully listen to the teacher. In addition, during the first author's teaching practices of nearly two decades in an engineering institution, he was also guided by the same pedagogical approaches as that of his teachers back in the 90s and the teachers in the two engineering institutions under investigation. The chief pedagogical technique in all these three cases was lecture-based teaching.

The lecture method of instruction is undoubtedly the oldest instructional method, and it is still the most prevalent method of instruction today (Hussian et al., 2011). In this teaching approach, a teacher explains a topic, derives principles/ equations, poses some examples related to the topic, and solves some numerical problems from the recommended books that are easily available in the market. On the other hand, students are the passive receptors of knowledge (Emalia, 2017) and thus achieve already assimilated knowledge and abide by the teacher's instructions. Also, Buabeng (2015) claims that in the high schools of New Zealand inside physics classrooms, the teaching and learning was guided by traditional lecture-based instructions. Moreover, in the high schools of Nepal traditional chalk-and-talk method of instruction is prevalent in which teachers are less likely to encourage the students' discussion and students are expected to be passive receptors of teacher's transmitted content knowledge without knowing the real meaning in students' daily life activities (Acharya et al. 2019). Most importantly, teaching and learning environment in physics classroom was defined by reiterating information from earlier lessons, defining terms of physical quantities, expressing the relationship between physical quantities using mathematical equations and solving numerical problems (Worku & Alemu, 2021).

Non-interactive Teaching and Learning

During the participant observation at the two engineering schools, the first author didn't see interactions between the teacher and students as teaching and learning were confined to copying the teacher's version of write-up from the whiteboard and following supplementary book. Apart from raising a few questions, the teachers were not in contact with the students and neither most of the students seemed to interact with the teacher. The teachers occasionally posed questions to the students but either the teachers replied by themselves, or they ignored the solutions owing to their speed of teaching. In addition, not all students actively participated in the learning process. Some of them were talking to their friends and most of them were not willing to address their teachers' concerns. While the teachers posed several closed-ended questions, most of the students remained silent and the teaching and learning was limited to one-way traffic (Ghimire, 2023). Moreover, during the participant observation, the first author noticed that both teachers were teaching quickly as if they had to cover the syllabus as quickly as possible.

Participants P3, P4 from institution A and participants P8 and P9 from institution B shared a common voice that their physics teachers taught fast. Likewise, P5 from institution B shared similar views but in indirect way saying that teacher was focused, on the completion of his course and this voice was in line with P4 from institution A.

Different views were echoed regarding the lack of focus in the learning process. P3 claimed that her classmates were busy with other activities like chatting with friends and using phones in class. Likewise, P2 and P6 claimed that students in the classes were talking to each other while the teachers were teaching. Similar voices from P1, P5, P9 were aligned with P2 and P6.

Most of the participants shared that there were few or no student-teacher and student-student interactions in the classroom. P1, P3, P5, P6 and P7 said that there were no interactions in the classroom in the form of discussions or other interactions. However, P2 claimed that there were very few interactions in the classroom. P8 argued that the teacher responded his questions by himself. Further P3 and P5 claimed that the teacher opposed while they raised concerns. P5 argued that the teacher didn't respond to his concerns but rather asked him to meet after the class or the next day. P3 was complaining throughout the interview that the teacher asked her not to raise uncontextualized questions thus trying to escape the students' concerns.

The first author felt that the teachers were not paying enough attention towards the teaching and learning process and the students' learning was limited of being deposited (Freire, 2005) the so-called knowledge to the seemingly empty minds of the learners (Taylor, 2015). Additionally, the role of teachers in the institutions under study was neglecting the fact that learning and learners are the heart of the educational process and treating the learner as a machine undergoing several cycles of programming and reprogramming (Adams, 2006).

The primary goal of science teachers would be to allow students to think and act like scientists rather than just learning or copying what others have already done (Fadaei, 2021). On the contrary, the physics teachers at both institutions were making students learn through a specified books or class notes rather than learning through social interaction and creating knowledge collaboratively (Thakur, 2014). Participant P3 views indicated towards the hegemonic ideological approach of the teacher at institution A. In classroom setting, the teacher's frantic activity- calling on students, granting privileges, and starting and stopping activities on those who are on the receiving ends of the teacher's action. Sometimes the instructor overlooks a raised hand, occasionally they will dismiss the questions, and sometimes they may deny a request for permission (Jackson, 1990). These assertions are in line with this research study.

Exam-centric Teaching and Learning

During the first author's participant observation classes at both engineering schools, he noticed several times in his observations that the orientation of teaching and learning physics was aligned towards exam-focused teaching and learning.

In addition to this, the research participants also shared their views concerning this issue. All of them claimed that the teachers emphasized exam-oriented teaching and learning activities. They further claimed that the teachers asked them to bring the collection of old question papers and prepare for the final examination based on questions asked in the previous final examinations. Also, the teachers were focused on the important topics while teaching several topics. The scenario portrayed that teaching and learning were aligned to prepare students for the final examination thus overshadowing the learning process.

During the first author's intermediate-level science learning trip, he, too, purchased a collection of old-fashioned problems, and as a result, he couldn't do much better in physics. His education was also exam-oriented.

Likewise, during his teaching career, he implemented the concept of answering a collection of past question papers, which he believed would improve both the learning process and academic accomplishment in the final examination. He made it mandatory for all students to answer each question from a collection of old question papers, limiting their learning because he was only concerned with preparing his students for the final exam so that better grades could be obtained for the credibility of his teaching, the name, and the fame of the academic institution.

The teaching and learning physics when the first author was a learner and a teacher, and the teaching and learning as observed at the two engineering institutions, both were confined within the domain of exam-oriented education, that places a strong emphasis on the evaluation of student proficiency through exam results (Chen & Zou, 2018) whose goal is to separate the minority from the majority and send them to a higher level of education. The primary purpose of exam-oriented education is to unilaterally improve learners' capacity (Meng et al., 2021). Since students cannot advance to the next level until and unless they pass the final examination, instructors forcefully make them learn to attain the final exam and achieve at least the pass marks.

Discussion

The main purpose of this study was to explore the teaching and learning practices of Physics in diploma in engineering institutions of Kathmandu district. The findings of this research revealed that the teaching and learning practices in the two engineering institutions were aligned toward a lecture-based instructional approach, non-interactive teaching and learning, and exam-oriented teaching and learning.

The teachers at those engineering schools taught different units, optics in institution A whereas mechanics in institution B. The cardinal instructional method is lecture-based popularly known as the chalk talk (Brookfield, 2005) approach. The traditional lecture is a teaching method that is well-known for disseminating material widely, but it is less successful at fostering deep understanding and inspiring the curiosity necessary to further explore the information that has been taught (Dacre & Fox, 2000). Additionally, this method of pedagogy effectively disperses a large volume of content to a wide number of students, but it does little to promote and enhance lifelong learning, which is a crucial skill for those working in the fields that are continuously evolving (Ahmed & Roy, 2014). On the other hand, the culture of learning was such that students in institution A were listening to what the teacher explained or wrote on the whiteboard while in institution B the students copied what the teacher wrote on the whiteboard. In this way, the learning was limited to following the prescribed set of protocols such as recommended textbooks and class notes thus delimiting the creativity among the learners. The surface approach of learning (Alagib et al., 2019) popularly known as rote learning was prevalent at those institutions in which learners seemed to be motivated by either a need to finish the course or a fear of failing, which causes them to concentrate on memorization of facts from the larger context. In addition to the participant observation, the interviews with research participants also revealed that the teachers started a topic, explained the laws/theories, and derived physical equations. The teachers were focusing on 'the simple implementation of centrally produced curricula and objectives' (Brookfield, 2017, p.52). This scenario portrayed a teacher's-controlled classroom in which the teacher is the only person who has control over the learning process and is both the source and transmitter of knowledge (Yesilyurt, 2022). Thus, teaching and learning seemed to act as a one-way traffic.

From the social constructivist viewpoint, learning and learners are considered at the heart of the educational process (Adams, 2006). The instructor's job is to act as a facilitator or guide (Taylor, 2014) thus providing students with alternatives and incentives to construct knowledge and understanding rather than acting as an authoritarian person. He/she has a prime responsibility of stimulating dialogue and discussions in group or individual thus supporting the development of understanding (Pritchard, 2009). However, the findings indicated that the instructor's job was not coherent with such a paradigm of learning.

Interactions between students and academic staff are an essential part of higher education since positive connections benefit students' educational experiences (Malm et al., 2020). In addition to this, students gain from interactions with instructors both inside and outside of the classrooms (Trolian & Parker III, 2021). However, the findings from this study suggested that at both institutions very few students were active and there was almost no interaction in the classroom.

Most of the participants reported that many students were disinclined in the learning process. In our view, the didactic teaching approach at those institutions might lead to the scenario reported by Acharya (2016) who claims that most science teachers begin the sessions with a problem the exercise book and choose one of the problems, typically the first, to serve as a model and demonstrate how to solve a specific kind of problem as science lessons are based on problems that are primarily available in practice books and recommended textbooks.

The non-interactive nature of physics classrooms in both engineering schools reveals the traditional teacher's centric pedagogical model which Serin (2018) claims that such instructional approaches are constrained by instruction that is heavily influenced by textbooks which in turn hinders students' decision-making and problem-solving skills. In addition, Acharya (2016) claims such approach does not effectively foster discussion, thinking and conversations in the classrooms.

Social constructivist learning theory emphasizes the interaction of learners with others and the dialogue with someone who is a more knowledgeable person as this paradigm of learning focuses on social interaction. In addition to this, a person can execute a given number of tasks alone but can perform a greater number of tasks in collaboration (Chaiklin, 2003). However, findings regarding the interactions in the classrooms also contradict the basic assumptions of social constructivism as the culture of interactive learning was predominated.

Exam-focused education is often despised, yet nothing has changed, instead, it has become even more intense (Chen & Zou, 2018) as the structured and predetermined responses were given emphasis from the recommended books, supplementary books and teacher's notes. Bemmoussat and Bouy (2019) claim that a highly exam-centric education system increased emphasis on testing and assessment has led to an increase in pedagogical malpractices.

Furthermore, several alternative terms and phrases such as item teaching, curriculum teaching, test oriented teaching, and teaching to test, all of which refer to classroom settings in which testing is regarded as an end in itself. Mackatieni (2017) claims that instructors utilize unscientific teaching techniques to enhance students' academic results producing a tense, hectic, and competitive culture in elementary and secondary schools that increases students' workload. The researcher further stressed that learners thoroughly go over the previous test questions in order to reproduce the content they have covered in regular classes. At those engineering institutions, the teachers were mainly focused on students preparing the content based on the final examination model questions as the data from participant observations and interviews were also coherent with Mackatieni (2017)

Teaching, learning, and assessment have traditionally been considered as three different yet interconnected aspects of education (Adams, 2006). Teachers typically place assessment second to instruction. Such a view of teaching, learning, and assessment echoes behaviorist ideals as testing is needed to make sure that mastery has been attained since learning happens sequentially and hierarchically (Thakur, 2014). As opposed to the behaviorist paradigm of learning social constructivism points assessment embedded inside the teaching and learning process (Adams, 2006). On the contrary to the social constructivist viewpoints the findings indicated that teaching and learning physics were focused more on assessment rather than learning. Students learning was best sidelined and worst ignored.

Conclusion

This study shows that the teachers' attempts to boost students' physics understanding in the classroom culture of teaching and learning physics were significantly insufficient. There was a lack of communication as well as collaboration among the involved stakeholders in the teaching and learning process. The activities were characterized largely by a lack of teachers support. The research also found that the entire teaching and learning strategy was aligned towards the exam-oriented educational model. Finally, the study indicated that the traditional teacher-centered approach to teaching and learning physics prevailed in the institutions under investigation. Based on the findings of this study, the authors contend that the transmissive nature of our age-old pedagogical approaches may be a key factor that should be considered in relation to students' poor academic performance, as this type of pedagogy does not promote active learning, such as inquiry-based approaches in physics teaching and learning in engineering institutions.

This study intended to analyze physics teaching and learning in engineering colleges, as well as to evaluate the actual process of teaching and learning to acquire solid information about how physics was taught and learned. The findings of this study focused on physics teachers' pedagogical techniques, as well as how students regarded teaching and learning physics theory. The findings could lead to advances in physics instruction that benefit students' learning. The findings also laid the groundwork for delivering informative recommendations to all stakeholders involved in Nepal's educational landscape. The findings could also help to introduce innovative pedagogical approaches such as inquiry-based and project-based learning that could be beneficial in the context of the Nepalese educational landscape. Furthermore, this research acts as a foundation for other Nepalese science/ physics education researchers in order to dig deep inside other pedagogical approaches that could be helpful in order to foster the four Cs approach- communication, collaboration, creativity, and critical thinking.

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