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Implementing design thinking in the teaching and learning of selected biology lessons in a Bhutanese higher secondary classroom

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ABSTRACT: *The current study has derived inspiration from the design thinking approach as one of the pedagogical means to respond to the need for teaching, learning, and assessment in the twenty-first century. Specifically, the study was intended to explore strategies to implement design thinking' in designing and delivering lessons in higher secondary-level biology classrooms. The study employed a participatory design approach which involved the participation of the researcher with the selected teachers in the co-design of biology lessons. This study was carried out over two weeks in one of the higher secondary schools in Samtse district, Bhutan. Hence, data for this study was obtained from the researcher's qualitative notes based on field engagement with three piloted teachers, and teaching observations. The data from observation field notes were presented in narrative descriptions, to provide rich descriptions of classroom activities and tasks, teacher and students' classroom interactions, and the design thinking process followed in the teaching and learning process. Findings revealed that both teachers and students have positive perceptions about the application of design thinking in biology class. The application of design thinking in biology class offers an opportunity for students to learn through the highest degree of collaboration, interaction, and creative thinking, unlike in a conventional classroom. Additionally, this offers an opportunity for building a foundation for teachers and educators to revitalize educational practices to prepare students to thrive in the modern era, by equipping students with the tools and capacity for innovative and creative thinking and the ability to solve problems.*

KEYWORDS: **design thinking, teaching and learning, participatory design, co-design, problem solving, creative thinking, critical thinking, Bhutan.**

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1. Background of the study

Education systems today, across the globe, are seeking competitive advantage by leading through innovation. As a result, today, we are experiencing a tremendous paradigm shift in the approach toward education and its outlook. The learning outcomes of twenty-first-century skills consist of learning and innovation skills, critical thinking and problem solving, communications and collaboration skills, and digital literacy (Noel & Liu, 2016). These skills are more important to students now than ever before to succeed in this globally and digitally interconnected world (Ross, 2017). As a result, today *"educators are continually looking for new ways of enhancing student learning and equipping students with skills that would enable them to cope with twenty-first-century demands"* (Retna, 2015, pp.5-19) such as meta-competencies going beyond cognitive knowledge (Sheer et al., 2012). Further, with the quest for teaching strategy for twenty-first-century skills and the dynamism of world traits, education today calls for a change in the dimension of learning wherein the focus is on how students can construct knowledge from their own experience (Azevedo et al., 2016). For example, many countries, such as Singapore, China, Korea, and India are investing in education systems that prioritize leading through innovation, some by directly investing in design schools or programs, and others by embedding creative thinking into the curriculum (Beckman & Barry, 2007).

To meet the demand and challenges of the current society, there is a change in trends in teaching and learning approaches in education every year. Traditional approaches to solving the challenges people encountered often seem ineffective (Luka, 2014), and therefore, the application of innovations in tools and methods in teaching and learning has become fundamental. Kalyani and Rajasekaran (2018) stressed innovative teaching is a necessity for all teachers to meet the educational needs of the new generations, whereby "innovative teaching means creativity and novelty of the teacher which changes the style and method of teaching" (p.23). A teacher needs to ensure that he or she can facilitate rather than teach so that there is learning by the students with the added consequence of garnering and sustaining experiences about their learning on the course being taught (Pande & Barathi, 2020). In today's world, one alternative approach which seems useful in the given context of time is embedding Information and Communication Technology (ICT) in the teaching and learning process. This approach has gained much attention in this digital age. As a result, Bhutan is gearing toward an ICT curriculum, teaching, and learning process in the school which is clearly emphasized in the Bhutan education blueprint (MoE, 2019). ICT is seen as a powerful tool to navigate the unseen problems that can hinder the process of teaching and learning. For instance, technology has greatly influenced education during the unprecedented COVID-19 pandemic around the globe. Had there not been ICT at such time, the teaching and learning processes would have been futile.

However, in the era of knowledge, rapid globalization, and economic development, one approach to education alone cannot do the work and it is crucial to explore and rethink on more innovative and robust pedagogy or model of learning that best suits the present world. It requires diverse innovative approaches to teaching and learning besides technology. Learning must encourage students to think outside the box, question anything and everything, think of solutions and become world leaders rather than simply an engineer or doctors (Zahir, 2018). Hence, the current study embraces the design thinking approach as one of the alternative pedagogies to respond to the needs of the 21st century.

2. Literature review

2.1. Need for design thinking in Bhutan

The Government of Bhutan invests more in the education sector than any other sector because education is the backbone of the development of the country (MoE, 2014). As a result, the need for transition in education, the right curriculum, and ambient teaching and learning environment is necessary with the change of time and situation. Among all, the pedagogical and assessment practices form the critical components of quality of education (Tenzin, 2017), which will enable the teachers to identify the area to help individual students to learn.

A study on the quality of education carried out by the Royal Education Council [REC] revealed that the majority of students were unable to understand core concepts and were also unable to apply knowledge to real-life situations across grades and subjects (MoE, 2014). This indicates a lack of authentic practice of deep critical thinking, creativity, and problem-solving skills-based activities in the schools by teachers. Consequently, the performance of secondary students in science across the country has been unsatisfactory and poor (BCSEA, 2018). Further, a study on the implication of transformative pedagogy in classroom teaching by Dorji et al. (2020) revealed that some school leaders and teachers are still inclined towards conventional lecture methods due to the mere excuse of insufficient resources, crowded classrooms, and thick curricula to infuse the activities in the classrooms. In addition, Utha et al. (2016) observed that Bhutanese classroom practices are dominated by teacher-centered and syllabus-driven. And notably, in Bhutan, the school-based assessments system is inconsistent (Luyten & Dolker, 2010) whereby the students are evaluated based on their grades undermining their skills and gaps in learning. Furthermore, Rehmani (2003) argued that this system does not take care of real learning.

This indicates there is a gap in the curriculum, teaching, learning, and assessment for students to develop critical and creative skills. An innovative approach to teaching like design thinking can offer an effective tool for teachers to improve their instructional strategy in teaching, learning, and assessment of learners. Therefore, to nurture our students with relevant knowledge befitting the present society, upscaling the competency of teachers in design thinking is deemed important if this education gap needs to be filled. Hence, this participatory design research has attempted to experiment and implement Design Thinking in secondary school biology classrooms and explored the perceptions of teachers and students on design thinking as a pedagogy for the teaching and learning process.

Well-established literature provides positive empirical evidence of design thinking in education. For example, Orthel (2015) claimed that if educators have a clear understanding of design thinking, they can improve teaching and learning, and reframe design-based and interdisciplinary inquiry in the classroom. Design thinking has gained considerable attention in education across the world. For instance, in Singapore, the adoption of a design thinking approach in the classroom teaching-learning process has resulted in enhancing skills such as creativity, problem-solving, communication, and teamwork as well as empowering students to develop empathy for others within and beyond the community (Retna, 2015). Design thinking in education supports teachers in broadening the process of traditional learning by encouraging students' creativity, problem-solving, and critical thinking; by which teachers strategized to maximize motivation in students (Kewk, 2011), and it promotes innovations and collaboration (Anderson, 2012; Caruso, 2011; Kwek, 2011; Sheer et al., 2012). Martin (2009) argues that in school, students must be nurtured to think like designers to enhance creativity among students and help them to understand the process of innovation. However, there is a lack of empirical research evidence and literature on design thinking in education, and understanding of the concept, adoption, and implementation in the Bhutanese context.

2.2. Design thinking in education

According to Explorance (2018), in the competitive and globalized world, approaches toward education have become more skill-based in which teaching and learning should center on real-world skills and competency development of learners. As a result, there is a need to improve the way lessons are designed and delivered with more relevant innovative teaching and learning styles. There is an increased interest in developing teaching strategies to foster students' creativity in many fields (Wible, 2020). Design thinking has drawn tremendous attention from professionals and scholars alike, as it provides a new approach to innovation and problem-solving (Panke, 2019, p. 282). Design thinking is one innovative teaching pedagogy that can provide an alternative strategy in teaching that replaces the traditional lecture method that most teachers use in the classroom. One set of skills required in today's highly technological and globally competitive world is design thinking (Razzouk & Shute, 2012). Design thinking explained a unique approach to solving problems in innovative ways (Orthel, 2015). Design thinking is a process that promotes the teaching and learning of important skills that are required for the twenty-first century (Retna, 2015) such as creativity and solving problems.

There are limited studies that provide evidence of implementing design thinking in biology teaching and learning. However, there are several ways design thinking can be implemented or integrated into the teaching and learning process in the classroom. One way, in education, design thinking skills can be learned through pedagogical approaches that involve problem-based learning, project-based learning, or inquiry-based classroom activities (Dym et al., 2005). However, the Design Thinking approach differs from the project or problem-based learning since students define the problem by themselves (Kolk, 2012). As an instructional tool, it can be used to allow students to express their ideas without constraint while engaging in design activities.

2.3. Design thinking process

The Hasso Plattner Institute of Design at Stanford (d.School) describes design thinking as a five-stage process (see Fig.1). These stages are not always sequential, and teams often run them in parallel, out of order, and repeat those in an iterative fashion (Meinel & Leifer, 2011; Dam & Siang, 2020). Further, as an iterative process, it essentially does not follow the sequential waterfall model where progress is seen as flowing downwards. The whole idea is to fail, and fail fast, to learn from the failures, and rapidly iterate in order not to miss opportunities and waste resources (Scheer et al., 2011; Lor, 2017, p. 43). All stages are indispensable and should be conducted subsequently without leaving some of them (Wolniak, 2017).

The design thinking process fosters several competencies in different phases. This study, however, adopted the five-stage model proposed by the Hasso Plattner Institute of Design at Stanford. A brief description of the characteristics of each step involved in design thinking is presented here as per the ideas (Ambrose & Harry, 2010; Tschimmel, 2012; Efeoglu et al., 2014; Vikram, 2019; Wolniak, 2017; Dam & Siang, 2020; Yakob, 2020) as detailed in the following: **Empathize -** This stage is used to determine the characteristics of the audience for which the product is designed through detailed observations, interviews, or surveys, engaging, watching, and listening; **Define -** It is generating a guiding statement that focuses on insights and the particular needs of the users; **Ideate -** Ideation is done by brainstorming a variety of ideas with the students and suspending judgment; **Prototype** - It could be a particular gadget, a role-playing activity, a cardboard box, or a sketch model is a path to quickly conveying an idea of the design process; **Test -** This stage was to test and solicit feedback on the created prototypes. In this research, Hasso Platner's design thinking model has been employed in the implementation of design thinking in the co-designing of lessons

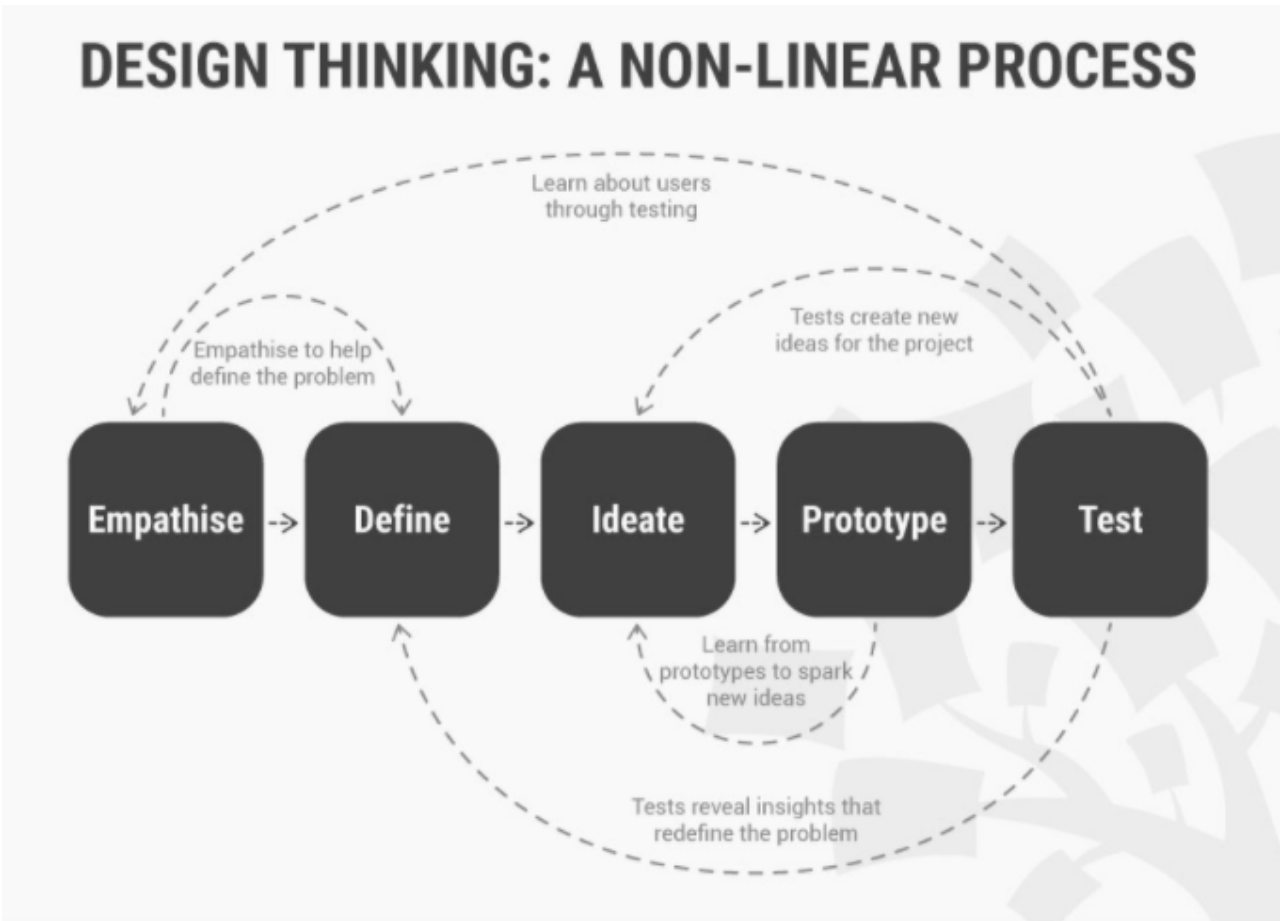

Figure 1. Illustrating the iterative five steps of design thinking. (Adapted from Dam & Siang, 2020)

and classroom teaching to promote twenty-first-century skills (such as creativity and innovation skills) by having the active involvement of students in the classrooms. This was done as the study attempted to implement the design thinking approach in teaching and learning biology in Bhutanese secondary school classrooms.

2.4. Purpose of the study

The overall aim of the study is to find strategies to implement a design thinking approach in Bhutanese higher secondary school biology classrooms in an attempt to answer the research question "How can design thinking be implemented in the Bhutanese higher secondary biology classroom?".

2.5. Significance of the study

Design thinking, with its emphasis on equipping students with the tools and capacity for innovative and creative thinking, offers great promise to make progress toward improving teachers' instructional strategies. Therefore, this study will contribute to educators' understanding of design thinking as an instructional strategy by offering practical knowledge of implementing design thinking into classroom teaching. Additionally, the results of the study will guide future educational researchers, who are looking to explore further on implementation and implication of design thinking in teaching and learning.

3. Methodology

The study is designed within the framework of Lev Vygotsky's sociocultural theory (1978). The sociocultural theory views human development as a socially mediated process in which children acquire their cultural values, beliefs, and problem-solving strategies through collaborative dialogues with more knowledgeable members of society. This theory aligns closely with the design thinking approach that entails the process of addressing the problem/issue. This research is designed with a qualitative research approach. This is because qualitative research provides much more flexibility to researchers in quickly adapting questions, changing settings, or any other variables to improve responses if useful insights into the problems are not addressed (Poppulo, 2019). Further, this study needs a qualitative aspect on the understanding, perspectives, and experiences of teachers about design thinking implementation in the classrooms.

This research has been intended to design a lesson using the design thinking approach. The researcher has collaboratively co-design lessons with the teachers who are selected as pilots, therefore the participatory design is the methodological approach for this research. Participatory design is a set of theories, practices, and studies related to end-users as full participants in activities leading to software and hardware computer products and computer-based activities (Greenbaum & Kyng, 1991; Muller & Kuhn, 1993; Schuler & Namioka, 1993; Muller & Druin, 2013). The essence of participatory design is about empowering the users and developing communication and collaboration between designers and users. It attempts to actively involve all stakeholders in the design process to ensure that the product/outcome meets the needs and expectations of all. It focuses on the process and procedures of design and not so much on the appropriateness and perfection of the design (Schuler & Namioka, 1993). Schuler and Namioka (1993) state that participatory design represents a new approach toward computer systems design in which the people defined to use the system play a critical role in designing.

A non-probability sample was used for this study with the idea that the researcher is targeting a particular group, in the full knowledge that it does not represent the wider population; it simply represents itself (Cohen et al., 2008). This sampling method is frequently used in small-scale research targeting one or two schools, two or three groups of students, or a particular group of teachers in case of ethnographic research, action research, or case study research (p.113).

The participants in this study consisted of biology teachers and biology students (class XI and XII) from Tendruk Central School under Samtse District. The selection of participants and study site followed the purposive sampling technique within the non-probability sampling

method, considering the approach and design of this study. According to Creswell and Creswell (2018), the idea behind qualitative research is to purposefully select the participants and sites that will help the researcher understand the problem and the research question. Moreover, according to Ball (1990), as cited in Cohen et al. (2008), purposive sampling is used to access the people who have in-depth knowledge about particular issues, access to networks, expertise, or experience. Therefore, participants for this study were purposefully selected to get a wide range of data on the research topic.

The sample size is made up of three biology teachers, and 8 students (for each focus group discussion). According to Creswell and Creswell (2018), there is no specific rule to determine the number of sites and participants for qualitative research unlike those found in quantitative research, and sample size will depend on the qualitative design being used. Tendruk Central School is located under Samtse Dzongkhag. It is the government school under the Ministry of Education, Royal Government of Bhutan, and currently provides education for students ranging from classes Pre-Primary to 12, and Special Education Needs (SEN) students (Bhutan Foundation, n.d.). Tendruk Central School is located 79 kilometers to the west of Samtse Dzongkhag office.

The existing qualitative educational research literature identifies several data collection tools. According to Creswell and Creswell (2018), the data collection procedures in qualitative research involve four basic types, i.e. observation, interviews, documents, and audiovisual and digital materials. For this study participant observation was used as the primary data collection method. For data analysis, thematic and narrative analysis were employed.

4. Results

The lesson observations present empirical evidence of how design thinking was implemented in the classrooms by teachers. Accordingly, the design thinking approach was used as an instructional strategy to organize the learning activities in the classroom by teachers. It was observed that all the teachers used design thinking steps to develop a sense of creativity among the students. For instance, teachers made successful use of ideation and prototype stages in organizing and imparting the lesson objectives through brainstorming, discussion, writing, drawing, and sketching activities.

Observation notes also indicated a modification in the design thinking process that the teacher made during a lesson activity. For example, the teacher decided to explain a concept briefly before the conduct of activities such as explaining how to brainstorm or redirecting students during a brainstorming activity. Additional observations about the teacher's design thinking practice were providing examples of empathizing and defining steps to direct the students to work on their own. Another observation made was teachers commonly used brainstorming activities and presentation of ideas during ideation and prototype steps. However, it was observed that teachers have different ways of using the design thinking steps.

For example, the teacher took students to field observation; Teacher 2 used interviewing and observation methods, and Teacher 3 used mind visualization in the empathize step. It was evident from the observation made, that they tried to embed design thinking with the inquiry-based practice, as these two approaches were very much related. Furthermore, observation revealed that, while students are engaged in the design thinking activities, they get motivated and excited, and developed an interest in the lesson which ultimately influences their learning of new ideas and creative skills. For example, students were observed discussing, writing, and creating through active involvement within their group with excitement. This indicates there are multiple ways to bring design thinking steps into classroom teaching that can create a conducive learning environment with freedom to learn, motivation, and the ability to think critically and creatively for the students.

The findings from lesson observations provide narrative and pictorial evidence of the initial attempts of teachers in implementing design thinking in their respective lessons. The findings

showed that it is a good opportunity for the teachers to experiment and experience integrating the design thinking approach in their lessons. Consequently, it also provides an opportunity for the students to learn from a new approach to teaching to uncover their creativity and critical and innovative skills. Both teacher and student insights provide data about the outcomes of design thinking as an instructional strategy used in the classroom teaching and learning process. Design thinking activities in the classrooms have provided students to think creatively and critically which was least taken care of in regular conventional classrooms. Teachers provided materials such as charts, pencils, markers, sketch pens, sticky notes, cardboard, and scissors so that students can use them for creating prototypes. Students have engaged actively to create any forms of prototypes; concept maps, drawings, cardboard boxes and models to convey the concept taught and learned from the curriculum.

Figure 2. Students engagement in design activity

5. Findings and discussion

5.1. Empathize stage

"Empathize" is the first stage of design thinking used in the lessons. The findings indicated that across all three Lessons implemented, the design thinking approach was used as an instructional strategy by teachers to organize the learning activities in the classrooms. The researcher's observation notes indicated that all the teachers used design thinking steps to develop creativity skills among the students through a series of activities. Moreover, teachers used different ways to conduct empathy activities. For example, In lesson 1 on "Invasive species and its control measures", an empathize was conducted using the observation method. The teacher let students watch and observe 3 min video clips on the consequences of invasive species followed by field observation to identify the common plant that is invasive in their school area. This activity has facilitated students to critically analyze the situation, gain a deeper understanding of the causes and its effects, then think of multiple ways to overcome this situation within the context of the locality. In lesson 2 on "analysis of individual carbon footprint", empathize was carried out using two methods, gathering information with the use of observations in the school kitchen and inquiry and user interviewing the cooks and teachers and then the mapping of information collected to identify user needs and insights from where they can develop a solution for users to control their carbon footprint. Furthermore, in lesson 3 on "prosthesis", empathizing was done through mind visualization about the problem of Special Education Need (SEN) students in their school. This activity was done to generate a feeling of emotions and empathy in the students toward SEN students. The lesson intends to develop a prototype by applying the prostheses concept to provide help for those SEN students with body part movement difficulties. Empathizing step in design thinking is first and crucial in letting the students be able to get into the real issues before generating the ideas to address the problem.

In this step of design thinking, students learned how to build empathy to understand and serve people. They develop solutions using tools, for example, user interviewing and field observation. Empathizing is a significant mindset used by the design thinking approach (Carroll et al., 2010). There are several methods to empathize with the users. According to the Hasso Plattner Institute of Design, this stage is used to determine the characteristics of the audience for which the product is designed through detailed observations, interviews, or surveys, engaging, watching, and listening (Dam & Siang, 2020). For instance, focused group students expressed that they enjoyed a lot carrying out the activities because

they acquired the opportunity to experience how to empathize with others. These results match those observed in earlier studies, for example, Anderson (2012) claims that design thinking helps to foster empathy and a "deeper understanding" of others (Brown, 2008; McDonagh & Thomas, 2010). These findings further support the finding of Retna (2015) who suggests that empathizing steps of design thinking let students build a sense of human-centered feelings that enables them to collaborate and communicate with a larger audience and brings behavioral changes among students. Rosen (2009) stated that there is a strong relationship between collaboration and empathy in which collaboration enables creativity and empathy, and empathy is said to allow for collaboration and in turn, creative ideas. Hence, Cupps (2014) stated that design thinking fosters change in the mindset of participants. There is an indication of empathizing steps used by the teachers during the lesson deliveries; however, the observation revealed that the teachers have limited it to superficial observations and interaction with the users. There is no in-depth inquiry to understanding the deeper user needs and emotions. A possible explanation for these results may be due to inadequate competency and experiences of the teachers in design thinking because this attempt was the first of its kind in their lesson. Another explanation for this is due to the time factor whereby empathy and a deep understanding of the users required enough time. This activity was carried out within a short duration of time. Nevertheless, during these activities, students were introduced well to the empathizing process, and the purpose it plays as a starting point for the generation of creativity and innovation. This is an important issue for future research, educators, and teachers to look into the possibility of how we can develop an empathy mindset for learners through a design thinking approach.

5.2. Define stage (point of view)

"Define" is the second stage of the design thinking process used in the lessons. In this stage, students were expected to identify the needs and insights based on the collected data from the previous stage and to develop a point of view for identifying a problem statement. According to Yakob (2020), in this step, a synthesis of the information is carried out that was collected during stage one. The purpose of this second stage in design thinking is to create a meaningful and actionable problem statement (point of view) (Hendricks, 2020). The observation notes revealed the teacher closely facilitated the defined stage of design thinking to creatively come up with a desirable problem statement. While introducing this stage, the teachers often applied a similar pattern of defining the problem. In all three lessons, three fundamental components; user, a deeper user need, and insight are identified to provide a viable problem statement. In the problem statement, for example, in *Lesson 1*, one group came up with this definition: "*Invasive species (cottonweeds) create problems for the farmer. Therefore, to have a better yield of the crop, we need to solve the problem to remove it before it dominates the crop"*. Within this problem statement, students have identified farmer (user), to remove (need) and have a better yield (insights). Similarly, in *Lesson 2*, after collecting the information, students performed mapping of concepts (i.e., empathy mapping) by clustering the information they wrote and generated through observations and interviews. The cluster of information created by students is then used to identify user needs and insight to define the problem. In *Lesson 3*, the teacher first provided an example of a problem definition, and then students came up with their own to address the issues of Special Education Need students.

According to Dam and Siang (2020), in the define stage, you determine a well-shaped articulated point-of-view that could bring about the necessary solution to the users. Further, in this phase of design thinking, the students 'focus is on becoming aware of the needs of the users or people while developing insights (Vikram, 2019). Define stage offers numerous benefits; it first identifies the problem designers are trying to solve and this keeps everyone oriented to the same solution. In addition, this stage also helps to define the problem in the most beneficial

way (Yakob, 2020). Therefore, it implies that the "define" stage provides students with the opportunity to relate the content they are learning with the information gathered from the users. Further, it provides students with the skills of decision-making, sorting out information, and drawing a conclusion. This is because, from this study, it was learned that students are made to relate the topic of lessons with the problem they are going to solve.

5.3. Ideate stage

"Ideation" is the third stage of design thinking used in the lessons. Teachers made good use of the ideation stage in organizing and imparting the lesson objectives using methods such as brainstorming, discussion, writing, drawing, and sketching activities. It was observed that all the teachers facilitated brainstorming activities to scaffold students to generate ideas with a question. The questions the teachers put to the students were; in *Lesson 1*; "how many ideas can you come up with the problem? What is your most original idea?" Similarly, in *Lesson 2*; "How might we?" question to prepare students for starting the brainstorming session, and in *Lesson 3*; "Discuss how you can apply the knowledge of support and movement system concepts in our school to have an inclusive environment" to start the ideation process. While students collaboratively carry out this activity, the teachers encourage students to list as many ideas for their problem definition from which they can quickly evaluate the best one to choose. Students put up their ideas generated through brainstorming activities into charts, sticky notes, and notebooks. The observations also revealed that while students are engaged in ideation activity, teachers keep activities open-ended, and monitor in case students require a small prompt or scaffolding to help them move in the desired direction. Further, it was also observed that the teacher explained the objectives of the stage aligning with the concept of the lesson as well as design thinking concepts for students, such as sharing ideas or brainstorming. These concepts were often supported with examples to reinforce learning.

Findings from the observations on the conduct of ideation activities by all three Pilot teachers revealed that brainstorming is the common method used to engage students to generate and articulate their ideas. This activity provides the students to practice working in a group, brainstorming, ideation, and sharing ideas. This observation agrees with the method proposed by Interaction Design Foundation (n.d.) which showed that brainstorming is a method design teams use to generate ideas to solve clearly defined problems where teams approach a problem by such means as "How Might We" questions. This method helps to produce a vast array of ideas and draw links between them to find potential solutions. Therefore, this finding further supports the idea of Dam and Saing (2020) that ideating is a critical component of the design thinking process which offers the combination of the conscious mind and unconscious mind. On a similar note, during the interview, the teacher participant (Teacher 2) described that the ideation and prototype stages of design thinking are crucial in the design thinking process because it allows all the learners to think critically and unveils their creativity. Ozturk (2020) mentioned three methods of ideation; brainstorming, mind map, itemized response, and PMI (Plus, Minus, Interesting). However, in this study, ideating through the brainstorming method conducted by the teachers serves the purpose.

While observing the students engaging in the ideation activity, the current study found that students practice and learn skills such as brainstorming, ideating, analyzing information, writing, collaborating, asking questions, and articulating ideas. The same findings were reported in the previous studies (Gompel, 2019; Cupps, 2014; Kwek, 2011). The study by Kwek (2014) found that DT helped to foster collaboration, gave them voice and choice, and allowed for powerful engagement. While there is the active engagement of students in groups, students expressed that they receive an equal opportunity to express their views regardless of high or low academic performance in the class. In this way, students expressed they learn through real-life experiences and increase

their skills such as judgment or creativity. The observation notes indicated that the teachers find it easy to facilitate the "ideation" stage of the design thinking process. Hence, this stage was found implemented more successfully by the teachers. This finding may be explained by the fact that the teachers are as effective in instructing discussion as they do in conducting activities in daily classroom teaching. However, there are other possible explanations such as students simply needing to think, discuss and write down whatever ideas they have come up with in the papers. The students are provided with the freedom to write as many ideas of their own as there are no boundaries or restrictions when it comes to idea generation.

5.4. Prototype stage

"Prototype" is the fourth stage used in the lessons. In this stage, students are made to put their ideas generated through brainstorming in the "ideation" stage into simple idea representations. Therefore, in Lesson *1*, students' prototypes consisted of two conceptual posters and drawings of homemade weedicides and pesticides to help farmers to control invasive species. In *Lesson 2*, students created two prototypes in the form of conceptual drawings of the efficient digital transport management system to help teachers and community people minimize the use of vehicles and carbon footprint and a paper model of the efficient cooking system to help cooks in the school kitchen. Similarly, in *Lesson 3*, the representation of their prototype is in the forms of *concept mapping of inclusive programs for SEN students, storyboarding, and drawing of advanced equipment (wheelchair).* With facilitation from the teachers, students collaboratively engaged in a series of learning activities to design a prototype or solutions to represent the concept they are learning. It was observed that during this stage, students not only learn to apply the design thinking process, but they also learn to apply the content of the subject in real-life situations. For instance, the concept of movement of muscles and bones is applied to create prosthetic support to provide people with movement disabilities (*in Lesson 3*).

Across the lessons, prototypes are kept simple to provide students with first-hand experiences of the design process, motivation for them to think beyond the textbook curriculum, and interaction among themselves to generate ideas and put them into sketches and posters. Storyboarding, posters and drawing methods used as a prototype in the lessons represent the visual, need statement, solution illustration, and the end product of ideas for easy and effective communication with the users. In the context of education, the design thinking model describing "prototype" is about bringing conceptual or theoretical ideas to life and exploring their real-world impact before finally executing them (Dam & Saing, 2020). A prototype can be a cardboard box or a sketch model, a particular gadget, or a role-playing activity (Ambrose & Harry, 2010). Following the present result, previous studies have demonstrated that students learn best when they take an active role in the education process, discussing what they read, practicing what they learn, and applying concepts and ideas (Davis, 2009; Smart & Csapo, 2007). Further, the study indicated that design thinking creates a vibrant interactive environment that promotes learning through rapid conceptual prototyping (Meinel & Leifer, 2011).

The results from this stage do not show evidence of the teachers' emphasis on iteration and evaluation of the prototype through taking feedback from the users. However, all the teachers made students provide suggestions and feedback on each other's work through the presentation method during the "test" stage. According to the design thinking model of d. School, an important component in the "prototype" stage is to take feedback from users and improve the prototype through iterations (Yakob, 2020). The prototypes were limited to concept mappings, posters, storyboards, and drawings with pens and paper. It seems possible that these findings are due to the teachers' first attempt to use design thinking as a teaching approach, and insufficient time and materials as they have expressed in the interview. Another factor may be due to the choice of lesson topics made by the teachers as teachers expressed during the interview that lessons will

go well only with topics that are suitable to teach using the design thinking process. However, it was encouraging to note that the teachers tried to make a good attempt to use design thinking as a teaching approach to engage students very well in classroom learning. It was observed that students when put into groups and provided with activities, they carried out with interest and active participation. From these observations, it may help us to understand that design thinking is feasible to use as a teaching method in Bhutanese secondary classrooms to engage students in learning creativity and innovation.

5.5. Test stage

The Test stage was the last stage of the design thinking approach for the co-design lesson activities. In this stage, students are required to test their prototype with the users for whom they have designed. Testing is part of an iterative process that provides the students with feedback and to learn what works and what does not work and afterward iterate, making necessary modifications based on feedback. Testing ensures that students learn in the design process for the users what works and what does not work (Efeoglu et al. 2014).

One of the most significant actions observed was changes in their teaching pedagogy, particularly in incorporating a design thinking model through inquiry and activity-based teaching. In the context of classroom teaching, teachers take the role of 'facilitators'- shifting the focus from teacher to student-directed learning. With facilitation from the teachers, students collaboratively engage in a series of learning activities through design thinking stages to create solutions for a problem they have identified. Design thinking was used as an activity-based teaching method in the classroom to engage students in creating, drawing, discussing, writing, and finding what they can do with their learning. In this way, teachers support students whereby the teachers used the methods such as group presentations, gallery walks, and storytelling. Students were required to share their prototypes with other students and provide feedback in the process.

In this study, the "test" stage has provided students to experience a design thinking process, enhance confidence in their learning, self-reflection, motivation to learn, and team building while involved in sharing their ideas and feedback sessions as students did presentations well and observed doing maximum interactions among themselves. This was also observed by Barron et al. (1998) that design-based activities can further enhance the self-confidence and the self-reflection of the students. It can also be inferred from this study that, from the teaching and learning perspectives, the testing stage of the design thinking process is the stage to evaluate the learning of students by evaluating their prototype or project, scaffolding them to improve through constant comments and feedback. Lesson plans prepared by the teachers can also be considered as a prototype that can be tested in the classroom where students are the user. The feedback and suggestions from students and teacher's self-reflection on the lesson activities can thus be used to make modifications and changes for further improvement of their teaching.

6. Conclusions

The lesson observations demonstrated design thinking to be one of the promising pedagogical practices which can be adopted by teachers at an individual level for secondary students learning. This was demonstrated through a process of planning and organizing the lessons in the classroom by teachers. As such, it was indicated that design thinking offers a strategy for teachers to engage their students in activities such as creating, drawing, discussions, and writing, and encouraging students to integrate their knowledge and experience. Additionally, the teachers have demonstrated that design thinking lessons can be carried out by taking a 'facilitators role'- shifting the focus from teacher to student-directed learning. Here, teachers can provide small activities for each design thinking stage, in which students are allowed to interact with each other and with teachers. In this way, teachers can be able to support students in the development and honing of their skill set beyond traditional learning. Observation revealed that

organizing lesson activities through the design thinking approach in the classrooms have triggered excitement and enjoyment, curiosity and collaboration among students. A series of activities engaged students in deep discussion, critical thinking, creative thinking, the ability to solve a problem, and systematic organization of their ideas. This indicates design thinking approach in the classroom influenced students thinking abilities beyond curriculum content.

This finding, therefore, can be confirmed that the design thinking approach has the potential for an application not only to designer or engineering education but can also be used for non-design-based education like ours. This was exemplified by the implementation of the design thinking approach in the teaching of biology by the teachers through challenging and thought-provoking activities within the particular lessons to scaffold twenty-first-century skills such as creativity, innovations, collaboration, and problem-solving skills in students.

This study further revealed it offers an opportunity for the teachers to experiment and experience embedding the design thinking approach in their lessons. This was exemplified by the teachers' comment that design thinking is a new learning experience and provides confidence for them to integrate it as the pedagogy in their teaching. Consequently, it also provides an opportunity for the students to learn from a new approach to teaching to uncover their creativity and critical and innovative skills. As indicated, with facilitation from the teachers, students collaboratively engaged in a series of learning activities through design thinking stages to share their ideas. This was visible from the interest, active engagement, and strong collaboration shown by students in each activity assigned under the design thinking steps. One reason students might have enjoyed design thinking is that it was different from their previous classroom learning experience as they have explicitly expressed during focus group discussions. Therefore, regardless of the success of lessons or limitations, students were introduced to and presented with the opportunities to learn the steps of problem-solving, creativity, or innovation through lesson activities with a design thinking process, which in turn would help them to transfer in their real-life situation. It can be concluded that these findings may help us to understand that design thinking is feasible to use as a teaching method in Bhutanese secondary classrooms to engage students in learning creativity and innovative process.

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