BEYOND THE CLASSROOM: EXPERT TEACHERS' PERSPECTIVES ON DEVELOPING INNOVATION COMPETENCIES THROUGH DESIGN THINKING PRACTICES

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Published: 18 April 2024

To cite this article (APA): Md. Aris, N., Ibrahim, N. H., & Abdul Halim, N. D. (2024). Beyond the Classroom: Expert Teachers' Perspectives on Developing Innovation Competencies through Design Thinking Practices. *Jurnal Pendidikan Bitara UPSI*, *17*(1), 72–81. https://doi.org/10.37134/bitara.vol17.1.7.2024

To link to this article: https://doi.org/10.37134/bitara.vol17.1.7.2024

ABSTRACT

Developing student innovation competencies through STEM education is an essential component of the National STEM Action Plan 2017 - 2025, in line with UNESCO's 2030 agenda to promote quality and innovation in STEM education. This study explores the perspectives of chemistry expert teachers to analyze the need to develop innovation competencies through design thinking practices among high school chemistry students. The study employs a design and developmental research strategy, emphasizing the needs analysis method during the initial phase. The study gathered data through semi-structured interviews and employed thematic analysis to examine the findings. The study's findings indicate a strong consensus among experts regarding the importance of developing competencies, particularly problem-solving, goal-oriented thinking, thinking system competencies, group work competencies, and networking competencies, through a design thinking approach. Furthermore, the study identifies a need for more application of teaching approaches based on design thinking in chemistry classes despite the acknowledged potential of this approach. The results emphasize the necessity of creating and applying a Design Thinking Chemistry Module to fill this void and equip teachers with the essential resources and expert guidance to incorporate design thinking into their chemistry lessons successfully.

Keywords – Design thinking, Innovation competencies, Need analysis, Design and development research (DDR)

INTRODUCTION

Education serves as a fundamental catalyst for nurturing a cohort of innovators and problem solvers within society. The National Science, Technology, and Innovation (DSTIN) Policy 2021–2030 (MySTIE) and the Malaysian Science, Technology, Innovation, and Economic Framework 10–10 elucidate the pivotal role of science, technology, and innovation (STI) in propelling Malaysia towards becoming a high-tech nation. By 2030 as outlined in (DSTIN (2013-2030), Malaysia aims to elevate its Gross Domestic Product (GDP) to RM 3.4 trillion and diminish its reliance on foreign labor. The transformation into a nation that thrives on an innovation-centric ecosystem necessitates the availability of highly qualified STEM professionals capable of meeting burgeoning demands. Consequently, students must be equipped with innovative skills tailored for global competitiveness in STEM professions[2].

The Sustainable Development Goals (SDGs) prompt deeper introspection into the paradigm of innovation and knowledge advancement [3]. The cornerstone of fostering innovation competency lies in establishing high-quality learning environments conducive to real-world problem-solving, fostering curiosity, and cultivating open-mindedness [4]. Design thinking, characterized by its human-centric

problem-solving approach, is increasingly embraced by researchers across various disciplines to spur innovation [5]–[7]. Design Thinking catalyzes innovation [8], [9] by serving as a cognitive framework that enhances comprehension of complex behaviors and phenomena. Hence, the potential of the design thinking approach is progressively explored across diverse fields [10], [11]. What distinguishes design thinking is its departure from conventional problem-solving methodologies, offering a systematic, human-centered knowledge acquisition process underscored by iterative learning experiences promoting creative and innovative problem-solving approaches. [12]–[14].

Recognizing the criticality of nurturing students' innovation competencies to empower them in problem-solving endeavors, particularly in chemistry, necessitates transformative shifts in the teaching and learning landscape. However, effecting educational change mandates unwavering dedication and transformative measures within the learning milieu. Therefore, to align with the Ministry of Education's directives and cultivate a fresh mindset among students, it is imperative to institute module development as a guiding framework and resource for educators. This initiative enables teachers to foster students' innovative acumen by integrating design thinking into the chemistry teaching and learning process, thus ensuring holistic development and readiness for future challenges.

LITERATURE REVIEW

Development of Innovations Competencies in Chemistry Education

Innovation competencies play a crucial role in addressing various global challenges, particularly in the realm of Chemistry, which is pivotal for achieving the United Nations' Sustainable Development Goals (SDGs) by 2030. Chemistry's significance extends to areas such as nanotechnology, sustainable energy transition, smart cities, innovative industries, and environmental and social issues [15]–[17]. Engaging in the thought process inherent in Chemistry fosters students' creativity, problem-solving abilities, and capacity to identify new opportunities [18]. In today's interconnected world, the recognition of innovation competence is paramount as it equips students to tackle complex problems and positively shapes their individual growth [19], [20]. However, research indicates that students often exhibit a low level of innovation competence, influenced by their learning environment [21]. Although some studies [22] suggest moderate levels of student competence, challenges persist.

A significant barrier to problem-solving in Chemistry lies in students' grasp of fundamental concepts [23]. Without a solid foundation, students may struggle to apply their knowledge creatively to address real-world problems [24], [25]. Students encounter difficulties in explaining natural phenomena and generating diverse ideas within the context of Chemistry [26]. Despite exposure to relevant concepts, high school chemistry students occasionally face challenges in analyzing and interpreting chemical data [27]. Therefore, there is a pressing need to cultivate innovation competence among chemistry students, particularly at the secondary school level [28]. This imperative underscore the importance of immediate and optimal implementation across disciplines to address these challenges effectively.

2.2 *The Potential of Design Thinking in Developing Innovation Competence*

Chemistry students benefit from actively constructing knowledge, collaborating in group settings, and solving real-world problems [29]. By engaging in these activities, students can bridge chemical concepts with real-life situations, fostering active learning and deeper understanding [30], [31]. Utilizing innovative learning resources enhances student engagement and promotes active learning [32], [33]. Additionally, conducting research projects related to students' daily experiences enhances analytical and critical thinking skills, contributing to higher mastery levels [34].

Effective teaching practices in chemistry not only make learning enjoyable but also improve performance and help students acquire necessary skills. Scholars have explored various methods to develop innovation competence among students, including integrating the design thinking approach into classroom instruction [35]–[37]. Educators utilizing the design thinking approach in curriculum development and teaching methods enhance the overall classroom experience [38]. Design thinking is recognized as a valuable methodology for nurturing students' innovation-oriented problem-solving abilities [39], [40]. However, in the Malaysian educational context, there is a lack of awareness among

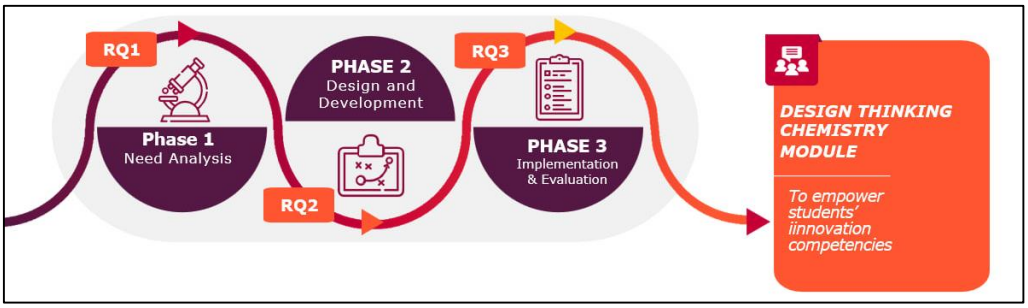
Science and Mathematics teachers regarding the elements of the design thinking approach [41]. Uncertainty persists among teachers regarding the practical application of design thinking in the classroom, highlighting the need for further support and guidance to promote students' innovation competence[42], [43].

METHODOLOGY

Research design

The research design of this study focused on leveraging design thinking approaches to enhance students' innovation competencies. The Design and Development Research (DDR) approach as shown in Figure 1, proposed by Richey and Klein [44], was employed to guide the investigation. DDR involves systematically examining the design, development, and evaluation process, establishing an empirical foundation for creating instructional and non-instructional products, tools, and novel or refined models governing their development. A needs analysis was the first phase in Design and Development Research for developing teaching modules systematically. The needs analysis phase is essential to determine the main research issues before developing modules [45]. In addition, needs analysis aims to explore current problems and assess the need to design modules [46]. McKillip's discrepancy model was used to determine the difference between actual and desired states. According to McKillip [47], the needs analysis phase identifies and analyzes the subject's needs, which will determine the results obtained and offer solutions to existing problems. This iterative nature of the DDR process ensures a continuous refinement and alignment of the study's focus on design thinking and innovation competencies in the context of chemistry education.

Figure 1. Phases of design and development research



Participants and Procedures of Research

A qualitative approach through semi-structured interviews is used in this study to obtain information from three expert teachers' perspectives on the need to implement design thinking in developing students' competencies. Moreover, this approach gives an advantage in controlling the discussion and allows research participants to voice their thoughts freely, and the data obtained produces accurate results [48]. According to Merriam [49], collecting qualitative data will provide a comprehensive picture of the phenomenon, enabling researchers to observe and examine issues and problems that occur in real situations. A semi-structured interview protocol is used as a research instrument to answer the research questions:

1. Is there a need to develop innovation competencies in chemistry education?
2. What are expert teachers' views on implementing a design thinking approach in chemistry teaching and learning to empower innovation competencies?

Collecting and Analysis Data

Language, content, and quality validity were verified for the interview protocol questions before the interviews. Thereafter, experts agreed to be interviewed, and their answers were transcribed verbatim. After completing the interview with the expert teacher, the researcher will thoroughly analyze the interview data obtained and analyze the data according to the steps suggested by Creswell [50] to see the meaning and feedback of the study participants. All experts verified the transcripts before performing the analysis, classification, and coding. Data analysis was performed by carefully reading the transcriptions to investigate emerging issues and possible themes relevant to this study.

RESULT AND DISCUSSION

In this study, we conducted face-to-face interviews with three experienced chemistry teachers (experts) to actively gather their perspectives on the needs and challenges of developing a design thinking module for high school chemistry students. The analysis of this research question consists of two main parts.

Needs to develop students' innovation competencies

The researcher found that all study participants agreed that innovation competence from the point of view of student's ability to convey ideas and combine chemical concepts in problem-solving activities should be the focus in giving students an understanding of chemical concepts. This competency is necessary to introduce the real-world context in teaching chemistry. In addition, teachers need to play an essential role in providing a learning environment that encourages students to engage in problem-solving activities. Experts also encouraged activities involving collaboration and discussion among students in chemistry class. The ability of students to collaborate and communicate effectively in problem-solving activities can positively affect students. The impediment to altering chemistry teaching approaches lies in the imperative to offer students direct experiences through hands-on activities for a comprehensive understanding of chemistry concepts. This challenge is evident in the expert statements presented in Table 1 below.

Table 1 Interview data for the development needs of the competency dimension of problem-solving innovation

ID	Supporting Datum	Competency	Relationship with Competence
P01	When the student ***has the experience of learning by solving problems***, he can see the truth, so we as teachers also have to play a role in inducing them to use methods appropriate to the current situation.	Problem-solving	The role of teachers encourages problem-solving competence
P01	Chemistry is complex if it ***does not have hands-on; students really cannot imagine***. As the temperature increases, the temperature decreases. It is a number. Students must do it to understand ...	Hands-on activities	support the idea of practical interaction with understanding.
P02	For me, if you want chemistry to look attractive, ***you have to do activities***... if there is no activity, it feels like letters... Chemistry will be a subject with many letters... All formulas.		The importance of experience in learning chemistry
P03	Students will usually understand a concept better ***when they can do something.*** They also tend to be active in activities they enjoy, especially regarding technology and the practical application of concepts.		More active and interested in hands-on activities

continued

ID	Supporting Datum	Competency	Relationship with Competence
P01	With appropriate chemistry project activities, students can ***use their knowledge to solve related problems.***	Application of knowledge / chemical concepts	Application of knowledge to solve problems
P02	Students have made "telang flowers" as an acid base indicator. Make ice cream..this is important for students ***to apply the chemistry concepts*** they learn at school to their real life.		The use of real materials in everyday life
P03	When students ***collaborate in a group discussion***, they know they ***understand*** or pretend to understand the concept…	Communication and Collaboration	The relationship of the collaboration process with the understanding of chemistry

Further, the expert agreed, as shown in Table 2, that chemistry students also need to be able to make problem-solving decisions. The dimension of system thinking competence through design project activities in chemistry can give space to students to consider ideas in obtaining alternative solutions. In addition, the need to apply innovation competency elements based on student goal orientation is also essential in chemistry teaching. The student's ability to generate ideas and persistence in taking steps to complete assignments can provide a practical learning experience. Experts also agreed that students will actively seek information through digital resources such as the Internet if group activity projects are allowed. Students reflect on their learning by evaluating how effectively they can apply the acquired information in practical activities.

Table 2 Interview findings for the development needs of the competency the thinking system dimension, and the goal-oriented attitude

ID	Supporting Datum	Competency	Relationship with Competence
P01	Corrosion-related topics also provide opportunities for design exploration. For example, they can ***design and make products*** such as electrochemical cell models.	Making Decisions/ justification of solutions	Consider how these concepts are related.
P02	The effects of chemicals in everyday life can give students the ability to ***think and formulate creative and innovative solutions***.	Generate ideas	Plan, implement, and complete tasks
P03	Students should ***be allowed to generate ideas or product designs*** relevant to the chemical concepts learned.		Produce useful products
P02	I told them to find and make an acid-base indicator from their materials. They ***make references from the internet, find videos from YouTube, and try various other sources.***	Networking	The process of finding material in the activity

The results of the study show that there is a need to improve efficiency in chemistry subjects. Although some competencies are considered fundamental, the importance of competencies deserves attention. The interview results underscored the importance of instilling innovation competence in chemistry students. Furthermore, they highlighted the necessity for students to grasp chemistry concepts and adeptly apply them, ensuring the cultivation of quality individuals for the future market. Therefore, teachers must possess the necessary knowledge and skills to achieve the set learning standards.

Expert teachers' views on implementing a design thinking approach in chemistry teaching and learning to empower innovation competencies

From the responses of Expert 1 and Expert 2, both experts agree that applying teaching based on design thinking can improve the innovation competence of chemistry students. Expert 2 also emphasized that a change in teaching approach is needed in chemistry subjects. Both experts agree that students can be encouraged to demonstrate the ability to explore ideas through group discussions and develop innovative solutions. This argument is proven by statements P01 and P02, which are:

> *"Agreed... design thinking can increase students' competence **to explore ideas**... because when he makes a **collaboration or a new discussion**, he knows he actually totally understands or only partially understands the concept. If we can make it until the **students can produce something**, it is perfect for our students." P01*

> *"I believe using a Design Thinking approach allows students to **approach problem-solving** more **creatively and collaboratively**. In chemistry, this approach can **encourage students to think** outside formulas and equations.... so we need a method or approach like this." P02*

Expert 3 acknowledged the positive effects that can be obtained through a design thinking approach in the chemistry class. Students actively learn and foster a deeper understanding of knowledge through a design thinking approach. However, experts also point out the potential challenges associated with this approach.

> *"Undoubtedly, applying a design thinking approach positively affects students. Students are not just memorizing facts; they **are actively involved in the learning process**, which **positively affects understanding**. However, we must also acknowledge that implementing a project-based activity-based approach **requires planning, adequate training, and the readiness of teachers and students**" P03*

The interview findings also show that the design thinking approach in the chemistry classroom involves practical projects beyond theory-based learning. This aligns with KSSM Kimia's goal to provide a learning environment that can provide experience in understanding chemistry concepts. This statement is supported by the P02 statement as follows:

> *"From this design project activity, students **solve problems and experience the experience themselves**. It is like an ice cream project in my class; A student put ovalette. The results are different from other groups. He will remember every time he eats ice cream." P02*

Based on the findings are highlighted to prove that teachers are aware that a teaching approach based on design thinking can have a positive effect on the development of student learning, especially from the point of view of improving student innovation competence, providing experience in building a knowledge context, and creating an exciting learning atmosphere in the real-world context. Our research advances the understanding of pedagogy, forming a more meaningful chemistry classroom [51][52]. Teachers play a role in creating an exciting learning environment, providing experience in building concepts through problem-solving activities in the real world. Although experts acknowledge the potential of design thinking-based approaches, teachers need more reference materials and professional support to improve their implementation. Therefore, providing adequate resources and implementing training programs for teachers are initiatives to encourage and shape the design thinking approach environment in the chemistry classroom. By addressing these challenges directly, educators

can create an environment that recognizes the potential of innovative teaching approaches and actively facilitates their implementation in improving student competence.

The needs analysis study in this research has given us helpful information about providing a concrete explanation to the researcher that there is a need to develop a design thinking module for high school chemistry subjects. In addition, the findings from this study present expert agreement on the need to develop competencies - innovation competencies, especially problem-solving, goal-oriented, thinking system, and group work competencies- and building networks through a design thinking approach.

Integrating competency elements through the design thinking process is essential for high school chemistry subjects, especially in preparing students as intended in the KSSM Chemistry framework. Our study extends the field of previous studies to see how the application of design thinking in the learning environment [53], [54], especially in the chemistry curriculum environment, positively affects student performance and competence. This approach ensures that chemistry students understand theoretical knowledge and develop practical and innovative skills that are important to navigate the demands of contemporary education. Our study aims to aid new and experienced teachers in fostering dynamic learning environments. By encouraging reflection, we empower students to apply knowledge in real-world contexts, enhancing their competence and preparing them for future challenges.

CONCLUSION

In line with the latest technological advances, educators must implement various learning activities to enhance the quality of classroom teaching and learning. The results of this study support the development of a design thinking-based teaching and learning module for high school chemistry subjects based on consensus and expert recommendations during the interview session. Through this module, we plan to transform and create a fun learning environment by applying elements across the curriculum and developing the expected competencies.

ACKNOWLEDGEMENT

We want to thank everyone who contributed to the success of this paper. This research was funded by a scholarship from Ministry of Education Malaysia (Hadiah Latihan Persekutuan (HLP)) and Universiti Teknologi Malaysia for conducting the research.

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