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Cultivating Innovation: Pedagogical Strategies for Enhancing Critical and Creative Thinking

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ABSTRACT

The objective of this study is to assess the level of critical and creative thinking of the foundation students of Universiti Utara Malaysia (UUM) in the class AALK0013 Critical Thinking and to identify the problems faced and solution deployed while doing a product innovation and invention project. The work is based on the quantitative research method, and the data is analysed using descriptive analysis of the questionnaires administered. The instrument developed from the Torrance Test of Creative Thinking (TTCT, Torrence, 1982) and the Watson-Glaser Critical Thinking Appraisal (WGCTA, Watson and Glaser, 1980) is comprised of forty items and subdivided into seven constructs. The study involved 59 students as the sample of participants. Quantitative data was analysed on the SPSS statistical tool to calculate the mean and standard deviation of the results of the critical and creative thinking abilities of the students besides providing an idea of the difficulties encountered in completion of the project. The specific objectives of the study are: To assess: (i) the changes in the critical and creative thinking abilities of students after the application of the product innovation and invention project, (ii) the challenges faced by the students during the project and (iii) the ways in which the challenges were dealt with by students. The results show improvements in the evaluation of cognitive abilities, identify gaps in knowledge and skills, issues of time management, shortage of resources as well as team and prototyping problems and present solutions to these shortcomings. It therefore becomes important to incorporate aspects of product innovation, invention activities in the curriculum to ensure they enhance the thinking skills and problem-solving qualities of every learner.

Keywords: critical thinking, creative thinking, product innovation and invention

1.0 INTRODUCTION

The aspirations of students to develop a diverse perspective, critical and creative thinking, problem-solving abilities, and an entrepreneurial mindset were emphasized in the Malaysia Education Blueprint 2015–2025 (Higher Education). By highlighting the innovation ecosystem and aiming to make innovation the main driver of the country's economic growth, this will assist Malaysia in achieving its seventh thrust. To guarantee that this objective is accomplished, students must be able to think critically and creatively to produce high-quality products. Students must master these subjects to generate creative ideas for creating high-quality products that can be sold. Students who start with innovative ideas and creative thinking will be able to realize the national goals.

It is impossible to understate the significant importance of critical and creative thinking within the walls of the classroom. According to research by Chiam et al. (2014), fostering such higher-order cognitive abilities is integral to empowering students to craft unorthodox solutions, inspect issues from alternative angles, and acclimate to fluctuating conditions. Further works by scholars Ma (2023) and Dai-you (2021) coincide with this assertion. However, numerous academic institutions continue to struggle with meaningfully implementing these competencies through pedagogies proven to be impactful. By exploring approaches to harmoniously weave invention and innovation into the fabric of the learning experience to catalyse critical and creative cognition in students, this paper aims to shrink this disconnect.

Ma, (2023), identify creativity and innovative problem-solving skills are in high demand across various sectors, from engineering and technology to education and beyond. Cultivating these abilities in students is a top priority for educational institutions seeking to prepare the next generation of problem-solvers and innovators. Classroom instruction plays a pivotal role in developing students' creative capacities and fostering an innovative mindset when done effectively. Stimulating creative thinking through a variety of hands-on methods is essential for empowering students to become active contributors to progress and innovation. By incorporating authentic product design challenges into the curriculum that encourage thinking outside the box and exploring novel ideas, educators can provide opportunities for students to develop innovative solutions through critically examining problems from new perspectives.

Creativity demands original pickings. This might mean thinking a new or coming up with innovative solutions for an old problem. In an age when many automated tasks, creativity is a valuable skill that is too hard for machines of occupy its place. Creative student progress leads to breakthroughs, production of goods and services that stand out from a crowded market. Even if it's designing apps or developing cooperation models that can provide a sustainable future-or writing film scripts, students who master creativity can rise to market industry changes.

Furthermore, critical thinking involves evaluating data, sifting evidence to see where the truth lies and then knowing that truth. For today 'internal world of information society, where information is bountiful and yet frequently unreliable, it is essential that students can think critically: to filter out factual data from fiction; understand complex issues and therefore tackle them effectively. It enables students to deal with problems in logic and reason, as well as in business science technology or any other field. These skills help students to cope with ambiguity, choose what objective appeals most to them out of all the choices in front of them. Students can start early to build a story and create thoughtful solutions for real-life situations.

The rise of automation, artificial intelligence and digital platforms means many traditional jobs are changing or disappearing. Students need and can become more innovative in adapting to these new technologies; learning not just how they came about but also using tools like AI or data analysis for their own the study of marketing these days demands that a student also understand social media strategy and data analytics. By creating novel ways to use these tools, they can shine in a competitive job market. On the other hand, the importance of global challenges such as climate change, sustainability, public health concerns become increasingly evident; students must think innovatively if they hope for solutions. Innovation enables students to make a substantial and unique contribution to solving complex problems of real meaning. Students studying environmental science today have to learn additional skills that allow them to create sustainable technologies and designs, the polluting footprint of which is minimal or that derive energy using renewable sources.

Teaching and learning Reflection

Enhancing critical and creative thinking among students is one of the goals that has preoccupied educators for many years because these skills are essential for problem-solving and creative work. Although acknowledging and using abstract ideas is rather problematic for many students because it poses a certain level of difficulty. Lecturers have realised that when students are in a position where they are unable to differentiate or relate between different ideas that are interrelated, they get disengaged. All these elements have been used in research with the stress on the effectiveness of fieldwork in enhancement of comprehension outlined. For a better development of these skills, the researcher suggests the use of invention, and product development in real life. Teaching students with lots of critical and creative projects helps to counter the issues they face when it comes to grasping theories. This makes it easy to establish connections between ideas and practice that may serve as a way of reigniting passion through practical tasks that exemplify critical thinking and creativity. When students are engaged on real-life projects, they stand a better chance of being able to practice what they have learnt; this may have eager them up, besides enhancing their skills in problem solving. (DeHaan, 2011)

Even while considering the strategies for teaching and learning activities of the topic Critical and Creative Thinking, concern arises in the mind of the researcher. In this regard, this concern arises from the huge area of discussion under this topic, where a myriad of strategies and techniques of cultivating these abilities among students is provided. Instead of expecting learners to memorise a range of strategies, it is critical that they understand the defining characteristics of sound critical and creative thinking. They also need to effectively know how to apply such view about problem solving and innovation, among others. This is in concordance with recent research done in education, promoting the notion of firsthand field interaction as a means of enhancing understanding and memory of substances that are hard to grasp (Ma, 2023). The students get prepared for invention and product development and in return, they develop competitive and innovative thinking processes as well as collaborative teamwork in problem solving across curriculum fields as noted by Ma, (2023, October 7).

Issues that learners encounter in terms of recalling, comprehending, and integrating abstract ideas often feature during the lecturers' discourses. Due to the challenge of being able to draw abstract figures and be able to remember them in the future, the student's motivation reduces when learning this subject. The assessment of the teaching and learning strategies showed that there are several strategies that the educators employed to teach critical and creativity skills, and they include field studies, lectures and visits. The study also pointed that the skills such as manual initiatives are needed to improve the practice of offering critical and creativity skills. In view of these concerns the researcher wants to use invention and product innovation to solve these problems. This approach helps to familiarise students with real life critical and creative thinking and helps them recover from the problems that they face while learning abstract concepts. Users of practical projects have improved chances of applying and visualizing what they have learnt and are also likely to have increased zeal hence better problem-solving abilities. This real-world experience also complements what has been advancing in the educational sector as of late that restates a new perception on learning through experience to enhance comprehension and recall of topics and concepts that are in some way challenged to grasp. The findings of the gathered data will entail the discovery and analysis of themes, patterns, and benchmarks that will be essential in the creation of teaching strategies that will be proposed and valuable in promoting product innovation or invention into the learning curriculum.

Problem Statement and Scope of the research

According to the analysis of the problems arising in connection with the acquisition of knowledge concerning critical thinking and creative thinking, the data on the students' performance, as well as the discussions involving lecturers, it is necessary to state that there are several issues, which must be solved to improve the effectiveness of critical thinking and creative thinking. As a further check on these problems from the students' standpoint, a questionnaire was completed by 150 students of a critical thinking class in third semester at the Centre of Foundation Studies, Universiti Utara Malaysia. The results revealed that 86.7% of the students were not interested in learning about critical thinking, while 13.3% who were interested in learning critical and creative thinking subject. Altogether, the primary learning difficulties were determined despite the students' concern towards assessment of critical thinking and creative thinking. The learning of critical and creative thinking skills poses a lot of challenges to students in class and how they can deal with the challenges and or barriers. Such difficulties can be beginning with the creation of ideas, the connection between the theory and the practice, and problems that may be encountered in the process of the creative work. In addition, students can fail to collaborate and communicate well in their respective groups, thus hindering their performances as well as becoming frustrated. Adding to this, it is crucial to identify these difficulties and predict how students can approach and overcome them in the given field to enhance the approaches to teaching and learning used in this sphere. In the feedback questionnaire applied to the students, their responses were coherent with the reactions the researcher noted during activities in the classroom and while answering questions and providing answers. The findings indicated that students' attitudes to learning were quite passive, and their knowledge was extremely weak when having to respond to questions that required application of moderate to high levels of intellect. Hence, the researcher postulates that corrective actions are severely wanted to rectify these concerns. A large amount of time should be spent showing, or telling, students about real-life cases. Classroom teaching activities must be engaging, and students must employ their reasoning and imaginative abilities to enhance their performance and knowledge concerning creativity and critical thinking as concepts and terms.

Objective and Research Question

Based on the focus of the study, the general objective of the research is to enhance students' mastery of critical and creative thinking skills with Product Innovation and Invention focused pedagogy.

Meanwhile, the specific objectives outlined are as follows:

1. To evaluate the level of student's critical and creative thinking through the implementation of product innovation and invention in the classroom.
2. To discover the problem, happen during the implementation of product innovation and invention in the classroom.
3. To identify how student solve the problem during the creation of product innovation and invention.

Based on the established research objectives, three research questions have been proposed as follows

1. What is the students level of critical and creative thinking through the implementation of product innovation and invention in the classroom?
2. What challenges arise during the implementation of product innovation and invention in the classroom?
3. How do students address and solve problems encountered during the creation of product innovation and invention?

2.0 METODOLOGI

Action Strategies

Focusing on interactive activities related to Product Innovation, where the implementation of Teaching and Learning (PdPc) optimizes face-to-face sessions with lecturers to ensure effective learning, actions have been carried out through the Product Innovation and invention approach as shown in Figure 1. Figure 1 illustrates the implementation of Product Innovation and invention activities during the class session.

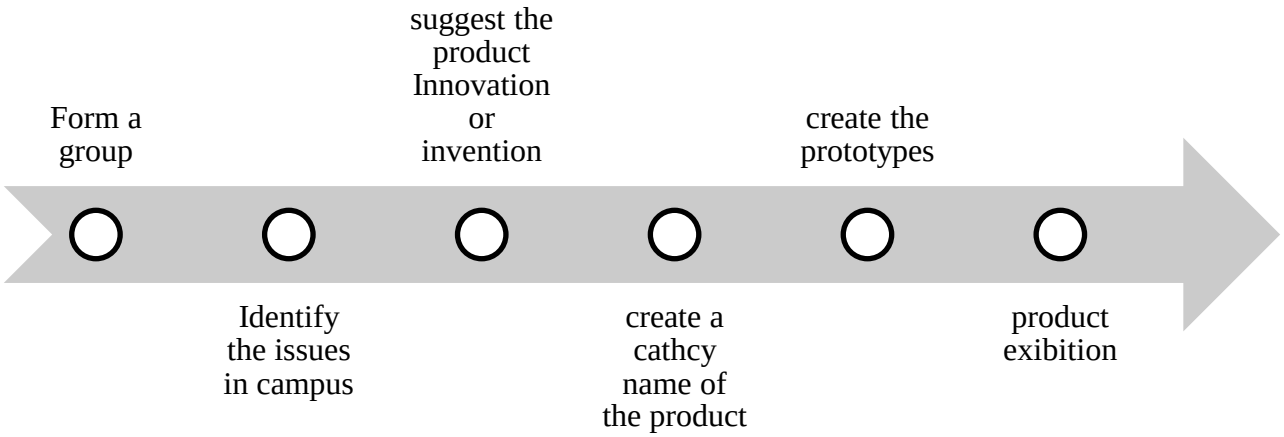

Figure 1: Implementation of Product Innovation and Invention

Implementation Phase

This study is action research. The design of this action research is implemented based on the Lewin model (1946) in Adelman (1993). According to Lewin (1946), action research demonstrates a spiral of steps. An action research cycle consists of four steps: planning, acting, observing, and reflecting. This cycle continues into the next cycle, which involves re-planning, acting, observing, and reflecting to produce a new cycle. Lewin's action research model is shown in Figure 2.

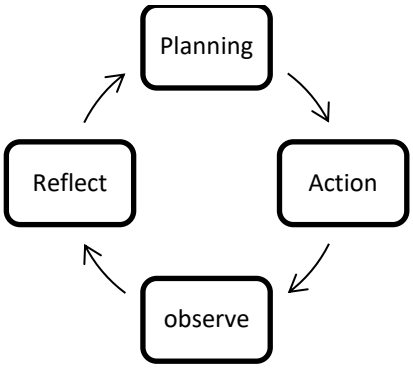

Figure 2 Lewin's Action Research Model (1946)

The implementation of this action research through Lewin's model (1946) begins with planning actions. Based on the issues faced by previous semester students who lacked critical and creative thinking skills, the tasks given were traditionally structured, where students only submitted written assignments addressing issues they needed to resolve. This approach was outdated and made students bored with producing better assignments. Therefore, the researcher adopted a new approach to ensure mastery of

critical and creative thinking could be minimally implemented to ensure that the assignments given were produced with interesting and creative ideas. The implementation of product innovation and invention involves the process of planning and producing the product. Details and activities of the students are shown in Table 2.

Phase 1: Planning Phase

In this phase, Students begin in lectures to grasp how important it is that learners do critical and creative thinking in product development. Critical Thinking enables them not to get all mixed up in problems but approach them methodically and evaluate their responses, while creativity aids in new concepts and putting thoughts outside the box. The lecturer provides an analytical framework for innovation (improving or modifying existing products or processes) and invention (creating something entirely new). This lays the groundwork for students to understand what sets an evolutionary change apart from a revolutionary advance. The lecturer issues a topic for product innovation, mainly centred on some campus-related problem. This ensures that the innovation - or invention is directly related to the daily life of students. It is then easier for them to understand and solve the problem meaningfully.

Phase 2: Action Phase

In action phase, students brainstorm ideas within groups and discuss them. They do this to satisfy any specifications set by the lecturer. Group discussions can be used by students to trade ideas, unite ideas from different working parties and criticize each other's ideas. This promotes both unconstrained creativity with brainstorming at its best and meticulous thought which is forced to be constructive. The purpose of this Phase is particularly essential for idea generation and planning. The series of structured questions arrested students' thought patterns, forcing them to take a long hard mental look at the entire product. With such rigor students cannot help but have ideas that are grounded in the real world and useful as well. It also prompts them to work together and push critically on both what the new function is going for and all components.

Phase 3: Observe Phase

The lecturer builds a platform (Padlet and Trello) where students can update their progress. Using these online platforms, students can both record and monitor their progress visually. Uploading evidence of their work provides one contributor to accountability, helps students and lecturers both spot different stages in development. Student then will ask to present their ideas to receive feedback from their classmates. By putting their ideas in front of their classmates, students put themselves in for constructive critique and suggestions on improving ideas. This step will encourage peer learning reflection of all things also because students assess one another's work and receive fresh ideas regarding their own projects. All this dialogue is crucial as it leads to some thinking about what people do right or wrong when raising these questions further. On the observation phase feedback loops combine with the project. Students modify their ideas in order not to misunderstand, their accounts along with its simple review mechanism Feedback from classmates, teachers and lecturers helps students improve their ideas making them more effective and interesting This phase also ensures continual progress; it keeps members from forgetting any key element of the project or failing to finish some part thereof.

Phase 4: Reflect Phase

In the final stage, the product exhibition will organize by the lecturer to reflect to the student work. It is a showcase for product innovations. The lecturer also takes advantage of the exhibition to instruct students on how to present their finished products chances for commercial production, features that addition will give practical machines. The exhibition is evaluated using a set of criteria. Students must articulate the rationale for their invention, its use or practical application, and how they happened to think about it this way. At this phase also facilitates students to their own performance and the results of learning. In addition, when students present their work, it is an opportunity to develop communication skills, as they also look back and reflect on how they progressed from the initial idea until the production of the prototype. Students are able, therefore, to rethink their product innovation and invention from a different perspective. At this point students can look back over their learning process, criticize what has gone wrong in an honest and constructive way (constructive criticism), such that there is continuous improvement of both innovation itself as an embodied form that continually adapts to changing circumstances, using ever-more flexible methods for solving problems now coming on stage one after another. In this structured approach, students not only engage in creative or critical thinking but also learn from the practical skills: innovation, cooperation, feedback integration and self-reflection are vital for their later careers.

Table 2: Product Innovation and Invention Phase

Phase	Description of task
Planning	i. Planning the assignment related to the critical and creative thinking. ii. Provide an overview of what innovation and invention. iii. Lecturer sets the theme for the product innovation or invention to be covered for the brainstorming session. The product will follow the theme that set by the lecturer (based on the campus problem)
Action	i. Prepare a set of question to be answered before the students start to produce their innovation or invention. The question as follow a. What is the invention/work about? What is the issue/problem you are trying to solve with the innovation? b. Function/objective of invention/work? c. What is its used for? d. What are the components/elements/phases involved in this invention/work? Where did you get the idea from? What is the inspiration for this innovation? What are the references used to get the idea for the innovation? e. What is the benefit/contributions of this invention/work to the society? f. Illustration of Invention/Work ii. Student will brainstorm the idea from the group members as well as discuss to fulfill the criteria given by the lecturer.
Observe	i. The lecturer sets up a platform (such as Padlet or Trello) for students to update their progress on their product innovation or invention. Students upload evidence of their progress to this platform. ii. Students present their ideas in class to receive feedback from their classmates, helping them improve their product innovation.

Reflect	i. The lecturer will organize a product innovation exhibition where students will present their products to evaluates using a provided rubric. ii. Students will prepare and display their products during the exhibition. iii. Students will present their products during the exhibition and justify their choose product

Research Respondent

A total of 59 of semester 3 students from the Critical Thinking course (AALLK0013) at the Centre for Foundation Studies, Universiti Utara Malaysia, are involved in this study.

Instrument

The collected data from the questionnaire were analysed using descriptive analysis involving mean and standard deviation to assess students' critical thinking and creative thinking skills as well as the problem identification during the study. Quantitative analysis was conducted using SPSS software. The research instrument was adopted to suit with the research from The Torrence test of Creative Thinking (TTCT, Torrence,1982) and The Watson-Glaser Critical Thinking Appraisal (WGCTA, Watson and Glaser, 1980) with 40 items divided into 7 constructs **(table 1)**. The instrument was developed to get the feedback from the students after the implementation of the product innovation and invention in the classroom.

Table 1 Instrument of the research

Instrument	Items	Sources
Creativity skills	1. Fluency 2. Originality 3. Elaboration	Torrance Test of Creative Thinking (TTCT)
Critical Thinking Skills	1. Inference 2. Recognition from assumption 3. Interpretation 4. Evaluation on argument	Watson-Glaser Critical Thinking Appraisal (WGCTA)

Data Analysis

The research aims to evaluate students' critical and creative thinking skills through the implementation of product innovation and invention in the classroom, structured around three key objectives. As stated in **table 2** below, a survey will assess the level of the skills, with descriptive analysis used to interpret the results. Second, students' feedback will identify challenges encountered during this process, analysed through thematic analysis to uncover recurring issues. Lastly, additional feedback will reveal how students solve problems during their creative projects, again employing thematic analysis to highlight their strategies. This comprehensive approach combines quantitative and qualitative methods to provide valuable insights into student abilities, challenges, and problem-solving strategies, ultimately informing future educational practices and curriculum development.

Table 2: Data analysis methodology

Research objectives	Data collection	Data analysis
To evaluate the level of student's critical and creative thinking through the implementation of product innovation and invention in the classroom.	Survey	Descriptive analysis
To discover the problem, happen during the implementation of product innovation and invention in the classroom.	Students feedback	Thematic analysis
To identify how student solve the problem during the creation of product innovation and invention.	Student feedback	Thematic analysis

3.0 RESULT

3.1 Demographic Analysis

3.1.1. Gender

The sample's gender distribution is shown in table 3. It shows that women represent 66.1% of the total participants and men fill comprised the remaining 33.9%.

Table 3: Gender Distribution

Gender	Frequency	Percentage
Male	20	33.9
Female	39	66.1

3.1.2 Age Distribution

According to the data that has been provided, most students are in the 19–21 age range, making up 96.6% of all students. There are 57 students who fit into this age group. In comparison, the age group of 22–24 students make up only 3.4% of the student body, with 2 students falling into this cohort.

Table 4: Age Distribution

Age	Frequency	Percentage
19-21	57	96.6
22-24	2	3.4

3.2 Analysis of Research Objectives

3.2.1 To evaluate the level of student's critical and creative thinking in the implementation of product innovation and invention in the classroom.

The average **fluency** score of 4.13 suggests that students generally demonstrate a strong ability to generate multiple ideas or responses in creative thinking tasks. However, with a standard deviation of 0.80, there is a moderate level of variation in these scores, meaning that while some students are highly fluent in their idea generation, others are less so. The range of scores, from a minimum of 1.00 to a maximum of 5.00, indicates that a few students scored very low, struggling with fluency, while others achieved the highest possible score, showing exceptional ability in this area.

There are several ways through which students can showcase their fluency which includes the following, the product innovation and invention project, the students are able to come up with different ideas. They

can toss out as many ideas as are feasible given the timeline which goes well with the creativity endowed upon them when under time constraint. Moreover, the adequacy of the students, especially their ability to bend and always look at the problems with fresh perspective is very clearly seen. This is especially important where they realize that there is a need for breathing space while working on the ideas – knowledge of the incubation period is thus deemed crucial. Lastly, the fact of their not yielding to the temptation of holistic thinking before analyzing all the necessary information as well as keeping their minds open to other options strengthen the argument of the increased level of fluency in critical and creative thinking. The 95% confidence interval for the mean differential fluency varies between 3. 92 to 4. More understanding can be derived from the fact that the said percentage, 34, does not include 0, hence suggesting that students' fluency is rather higher than the test value. Fluency appears strong in most of the classes and indicates that students are well prepared to do creative problem solving and idea generation during the product innovation and invention project.

The average **originality** score of 4.23 indicates that students generally have a strong ability to produce unique or novel ideas in creative thinking tasks. With a standard deviation of 0.74, there is slightly less variation compared to fluency, meaning the originality scores are more consistent among students. The scores range from 1.33 to 5.00, showing that while some students struggled slightly with originality, the lowest score is higher than for fluency, and the highest score reaches the maximum, suggesting that some students demonstrate excellent originality. Accordingly, it suggests that there is not either right or only answers when searching for novelties; they can be as trivial as putting a shoe on one's head. Which implies that students are likely to focus more on novelty than any other competences when called upon to give ideas. It also proves that when the number of responses rises, the creativity rises as well; this is because students can come up with responses which are not necessarily the most conventional ones. This can be attributed to their ability to reason well hence they are able to address more of the fundamental and more likely generate new designs. Creative thinking strategies: Students come up with ideas that the other members may not probably think of, thus making them be unique in the process of innovating. They also can switch from a normal perception to a different one and this informs their manner of handling problems. Their ability to look at things without the biases of the conventional way of doing things is crucial in delivering the product innovation and invention project. Furthermore, students unleash innovation in handling the product innovation since they can develop an aesthetic attitude, in the process observing beauty in art. This creative thinking is also reflected in the ways they can nurture the germs of idea- and change-generation to achieve a continuous creation of new ideas. The students also do not get stuck as they dare to question the rules that have being set and developed, skills that make them most flexible to bend conformities when needed making them creative. They employ fantasizing as means by which they assert propositions and solve issues creatively, and they discover that, dreaming and being emotional is helpful towards the effectiveness of their creativeness of the project.

Additionally, students can put two elements together or apply them together so that ideas or objects can be depicted in peculiar structures, and to think beyond the surface: to think internally and involve the process. From them, the boundaries of a problem are extended and broken, as well as, as a rule, the use of humour in the creative process, which contributes to originality in the implementation of a product innovation and invention project. In general, the numerical data provide the evidence for affirming the hypothesis which states that the students come up to a certain degree of creativity, as well as the stances they take and the behaviours they exhibit in terms of creative thinking practices and approaches during the project.

On the other hand, the average **elaboration** score of 4.27 suggests that students generally perform well in adding detailed information to their ideas, indicating a strong ability to expand and refine their creative thinking. With a standard deviation of 0.78, the variability is like fluency, meaning there is a moderate range in how detailed students are in their thinking. The scores range from 2.00 to 5.00, showing that even the lowest-scoring students provide some degree of elaboration, while others reach the maximum score, demonstrating exceptional ability to enhance and develop their ideas. The higher minimum score compared to fluency and originality suggests that students are generally more consistent in their ability to elaborate on their ideas. This indicates that students are proficient in fleshing out ideas with depth and complexity, ensuring that their contributions to the product innovation and invention project are thoroughly developed and well-considered. Additionally, they demonstrate the ability to capture the essence of given information to produce imaginative and appropriate titles, further enhancing the quality and creativity of their work.

Furthermore, the average **inference** score of 4.29 indicates that students are generally strong at drawing conclusions based on evidence, showcasing solid critical thinking skills in this area. However, with a standard deviation of 0.85, inference shows the highest variability among the measured skills. This suggests that while some students excel at making logical inferences, others struggle more. The wide range of scores, from 1.00 to 5.00, further highlights this disparity, with some students performing very poorly while others reached the maximum possible score, demonstrating exceptional inference skills.

The mean **assumption** score of 4.12 indicates that students generally demonstrate a strong ability to recognize and evaluate assumptions, reflecting solid critical thinking skills in this area. However, the standard deviation of 0.79 suggests a notable degree of variability among students' performances, like trends observed in fluency and elaboration skills. This variability implies that while many students excel in recognizing assumptions, there are others who struggle more significantly. The score range of 1.50 to 5.00 further emphasizes this disparity, showing that, although the minimum score is relatively low, a considerable number of students achieve high marks, highlighting the diverse proficiency levels within the group. Overall, these findings suggest the need for targeted interventions to support those who may be facing challenges in this critical thinking component. Showing that this competence is quite high, it turns out students show an increased awareness of assumptions, trying not to make errors when completing the product innovation/invention project. They consistently use general rules and guidelines in their reasoning but not by using emotional reasoning or extreme attitudes when they evaluate the truth or falsehood of a statement before deciding what to do. They also believe that transformation does not occur the next day and their reflective process to produce thoughtful, strong results for the project is in fact argumentative by nature — they are critiquing facts.

The **interpretation** skill in critical thinking stands out with a mean score of 4.31, the highest among all assessed skills, indicating that students are particularly adept at interpreting information. This strong performance suggests a solid foundation in understanding and making sense of complex material. The standard deviation of 0.76 reflects moderate variability, which is consistent with the patterns seen in other critical thinking skills, indicating that while many students excel in this area, there are still some who struggle. The score range of 1.56 to 5.00 highlights this disparity; although some students achieve the maximum score, others perform significantly below expectations. This range underscores the importance of providing additional support and resources to help those who may be weaker in interpretation skills, ensuring that all students can enhance their critical thinking capabilities**.** They enjoy reviewing data to determine if it makes sense, is correct or true (valid) and then whether the situation at hand values that

specific data before taking steps in a project. They make a clean separation between observation and inference, discuss only the main points during discussions, focus on coherent communication with care about clarity and precision**.** The question well helping them sort out the truth from everything that is not while clearly identifying problems, investigating evidence and gaining knowledge about whatever assumptions or biases they may have. In plain word, this means that they always search for the best solutions in response to challenges and issues appearing during each stage of product innovation or invention (including implementation) which results from a full support finishing out the project effectively and timely.

The **argument evaluation skill** in critical thinking received a mean score of 4.05, indicating that students are generally proficient at assessing the strength and validity of arguments. This high score reflects their capability to critically analyze and engage with various viewpoints. However, the standard deviation of 0.79 points to moderate variability among student performances, suggesting that while many demonstrate strong skills, there are notable differences in ability levels. The score range of 2.00 to 5.00 further emphasizes this disparity, as it shows that some students are quite effective in argument evaluation, achieving the maximum score, while others face more significant challenges. This variability highlights the need for targeted interventions to help all students improve their argumentative skills, fostering a more robust critical thinking framework within the classroom. Its show students' critical and creative thinking abilities incredibly strong for all constructs, as they believe there is only one way to be right in appraising the success of a product innovation/invention project (rationalizing doing so), can generate no magic/illusion or take in quickly on themselves high ruins other products when needs making decision what thoughts ever going to rise out during project production. The analysis indicated that students were capable to make and investigate original ideas, applying knowledge and an ability to interpret data, whilst critically evaluating arguments. They can also sense implicit assumptions, think both logically and imaginatively as well as communicate with precision and clarity. Though the results speak to student competence in basic critical and creative thinking over time, which stems from several contexts that are relevant for product innovation/invention projects. This is on par with evidence showing that executive functions and social emotional learning are trainable (thus improving problem solving which in turn increases innovative capacities).

Table 5: Descriptive analysis for Research Objective 1

INSTRUMENT	**CONSTRUCT**		Mean	Standard Deviation (SD)
Creativity skills	Fluency		4.13	.802
	Originality		4.23	.742
	Elaboration		4.27	.784
Critical Thinking skills	Inference		4.28	.852
	Assumption		4.12	.789
	Interpretation		4.30	.763
	Argument		4.05	.797

3.2.2 To discover the problem, happen during the implementation of product innovation and invention in the classroom.

The researcher identified five themes in the students' problems they encountered during a Product Innovation and Invention Project (based on responses from them through survey) — lack of skills and

knowledge, time management and scheduling issues, resource constraints, team dynamics and cooperation, and prototyping and implementation difficulties. Many responses indicated they lack the requisite abilities and experience to develop an app and run a project. This shows a major gap in technical skills and tooling awareness that is hampering any kind of advancement or pace within projects. The result of this apparent training shortage is significant, as many responses reveal that there are indeed gaps in these fields that can be filled if certain team members receive more instruction. Here are the open responses as provided by the student on survey:

“My innovation project is an app. So, me and my teammates had problems creating the prototype, as we didn't have any experience in creating an app before.”

“Lack of knowledge and some skills in editing.”

“Not knowing how to use Figma to create the prototype.”

On the other hand, Issues related to managing time effectively and balancing commitments among team members are frequently mentioned. Effective time management is crucial for project success, and the inability to balance project tasks with other commitments often leads to delays and last-minute work. Effective time management is critical in balancing project demands with other commitments. The responses indicate that many teams struggle with scheduling and allocating sufficient time for project tasks, leading to delays and rushed work. Improving time management practices could enhance project efficiency and reduce stress. Example responses stated by the students are as follow:

"More time needed for the product invention.”

"Time management between members with other commitments.”

"Yes, time barrier with a packed schedule.”

"Not really, probably just time management.”

In addition, challenges faced by students in the pedagogy that are oriented on product innovation and invention are closely associated to resources constraint. This included the problems of finding materials, tools and budget necessary. This is a major issue, as the team does not have enough to purchase basic things that are needed in manufacturing of prototype and completion of project. Necessary resources are fundamental for project development. Both responses underscore the material, tool and budget challenges typical to makerspaces: resource planning needs to be revisited for improved project success. A few of the answer’s students gave included:

"Yes, to complete the project, there are a few objects or things that are expensive and hard to find online."

"Yes, budget to complete our design."

"Yes, we don't have transportation to buy the ingredients needed."

"Limited tools to make."

There are other challenges or obstacles which also occurred in the development and invention.

These include team dynamics as part of the project. This theme shows various problems in the team such as little collaboration, low productivity and different contributions. The successful execution of a project largely depends on teamwork. Problems in team dynamics wreak havoc on the project progression and its quality. The success of a collaborative project depends on team dynamics. Problems like non-participation reduce progress, along with procrastination and weak communication. Developing a friendly and proactive team atmosphere is requisite in the face of these challenges. Here is a response example from the students as follows:

“Not every member in the group is well aware of what the project is (just follow what the leader says and not having any opinions and wait for others to take the lead)."

"Some team members procrastinate and lead to last-minute work."
"Yes, in terms of generating ideas and cooperation from the group member."
Finally, issues faced while generating and implementing the prototype. During the prototyping process, practical implementation hurdles often come up, leading to rounds of trial and error before a functioning prototype is realized. Real challenges translate from the prototype phase to hands on iterative problem yes solution capture. It reveals that changes and revisions may frequently differ due to unforeseen issues arising in the team's work. Strengthening Problem solving abilities and promoting a more robust mindset can allow teams to get over these hurdles faster. Teams that keep these themes in mind are going to generally perform better and persevere through the toughest moments of product innovation and invention projects. Example of the responses:
"We have troubles putting the alarm on the handbag because it keeps falling."
"Yes, we got some obstacles regarding how to combine all those three items into one product."
"Constantly revising ideas to achieve a better one."

3.3.3 To identify how student solve the problem during the creation of product innovation and invention

Based on the survey's data, the research scholar categorized responses pertaining to the dynamism of teams and execution of projects into four broad themes: effective team collaboration and communication; learning and utilization of resources; problem solving and adaptivity; time management and task delegation. The team provides an environment that encourages every member to contribute ideas and join in the discussion. Regular meetings are held to maintain consistency and provide an opportunity to quickly correct any deviations from the plan. The project leader mainly monitors the interplays and activities by guiding behaviours for consistency to accomplish timelines. There is a high level of idea exchange and effective contribution from members during brainstorming sessions for the deliberation and augmentation of the project. The reactions from the students are presented below:
"We divided the task fairly for everyone and practiced two-way communication in our group."
"Frequent meetups with my team and seek help from lecturers."
"The leader took the lead, initiated discussions, and gave tasks accordingly."
However, at the team level, where a customer success support agent might use YouTube or attend an online course to brush up on new skills and troubleshoot issues. They also take help from teachers, friends or experts who give new ideas and improve the quality of work. Furthermore, they look for ways to find another method even if the traditional way no longer exists or when it does not fit a new need showing their capacity in creativity and being malleable with challenges. Answers as told by the students:
"Learning with friends and YouTube and exploring it myself."
"We use an alternative object to complete our product, such as replacing the metal rod with a chopstick."
"Ask parents" and "Discuss with my friend."
In addition, the team applies creative and critical thinking to solve technical issues to adapt properly. They test and iterate many ideas until they find the one that works. They adapt to limitations by making use of alternative tools or materials, showing flexibility and innovation in solving problems. They may test various versions or materials to achieve a desired result, so long as the final product meets their end-game project needs in alignment with those survey responses.
"Do a lot of tests from my group ideas."
"Try different tools that give a similar effect."
"Discuss with team members and find the best solutions to our problems."

To team upscaling regarding time management and delegation, responsibility is divided in a way that we always have the right kind of person available which will help us from having an inefficient workflow. To ensure everyone keeps up with their deadlines, the leader must remind team members of tasks in a timely frame. Also, team workers have learned multitasking such as handling multiple jobs at the same time to hold up the process and reach the objective of a project. The survey that came out in October laid out the responses of students to this statement as:
"Separate the work with members."
"The leader takes the lead, initiated discussions, and reminded team members about future deadlines."
"Multitasking."

4.0 DISCUSSION

This research used questionnaire responses of 59 students who took critical thinking course at University Utara Malaysia to obtain several crucial insights which could be applied into further depth in understanding the problems that confronted by the university student, and effectiveness of teaching strategies existed respectively. This research will provide a way of thinking about how to categorize the differences between critical and creative thinking, problems that are encountered through implementation of those goals and strategies students employ in connection with invention or product creation.
Results showed that most students were excited to learn about critical thinking, demonstrating a high level of interest. However, there remain significant obstacles to developing critical and creative thinking skills. The students' struggles with critical and creative thinking activities also directly mirror how they did in conceptual reasoning chores that needed pretty high levels of idea formation. This glowing need stresses a necessity of pedagogical strategies tailored to the gamut of critical or creative abilities exhibited by learners. Some of the examples can be like some students would have good thoughts to something antecedental undiscovered, however they'll not return that within the sensible use. To narrow this gap, and enhance student performance in general, these gaps can be addressed through specified actions as well as feedback.
However, students feedback and survey results do imply several limitations in the day-to-day implementation of product innovation and invention. Students tend to put hurdles in their way, which include looking for new ideas and converting theoretical knowledge into a practical one hence breaking off the barriers of creativity and critical thinking. Within organizations, a lack of collaboration and communication can result in operational inefficiencies causing frustration among team members that leading to bottlenecks blocking progress. Supported by Banaeianjahromi, et al. (2019) points it out but does not show that the lack of quality communication and collaboration causes many bad symptoms for example, no common goals nor a proper shared mind among teammates. When there is misalignment, it breeds distrust among team members that only serves to compound issues of working effectively together. They add up, worsen till these little stresses within organizational processes. This suggest that how teaching is currently being done might not be adequate to enable students with the necessary innovation and product development skills.
On the other hand, to improve instruction, lecturer need to understand how students deal with these challenges. student feedback indicates that they are amenable to using different approaches, including learning independently, working in groups and sourcing external information when needed. Carless and Boud (2018) mentioned in the investigation by de Kleijn (2021), then highlight that, as educators we should also consider to equally support students effectively using feedback suggestions literacy may

scaffold. In other words, empowering students to internalize and use feedback that enriches learning how they learn or problem-solve. This will allow students to make the most use of their feedback, enhancing academic performance on a greater scale. Even worse, it appears that the lack of structured support and opportunities for real-world implementation in the classroom is preventing these from being as effective. The problem-solving skills will not increase without the exposure to practical experience, interactive teaching and learning curves.

Besides, students develop an understanding of critical and creative thinking skills through hands-on, real-world modelling & inquiry-based problem-solving activities with classroom management completely agree with Guido (2017) as stated by Gholam (2019), they add up to seven benefits from that. These advantages include building the curriculum content, supporting better understanding and encouraging both initiative and self-management. Experience and flexibility by incorporating students in the process, they build these crucial skills which allow them to better adapt learning environments; hence ensuing more active class participation. Modelling and problem-solving using inquiry has been widely accepted as one of the most powerful pedagogical approaches in classrooms, when used together with real-world examples. These activities not only assist students to have a richer notice of critical and creative thinking become skilled transactions skills but also provide other advantages. These activities are primarily helpful as they promote curriculum building. Students can get a much better grip on subject matter by doing some hands-on, real-world modelling of the things that they are learning. In addition, such activities facilitate a deeper grasp of the content material because students must engage and physically apply what they are in understanding how things work. (Saputra, 2022). To making students feel like practicing creativity, hands-on inquiry-based modelling activities can train them in initiative, and self-management. Student ownership will come from allowing the students to learn and solving the problem on their own, but an engaged student in participation leads to more engaging and active participation in the classroom as students feel like they have been empowered and can take control of their education life. Additionally, these exercises teach students how to respond in various educational environments. By including students, this provides them with essential skills which prepares them for success in other educational environments.

The results in this area imply several areas that need correction, if the issues are to address the shortcomings identified and improve the effectiveness of critical thinking instruction. Educational experiences should primarily aim to facilitate student participation and encourage learners to think critically in relation what is done beyond the classroom on a routine basis. They may include case studies, simulations or practical projects with real-world applications that test student´s theoretical knowledge. In the next point that is positive feedback with resolving issues of group work and non-effectiveness, creating a collaborative learning environment help students engage their communication and even teamwork skills. Third: providing additional support such as peer review process, mentorship and tailored resources will also help student in solving problem by guidance, improving their self-critical thinking and developing innovative mind set. Research by Suparni, (2020), suggests that critical thinking is not only central to an education, but it's one of the most important elements underpinning good character. The incorporation of creative learning strategies is required to boost the critical thinking skills in students. The study adopts the classroom action research orientation, specifically using Kemmis and Mc Taggart's model of planning, acting or implementing a plan in class based on outcomes from that planning stage, observation, reflection steps. On the other hand, the integration of problem-based learning is a supportive approach that can improve problem-solving and critical thinking in the education context by creating an authentic experience (Magpantay & Pasia, 2022; Benedicto & Andrade, 2022). Framing questions in such a way that students

can apply pea-theoretical knowledge to real-world are two principles for critical thinking. Besides a collaborative learning environment enables students to voice out, discuss ideas and help one another informally in order that critical thinking skills & teamwork blossoms. In addition, mentorship opportunities and tailored feedback on their work as well a guidance to develop their analytical skills can raise self-appreciation of critical thinking. Such holistic solutions power students to be independent, inventive thinkers who can use what they know at the real-world.

In conclusion, even if students have a great interest in critical thinking, the difficulties they encounter underscore the necessity of focused interventions and enhanced instructional strategies. Through the implementation of interactive teaching techniques, practical application, and improved support structures, educators may assist students in acquiring the critical and creative thinking abilities that are essential for success in product innovation and invention.

5.0 REFLECTION

Using a teaching framework focused on innovative product-creation we have made important findings into the efficacy and scope of an application like this. Simply put, it has been impactful and transformational in an educational context that is meant to hopefully provide a great deal of depth for students as they learn the critical importance of product innovation dovetailed with hands-on improvement skills.

The entire pedagogical model revolves around activity and moving away from traditional passivity. The approach is designed to address the gap between academic learning and practical application by integrating structured activities whereby students can apply theoretical concepts directly into real-world problems. This experience not only illustrates the importance of theoretical knowledge; it also equips students to relate product innovation theories back and forth with real products. The practical application of concepts through real-life scenarios has made learning more meaningful, enabling students to appreciate the intricacies of product development.

One advantage that this approach has is the nurturing of critical thinking and problem-solving abilities. Mind mapping as a technique connecting the core elements of innovation in product development entails, further implies higher order cognitive functions from students. This enforced them to structure their thinking, dissect complex problems and come up with creative solutions. These are vital skills in the world of product development, where new ideas need to be generated, and challenges will be faced along the way. It also resulted to a notable enhancement of student motivation and engagement within the pedagogical model. This experiential, practical approach to skills development the games and discussions culminate in problem solving exercises based on real challenges many of students stated has compelled a greater sense commitment. The creativity and perseverance of students increased due to their active participation in these activities. This increased motivation becomes essential to push through the problems of product design and development.

It also offers great opportunities for spotting and healing weak points. Structured activities guide students and researchers can detect areas of improvement, provide timely interventions, and evolve teaching strategies constantly. This made a model that could adapt and evolve as needed through its evaluation cycle, making in-class learning more responsive to what would be most effective. In addition to this, an enhanced development of innovation thinking transpires through solving real-world problems and students thus acquire experience that is beneficial in relation to their future professions. Students are prepared to address real world challenges and solution problems that occur in product development, providing them

with the skills needed for professional success. This real-life connection to the subject matter, then, not only helps students become more adept critical thinkers and problem solvers.

The success of this pedagogical model suggests that it may be further used and replicated in the future. Next steps might consider incorporating more add-on components, for example feedback mechanisms and design iterations to enhance learning outcomes at scale. Broadening the model to incorporate varied views and interdisciplinary action would similarly provide students a more wholistic view of product innovation. To keep this approach working effectively all the time, a persistent focus on creativity and innovation is essential. Periodically updating the curriculum to include contemporary issues or challenges in product development and encouraging students to explore new technologies will help keep it both valid and influential.

In conclusion, as a teaching concept for product innovation and first-hand experience epochs, the pedagogic approach has indeed proved its worth: promoting students' comprehension while developing their power of critical thinking and sense challenge. By refining this concept, which will result a new kind of methodology, educators should be able to nurture students into both high-Caliber and inventive professionals able for the future challenges. The insights gained from this research underscore its effectiveness in fostering a deeper connection between theoretical knowledge and practical application, ultimately contributing to the development of competent and creative individuals in the field of product innovation.

6.0 RECOMMENDATION

The study provided some suggestions for future research to help improve the visibility of adaptation on product innovation pedagogies and moved forward. This research would encompass the curriculum setting, government policy in education and student engagement. Include full trainings on core product innovation and app development tools within the curriculum.

curriculum setting

Deliver basic software tools training example Figma, prototyping basics and app development essentials This method of trained-while-doing, ensures that students get the skills and knowledge before they are involved in a project work. This method does the hard work of bridging technical expertise and combing through real challenges for product innovation. Conversely, future research can inform policies that support students who may have educational needs beyond standard course experience and availability by offering flexible learning pathways and supporting project-based learning. Grant and or incentivize institutions to follow through on this training effective project management, time management output. The varied learning spaces have allowed students freedom over these different facilities for them manage time more effectively between project commitments. Secondly, include teamwork and cooperation skills in curriculum requirements. This would have courses or activities based around effective teamwork, communication and conflict resolution.

Government's policy

Design requirements to provide financial support and resources for innovations, such as grants specific material-subsidy tools-share facilities equipment access. This can be facilitated through government support (set up to help mitigate these financial or logistical burdens, ultimately allowing students to access the resources needed for successful project completion. Furthermore remote policies that support collaborative learning environments as well payment to a team projects can also be helpful supported by the government in terms of funding. Additionally, provide funding for innovation labs, maker spaces and

equipment students can use to prototype solutions. The mentoring and financial support can allow students to utilize prototyping facilities, thereby helping in overcoming the challenge of implementation which is crucially linked with better project outcomes. Collaborative learning, supported by the government can improve team dynamics and help in increasing the success rate of projects.

Students' engagement

Promote students to attend skill-building workshops, online courses and peer-learning groups. Facilitate students to collaborate with professionals and seasoned mentors through real-world projects. Involving students directly in learning process and real-world application further develops necessary skills needed to drive successful project execution, translating into innovation. Institutions, in general, therefore must take steps like the use of project management software and other planning tools. Encourage students to use these resources when constructing their task plans so they can keep track of deadlines. By providing students with practical tools and techniques to manage their own time-flipping, it becomes tightens the outcomes of classroom projects.

The results of this study, and as such the conclusions that are drawn from them add to our understanding of teaching approaches which foster critical and creative thinking ability by providing examples for educators who aim at incorporating product innovation & invention in their pedagogy. This research could have far-reaching implications for education by elucidating how inquiry-based pedagogical interventions can foster the development of competent action systems and enable students to be active change agents in progress and innovation.

7.0 CONCLUSION

The data analysis has exposed very interesting outcomes in developing creative and analytical abilities of students. Durable and highly significant improvements can be observed in the statistical results across multiple dimensions (Fluency, Originality, Elaboration, Inference Assumption Interpretation Argument). In general, the mean differences within each dimension were all positive implying that students made strong gains in these critical and creative thinking dimensions. Overall, the results highlight students' creativity and critical thinking capabilities at a global dimension. The confidence intervals in each dimension validate that these improvements are statistically significant. Although the outcomes are largely positive, several barriers have been identified that may affect how well young people and schools can increase creativity or critical thinking skills. Educational institutions, by means of targeted curricular modifications, supportive policies and enhancing student involvement in creative thinking processes can overcome some of these barriers more effectively to foster creativity and the capacity for critical inquiry among students. By implementing these, universities would build a better pedagogical place of study that supports students in becoming their complete selves with innovation and critical thinking as well creative skills.

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