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Assessing Students' Creative Thinking With The Implementation of Design Thinking Based Project

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Abstract: The focus of this study is to apply design-thinking learning to measure students' creative thinking skills in microbiology courses at universities. The type of pre-experimental research with one group pretest - posttest design. Respondents were 27 student in four semester in the biology education study program, Hamzanwadi University FMIPA. Data collection techniques using Worksheets based project with indicators for design project: problem, solution, objective, and procedure. Data analysis techniques are descriptive quantitative by calculating the gain test of creative thinking skills, the percentage of creative thinking ability categories, and the percentage of fermentation product categories. The creative thinking gain score on the components: posing problems 1.09., proposing solutions 0.88., stating objectives 1.07., and compiling work methods 1.65 with a high category. The percentage of product categories made is general 29.2%, and modification 0.8%, no new fermentation products are produce. Through design thinking, educators can adjust their teaching methods to meet the various learning styles of students, making materials more accessible and relative. By combining real-world problems and practical activities into learning, students are encouraged to think creatively when solving challenges related to microbiology, resulting in creativity in making fermentation products. Design thinking based project learning can measure students' creative thinking skills in microbiology courses, even though at the ideate stage they repeatedly prepare project designs during the learning process and at the prototype stage there is a failure in making fermented products

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Introduction

The ability to think out-of-the-box is becoming increasingly important amidst the demands of an increasingly competitive job market, so that high-level thinking skills are needed in the 21st century, these skills include problem-solving skills, critical thinking skills,

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and creative thinking skills, innovative, able to collaborate and communicate. Widiawati et al, (2018); Gleason, (2018) these skills are very important in the future and must be included in the curriculum. Ozturk & Guven (2016); Carter et al (2017); Özreçberoğlu & Çağanağa (2018) stated that the main components of the current curriculum are improving problem-solving skills and are part of the high-level thinking required. These skills are very important for students to face the rapid developments in the world of science (Ritter & Mostert, 2016). The goal of the education system also wants students to have these abilities, think, and process the knowledge they learn. To achieve this goal, these goals can be integrated into the learning process; Susilawati et al, (2022) through the learning process can help the development of personality, intelligence, potential, and character of students.

Currently, the world of education focuses on the problem of the inability of the younger generation to think creatively. Several research results reveal the same thing; Chia & Goh (2016) According to their qualitative research, students' problem-solving skills and their ability to think creatively did not improve. Thomas & Strunk (2017) significantly failed to show the level of student success in science. Alfares (2021) Students face difficulties in understanding the problems posed by teachers. The results of the latest PISA study, Indonesian students showed relatively moderate weaknesses overall in creative thinking (OECD, 2024). In an increasingly complex and dynamic era, creative thinking skills are a valuable asset for every individual. The ability to see problems from new perspectives, create new combinations of useful ideas, and find unusual solutions is known as creative thinking skills (Nurmalia et al, 2020; Wati et al, 2020). Kivunja, (2015); Corazza, (2016); OECD (2018) said that creativity is one of the most difficult psychological constructs to explain and is considered one of the most important skills to be taught to students in 2030 because it involves elements of knowledge, critical thinking, and motivation. Usmeldi & Amini (2022), Students have a creative soul, but if they are not trained and developed, they tend to imitate and accept what is there without trying to find new ways.

Learning in universities today tends on tasks given to students so that these high-level thinking skills are not visible, problem-solving abilities are very rarely seen in students. Kumalasari et al (2017) said that students sometimes fail to understand important concepts in science learning and fail to understand information correctly. Conradty et al (2020) that teachers usually face pedagogical problems in incorporating creativity into classroom practice. Sandika & Fitrihidajati (2018), stated that ineffective learning methods have an impact on students' creative thinking skills, scientific attitudes, motivation, and learning achievement. Studying biology in college is inseparable from problems that occur in the surrounding environment, which require students to explore and improve creative thinking skills. (Kaya & Elster, 2018). Luo et al, (2020); Wahyu et al, (2020) stated that science learning includes increasing conceptual knowledge, scientific literacy, problem-solving skills, reasoning, and analysis. Ariza et al, (2021) Science education must be transformed by emphasizing process and debate. Institutions need to use creative, innovative and unique strategies to develop content or curriculum in the teaching process in order to achieve quality and effective learning,

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cognitive knowledge, students' professional skills, and change the paradigm of thinking from didactic to holistic (Vogler et al, 2018; Spector et al, 2020; Sandhyavi & Lalitha, 2020). With this paradigm shift in teaching, teachers now act as facilitators in teaching students' skills such as innovation, creativity, critical thinking, teamwork, and communication skills (Kennedy & Lee, 2018; O'Sullivan et al, 2019; Guo et al, 2020; Saad & Zainudin, 2022).

Therefore, teachers can plan their teaching strategies with learning models, media, learning resources, and teaching materials used. Design thinking is one of the contemporary learning methods that can be used to teach students problem-solving skills, ideation, creative and collaborative thinking. Verganti et al, (2021) stated that this thinking construction is a formal approach to solving creative problems characterized by repeated emphasis on users, concepts, and prototypes. (Carmen & Rohit, 2017;). Veerasinghan et al, (2021) recommend design thinking in lesson plans as a global effort to teach 21st century skills. Şenyiğit (2021), by implementing modern education teaches students to gain knowledge and use it to solve problems with scientific ideas. Ladachart et al, (2022) recommends that effective design-based learning be implemented to develop students' scientific understanding. Design thinking in this learning is used as a learning model to facilitate students in carrying out their project assignments in processing food ingredients around them into products that have high economic and nutritional value by processing them into fermented foods. Some real issues that are very contextual can be addressed by students, for example in processing local food sources that are abundant around them, especially in the East Lombok area which is a producer of major food ingredients, namely grain crops such as corn, seasonal legumes such as soybeans, peanuts, and green beans, and tubers such as cassava and sweet potatoes. These three types of food sources can be utilized to be processed into products that have high nutritional value and have high economic value. In the context of learning, design thinking can be used to actively involve students in the learning process, develop creative thinking skills and create solutions that are relevant to real life. Moesley et al (2018); Tsalapatas et al., (2019); Sadiku et al, (2019) argue that design thinking is an approach to learning that is oriented towards problem solving to help students improve their creativity, engagement, and talent. Design thinking is a human-centered approach to solving problems in creative and innovative ways (Manzakoğlu & Oraklibel, 2021). Zhu et al, (2024) highlighted the importance of design thinking in the curriculum to equip students with the competencies needed to succeed in the 21st century workforce, due to its contribution to more effective pedagogical practices for the development of creative thinking (Samaniego et al, 2024). With its benefits and strong empirical evidence, design thinking is worth considering for implementation in learning, especially in microbiology lectures on the material on the use of microbes in processing food ingredients. The problem that arises is whether the design-thinking model can measure students' creative thinking skills in microbiology courses in higher education.

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Research Method

The class used in this study was one class using One Group Pretest – Posttest Design, adopted from Creswell & Creswell, (2018). Respondents were 27 people who were taking microbiology courses in the even semester of the 2023-2024 academic year, biology education study program, FMIPA, Hamzanwadi University. The design thinking stages used include: Empathize, Define, Ideate, Prototype, and Test (Barret-Zahn; 2022). Data collection uses tests, and project designs with indicators: problems and formulating problems, solutions, goals, and methods of work. The following is a presentation of the research flow in chart 1.

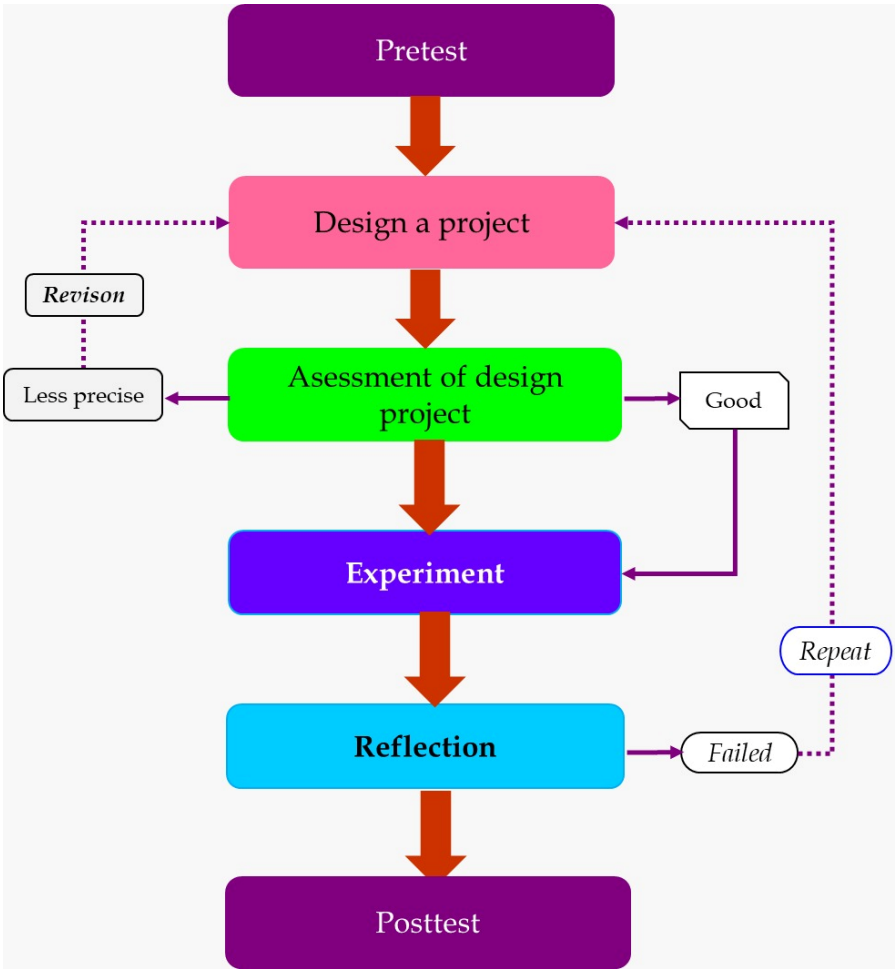

Chart 1. Design thinking based project research flow

Data is obtained quantitatively because it measures the level of student creativity in designing products as a representation of their concepts. Assessment of learning outcomes by calculating the pretest and posttest gain scores (Savinem & Scott, 2002):

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$$g = \frac{(s\,post - s\,pre)}{(s\,max - s\,pre)}$$

g = Improvement score
S_{post} = post-test score
S_{pre} = pre-test score
S_{max} = maximum score

Based on the results of the obtained score, it is then categorized into the following criteria:

Table 1. Grade interval for categorization

No	Score	Category
1	g < 0,3	Low
2	0,3 ≤ g ≤ 0,7	Average
3	g > 0,7	High

Result and Discussion

This paper discusses the application of project-based Design Thinking in microbiology courses with fermentation material. The design thinking approach in learning, we can dig deeper into the potential of local food ingredients and create unique and high-value added fermentation products. Fatmawati (2016), tudents not only learn learning theories, but they also want to apply them and solve problems in everyday life and social. To make it easier for students to conduct investigations, teachers provide project-based worksheets. The following describes the design thinking process based on projects in making fermentation products.

Empathize; students observe and identify in their surrounding environment what raw materials have the potential to be made into fermented food/drinks. Problem identification shows opportunities for design interventions and creative solutions (Peng, 2022). From the results of the observation, the raw materials identified include soybeans, green beans, peanuts, red beans, cowpeas, komak beans, winged beans, corn, seafood, cassava, sweet potatoes, taro, potatoes, coconuts, and vegetables.

Define; based on the results of observations, students create problems and formulate problems about how to process raw materials in the surrounding environment into fermented products. With complex problems, students can design solutions to these problems by exploring supporting data sources, accessing and managing information to solve problems faced collaboratively and responsibly. Provide opportunities for students to find problems and apply, build, and interpret new knowledge in creative, flexible, and original ways. Fatmawati et al (2022), because biology learning is application-oriented and responsible for society and the surrounding environment, high-level thinking must be applied, at least at the stage of creative problem-solving abilities. This allows students to improve their abilities by exploring ideas and being open, reviewing possibilities, choosing topics and planning, developing schedules, making and testing products, and communicating results (Steffen et al, 2022; Xing & Chen, 2022). From the results of data analysis, students still have difficulty in explaining problems and formulating problems, this can be seen in the design of the project that was made.

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Ideate; students put forward ideas for processing raw materials into fermented products based on the results of observations, identification, and problems that have been previously raised. This idea is obtained from designs that have been made by students; each team produces various ideas in each project design that is discussed. From the results of the project design discussion, students changed the idea of making products several times, the causes were that the raw materials were expensive, the tools and sizes of materials to be used were not appropriate, the work method was not systematic and the products to be made were common, meaning they were often encountered. For this learning, the processing of fermented products is directed at processing local raw materials that are rarely or never made into fermented foods such as tempeh which can be made from green beans or komak beans, tape can be made from sweet potatoes or taro. The main function of product design is to engage in creative problem solving, from the design students' creative ideas will be seen in processing local food sources around them. Filho et al, (2016); Chiu, (2020) this challenging project involves students' needs and problems, problem solving, decision making, independent design, and realistic product presentation. Liu & Zhao (2021) Students can gain an understanding of innovation and work practices through product design exercises. Design Thinking provides an easier and more active way to create project-based solutions in solving contextual problems (Ananda et al, 2023).

Prototype; students create one of their best ideas to experiment with making fermented products. During the experiment, several teams failed to make fermented products. From this process, there will be changes in ideas in the product manufacturing process. When students fail to make fermented products, they improve the working methods that have been written in the design and do the experiment again. Seifried & Wasserbaech, (2019); Murphy (2020) stated that in understanding the problem, brainstorming for possible solutions, making and testing prototypes, making improvements, and learning from failures so that they can change their mindset in making designs. Varianytsia et al, (2022) the criteria for design thinking are collaboration and conducting experiments. During the prototyping and testing stage, students create prototypes based on ideas and complete their work in various versions (Avcu & Ayverdi, 2022).

Test; lecturers and students reflect together on the fermentation products that have been made, namely by reflecting on the experiment, the final results of the fermentation products made, the causes of success or failure, and conducting organoleptic tests of the fermentation product results. If the product fails in making the product, it will be repeated again by revising the project design.

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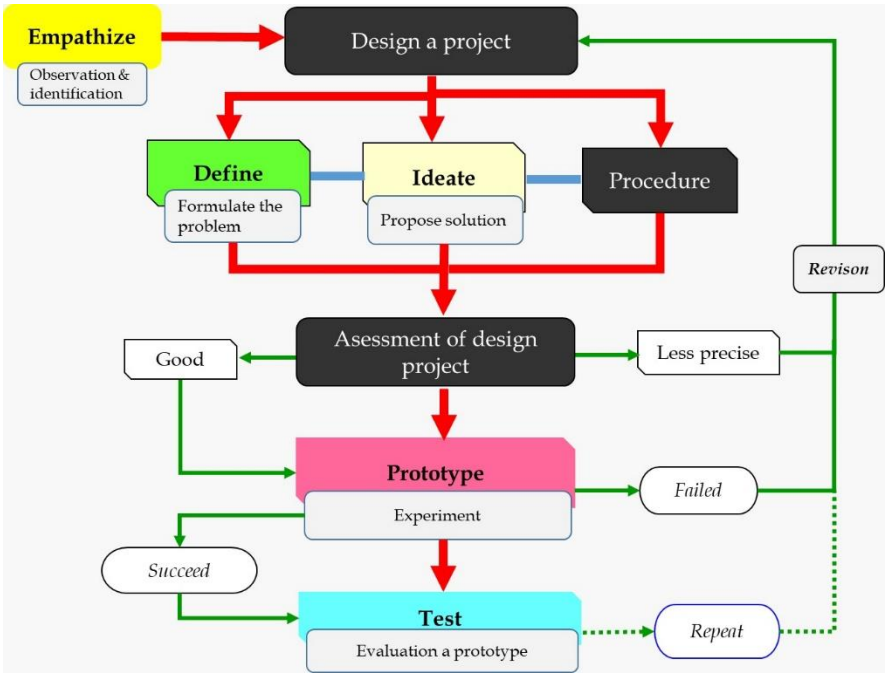
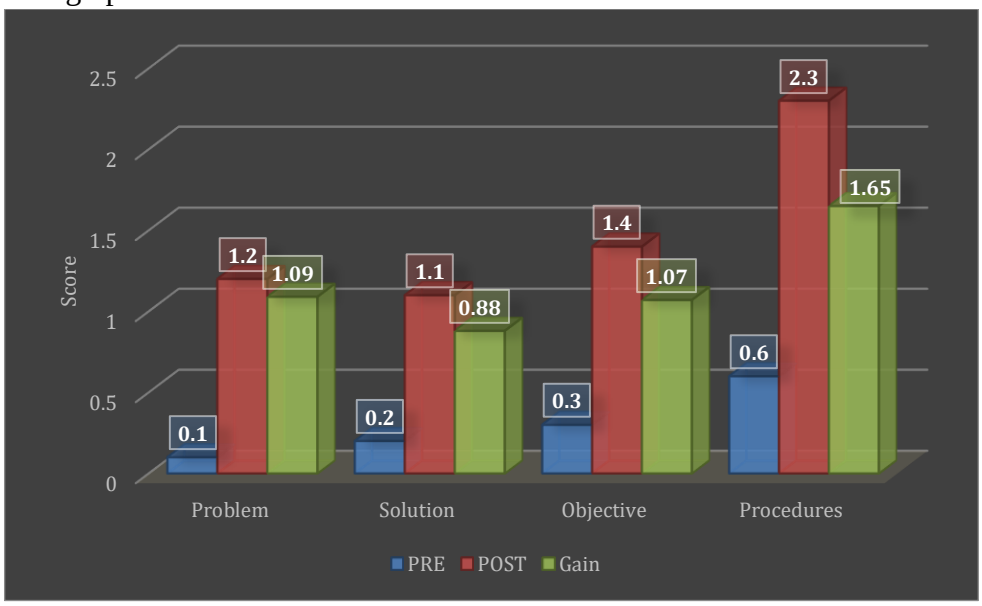


Chart 2. Design thinking learning flow on fermentation material

To determine the students' creative thinking ability, a test is given at the beginning and end of the learning process. The goal is to assess the improvement of students' creative thinking ability on fermentation material. The test assessment is like the project design that consists of four components, namely problems, solutions, objectives and work methods (presented in graph 1.



Graph 1. Score of increasing students' creative thinking on fermentation material

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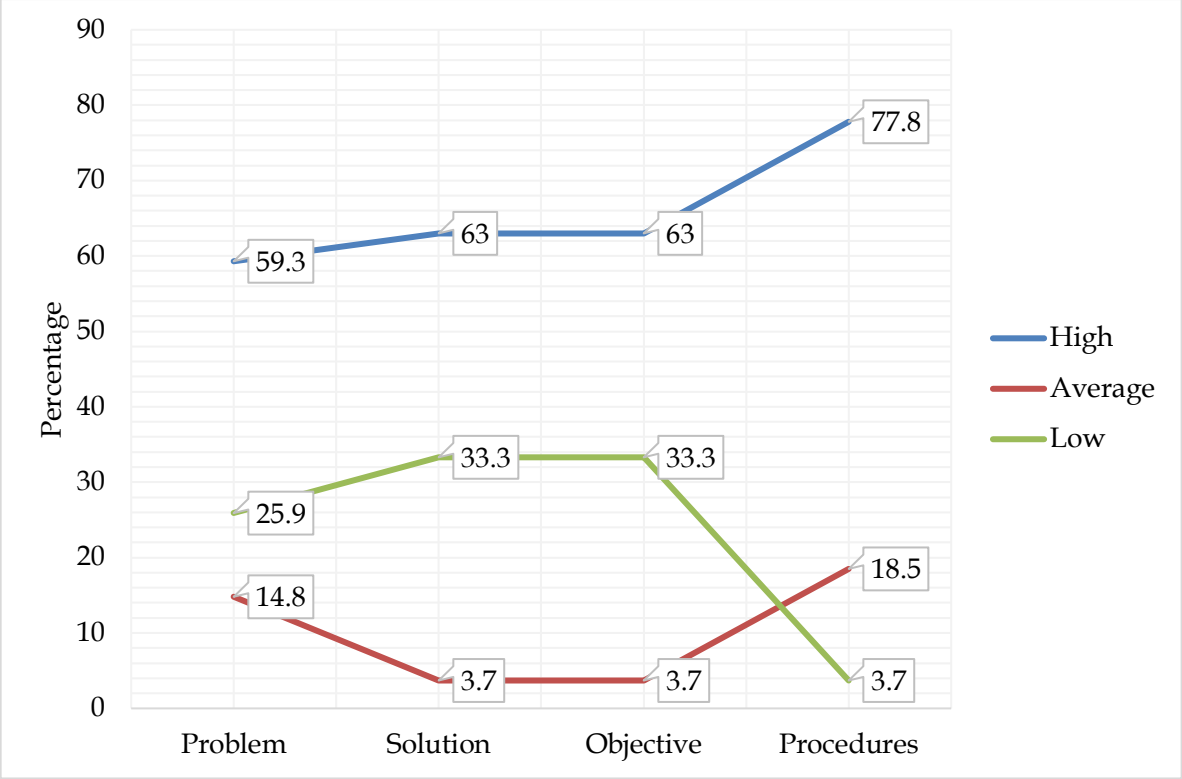
Score gain shows that there is an increase in the problem-posing component (1.09), the solution-proposing component (0.88), the objective-stating component (1.07), and the method-setting component (1.65). Design thinking can improve students' creativity skills (Pratomo et al, 2021). Design thinking-based learning has a significant impact on students' thinking skills (Li & Zhan, 2022; Zulyusuri et al, 2023). Based on the results of this increase, students' creative thinking skills are categorized into three categories, namely high, medium and low. The following results are presented in graph 2.



Graph 2. Categories of student abilities in making designs

From the results of the categorization, creative thinking skills with a low category are still seen in students for all components of their project design with the following details: 25.9% write down problems, 33.3% put forward solutions, 33.3% write down objectives 33.3%, and compile work methods 3.7%. If the process is analyzed, students who get this low category are because they are not very active in groups in compiling project designs and conducting experiments, resulting in a lack of knowledge about fermented food processing. While students who get the medium category, the students are classified as active in each group work both in compiling designs and conducting experiments, in contrast to students with a high category, all students in the group are very active in asking about their project designs, experimental

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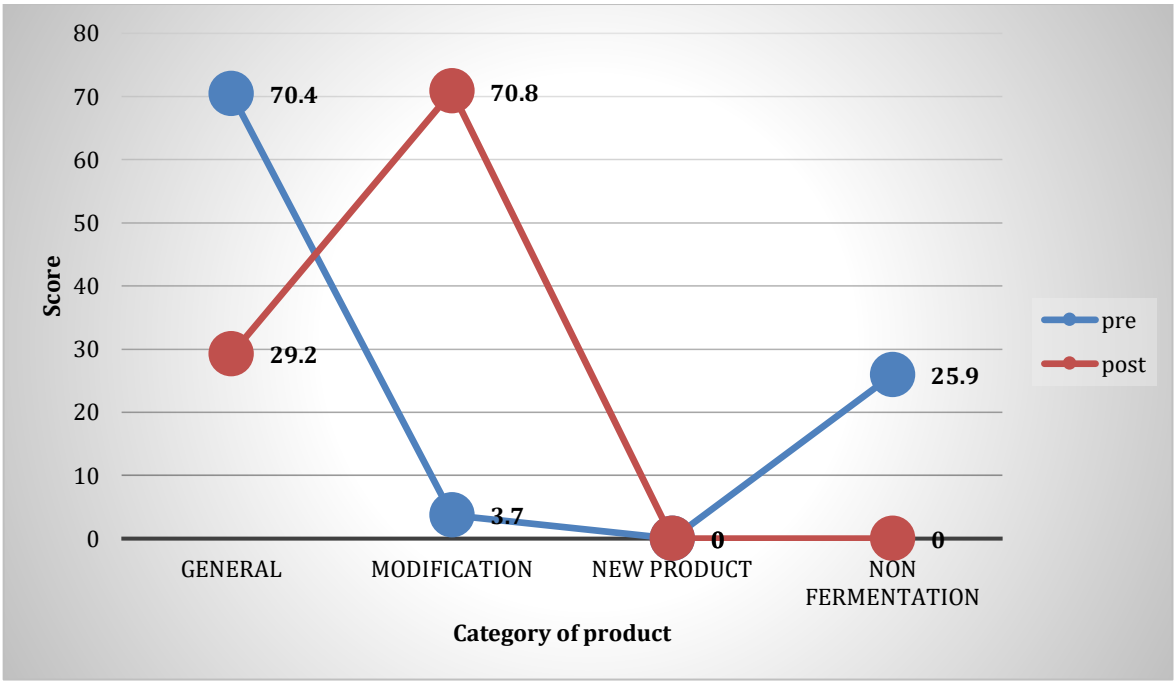
activities and consulting the results of their experiments both directly and via WhatsApp chat. Loginova et al, (2022), students who participate in competitive project activities can facilitate the development of creative thinking skills. Involves several cognitive activities, such as analyzing situations, defining problems, modeling ideas, designing solutions, predicting outcomes, questioning unexpected outcomes, and managing the design process (Sung & Kelly, 2019). Through this design-based activity, it is expected that students will not only develop scientific understanding but also use design thinking to facilitate their conceptual learning (Ladachart et al, 2022).

Next, the fermentation product categories made by students were carried out, namely the general, modified, new, and non-fermented fermentation product categories. The following is the percentage of the results presented in graph 3.



Graph 3. Fermented product categories

Graph 3 shows that there is a difference in the percentage of fermentation products made before and after the experiment. During the pretest, 70.4% of students wrote the names of fermentation products that were common, meaning those that have been widely made and marketed, 25.9% non-fermented products, 0% new products and 3.7% wrote modifications of fermentation products. After students conducted discussions, consultations, and experiments in making fermentation products, there was a change in the percentage of product categories, namely common (29.2%), modifications (70.8%), new products and 0% non-fermented. This means that the application of the design thinking process has an impact on students' creative

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thinking skills even though during the process students experienced several changes in project design and experienced failure in making fermentation products.

In fact, there is no human being who is not creative; it just takes continuous practice and practice to hone these skills. This can be done by integrating it into courses, providing opportunities to conduct investigations, and searching from various sources. Creative thinking is basically a person's ability to think divergently, seek and find solutions, ideas that can be developed in various ways which will ultimately produce a prototype by combining existing products, or even creating something different from other products. Runco et al (2022) stated that divergent thinking allows individuals to identify various possibilities. The ability to see problems from new perspectives, create new useful combinations of ideas, and find unusual solutions is known as creative thinking skills (Razali et al, 2020).

In biology learning, creativity is very important for students including building new ideas to help students solve their own problems (Fatmawati et al, 2021). Therefore, design thinking in microbiology lectures as an effort to empower students to become active participants in learning, train high-level thinking skills, prepare to face challenges in their future careers. Through collaborative projects and experiential learning opportunities, students can develop a holistic understanding of microbiology and its relevance in various industries. Dam & Siang, (2018), this approach provides an iterative framework for understanding individuals, identifying challenges, designing optimal solutions, and engaging in experiments. Cropley, (2015); pankem, (2019); Uligoj et al, (2020) the characteristics of this design thinking approach include user-centeredness, problem solving, creating solutions, increasing empathy, developing a shared vision, visualization, and prototyping. The design thinking approach, as a pedagogical method to increase students' creative self-efficacy and foster their interest (He et al, 2023).

Design thinking is a divergent way of thinking used by individuals when engaging in design-based tasks and contributes to individual creativity (Lee et al, 2019; Li et al, 2019). By combining design thinking and creative thinking, it provides a flexible structure to guide educators in approaching practical problems creatively (Henriksen et al, 2017). Experimental design thinking and creative thinking complement each other, forming a unified whole of innovative experimental design thinking (Yang et al, 2022). The main goal of design thinking is to increase students' self-confidence which can be considered as an expression of creative self-efficacy, (Karwowski et al., 2019; Novak & Mulvey, 2021; Polat & Bayram, 2022). The application of design thinking works well when done with group projects (Weiss, 2023), because design thinking uses a series of cognitive, strategic, and practical procedures to create an innovation (Griffith & Lechuga-Jimenez, 2024).

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Conclusion

Design Thinking is a method that can be used to improve the quality of learning at various levels of education. Design thinking in microbiology learning is student-centered by prioritizing empathy, collaboration, and iteration. Educators can create learning experiences that better engage students and improve their understanding of complex scientific concepts. In this way, design thinking can help bridge the gap between theoretical knowledge and practical application in the field of microbiology. The results of the research that has been conducted can be concluded that design thinking based project learning can measure students' creative thinking skills in microbiology courses because the results of the gain test show an increase in each component of the project design made by students. Gain scores on the components: posing problems (1.09), proposing solutions (0.88), stating objectives (1.07), and compiling work methods (1.65). The highest percentage of students' creative thinking ability is in the high category for all components of their project design with the following details: 59.3% write down problems, 63% propose solutions, 33.3% write down objectives 63%, and compile work methods 77.8%. The percentage of product categories created is general (29.2%), modification (70.8%), new products and non-fermentation 0%. Through design thinking, educators can adjust their teaching methods to meet the various learning styles of students, making materials more accessible and relative. And by incorporating real-world problems and practical activities into learning, students are encouraged to think creatively when solving challenges related to microbiology, resulting in creativity in making fermentation products.

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