Transferable skills for pre-service chemistry teachers in Indonesia: Applying a design thinking-STEAM-PjBL model

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The aim of this study is to investigate the potential implementation of the design thinking-STEAM-PjBL model to influence pre-service chemistry teachers' transferable skills. The design thinking process is integrated into an interdisciplinary curriculum STEAM (science, technology, engineering, arts, and mathematics) designed to engage pre-service chemistry teacher in creative and innovative contextual problem-solving through project-based learning (PjBL). Thirty-nine first-year students in the chemistry education study program, at Universitas Negeri Jakarta engaged in the study. Researchers used qualitative methods to understand the pre-service chemistry teachers' experiences and the implications for their skills development. Data was collected through semi-structured interviews, reflective journals, researcher's notes, and classroom observation. Through five stages of design thinking: empathise, define, ideate, prototype, and test, pre-service chemistry teacher engaged in reflecting on their content knowledge to understand the rising temperature in Jakarta as an issue to be resolved. The results show that collaborative problem-solving activities develop informed and integrative thinking that leads participants to communicate clearly and effectively, and to creative unique solutions. In addition, the participants' degree of empathy encouraged them to build a sense of responsibility to contribute to the context of their environment. Thus, the practice of the design thinking-STEAM-PjBL model leads participants to become independent learners.

Introduction

Education is a strategic sector in providing students with 21st-century skills to support themselves in self-reliance and pursuing further education. Critical thinking, creativity, and problem-solving are essential for students to face life challenges (Baharin et al., 2018). Thus, teachers play an important role as agents of transformation in providing creative and innovative learning to support students' skills and character strengthening (Jennings & DiPrete, 2010; Ramírez-Montoya et al., 2021). However, teachers' incompetence is still a significant issue in Indonesia. It is reflected by the low average scores obtained by teachers at various levels in the teacher competency test in 2019. These critical issues impact the low quality of learning, skill development, and the formation of national character (Bailey et al., 2017; Hattie et al., 1996; Rusilowati & Wahyudi, 2020).

Chemistry is a scientific discipline that studies matter and its properties, the changes that occur, and the energy that accompanies it (Chang & Overby, 2011). By having a wide application, chemistry has become an essential aspect of human life and has excellent potential for the future. Through chemistry learning, students are directed to develop basic knowledge about how to live in the world, including how to deal with problems and act as responsible individuals (Hodson, 2003; Rahayu, 2019). However, students still often consider chemistry a complex subject to study because of its abstract nature and unique language, so they see chemistry as a separate part of life (Freire et al., 2019; Keiner & Graulich, 2021; Taber, 2013). Therefore, chemistry teachers play an essential role in bringing chemistry closer to students through contextual, effective, and meaningful learning. It requires teachers and prospective chemistry teachers to develop their competencies by having a set of skills known as transferable skills. Transferable skills are a broad set of knowledge, skills, work habits, and essential characteristics that college graduates must possess (Vermont State Board of Education, 2014).

Previous research identified the inadequate skills possessed by Indonesian pre-service chemistry teachers. Irwanto et al.'s (2018) survey of 220 participants reported that they still have low critical thinking skills. A study by Shidiq and Yamtinah (2019) revealed that they have poor communication and collaboration skills in teamwork. Yulina et al. (2019) disclosed that pre-service chemistry teachers showed flawed analytical thinking, and experienced difficulty in various analytical processes, such as specifying, generalising, analysing errors, matching, and making classifications. Jannah et al. (2019) investigated pre-service chemistry teachers' TPACK (technological, pedagogical, and content knowledge) understanding, finding that it needed to be improved, especially in terms of technological understanding and how to integrate it into learning practices.

The lack of transferable skills possessed by pre-service chemistry teachers in Indonesia may be an implication for chemistry education that focuses more on developing a chemical understanding rather than on evolving various broader skills (Overton & McGarvey, 2017). Transferable skills are essential for them to develop their pedagogical, professional, social, and personality competencies that direct them to become lifelong learners (Tang, 2020). Therefore, chemistry education must develop transferable skills through various approaches (Eilks et al., 2013).

STEAM (science, technology, engineering, arts, and mathematics) is an interdisciplinary learning approach that increases opportunities for active student involvement to develop various skills through project creation (Belbase et al., 2021). Previous studies have reported that STEAM-project-based learning (STEAM-PjBL) in its pedagogical practice encourages content understanding, presentation skills, collaboration, self-evaluation (Ubben, 2019), and development of collaboration skills, exploration, problem-solving, and learning attitudes (Hawari & Noor, 2020). Graham (2020) identified that an effective method for implementing STEAM in learning is design thinking which emphasises problem-solving that encourages the development of innovation, 21st-century skills, literacy, and entrepreneurship (Kalin, 2019).

Brown (2008) stated that design thinking is a methodology for carrying out innovation by combining creative and analytical approaches with a human-centred framework through cross-disciplinary collaboration. Eftekhari (2019) argued that design thinking is a learning method that provides a potential to gain impact from different pedagogical practices, by encouraging students to understand knowledge for actual application in real life. Through an iterative process, design thinking as a human-centred framework (Sorice & Donlan, 2015) provides opportunities for learners to solve contextual problems based on personal perspectives, and to consider various stakeholders and the general public as users. Therefore, through this analytical and creative process, students can develop multiple skills such as creativity and innovation (Balakrishnan, 2022; Ladachart et al., 2021), 21st-century skills and lifelong learning (Lake et al., 2021; MacKinnon et al., 2020), collaboration, and entrepreneurial skills (Arrington & Willox, 2021; Naghshbandi, 2020), and teacher professional development (Azukas & Gaudelli, 2020).

Thus, the researchers analyse the need to develop transferable skills for pre-service chemistry teachers, and how that may be recognised as a critical problem in teacher education, requiring to be addressed as a matter of urgency. This study reports upon one way to involve pre-service chemistry teachers in the learning experience of solving contextual problems by implementing the *design thinking-STEAM-PjBL model.*

Method

Research design

This study aimed to answer the research question: What is the potential for implementing the design thinking-STEAM-PjBL model in a basic chemistry course, to develop the transferable skills of pre-service chemistry teachers? Thus, the aim was to investigate how well the pre-service chemistry teachers engage and can respond to learning that emphasises this creative and analytical process. Qualitative methods have been designed to enable researchers to understand the overall behaviour, perceptions, actions, and ways of thinking in the social phenomena experienced by participants (Guba & Lincoln, 1989). This study involved 39 first-year students in the department of chemistry education, Universitas Negeri Jakarta, comprising 5 male students and 34 female students. The institution is one of the state universities in Indonesia that prepares students to become chemistry teachers at the secondary school level. The basic chemistry course is a compulsory subject that pre-service chemistry teachers must master as teaching material. Therefore, this research focuses on implementing the design thinking-STEAM-PjBL model in basic chemistry courses.

During the model implementation phase, eight groups were assigned by lecturers, each comprising of 4-5 people. Due to the Covid-19 pandemic situation, the study was conducted during six online meetings (Dec 2021 - Jan 2022). Each group held online discussions by utilising *Zoom, Jamboard* and *Moodle* as synchronous and asynchronous learning media. Researchers raised the issue of temperature rise in Jakarta, closely related to thermodynamics, as one of the topics studied in basic chemistry courses. This issue became the starting point for all groups to identify various users' challenges and needs and to create products that solve the associated issues.

The learning activities and data collection were carried out in Indonesian and translated into English by the authors. The design thinking process used in this study was developed by Kelley & Brown (2018), involving students in the empathise, define, ideate, prototype, and test stages (Figure 1).

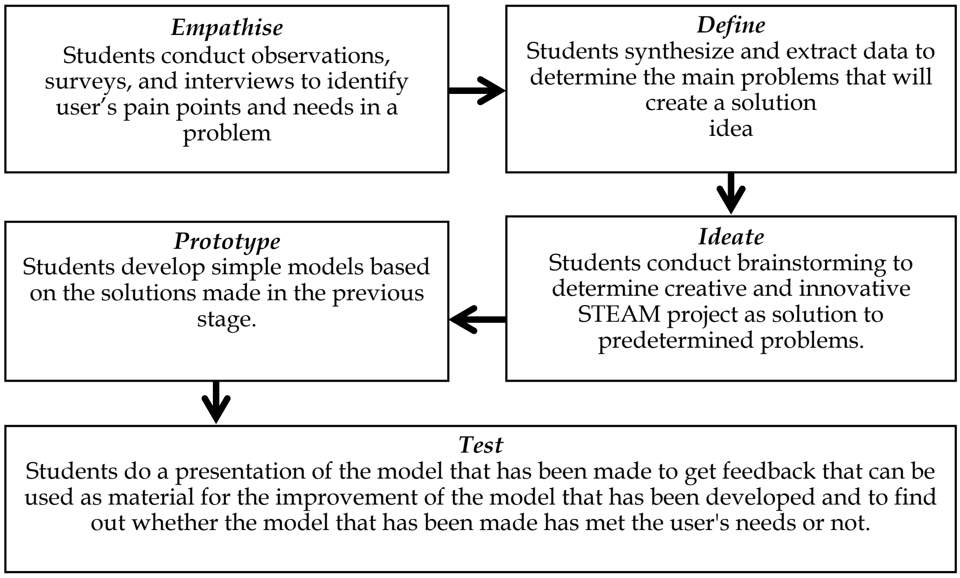

Figure 1: Design thinking-STEAM-PjBL model learning stages

Data collection

Qualitative data was collected from semi-structured interviews, reflective journals, researcher's notes, and classroom observations during the implementation of the design thinking process in basic chemistry courses. Eight external observers were involved in the study to closely observe the pre-service teachers' experience in each group. Students wrote reflective journals at the end of each meeting to explore their experiences, understandings, feelings, difficulties, and their assessment of the perceived development of transferable skills. Examples of these questions:

- What challenges did you face in today's activity, and how did you solve them?
- Describe how your proposed ideas relate to the basic chemistry concepts that are being taught?
- Would the skills you feel you have developed be of use to you as a pre-service chemistry teacher? Provide the reason.

After the design thinking process ended, semi-structured interviews were conducted with students individually, and in groups through focus group discussion activities. The purpose was to explore students' responses to the implementation of design thinking in chemistry education courses and to measure how successful the practice was in supporting the development of their transferable skills. The following are examples of interview questions that have been asked.

- Of the five phases of design thinking, which one do you find the most challenging? Why and how do you deal with it?
- When you are faced with a complex problem, how do you identify the main problem that needs to be solved immediately?
- Tell us how you and your team worked together to create a creative and innovative solution?
- If in the discussion forum there are contradictory arguments, how do you respond?

Data analysis

Data analysis was carried out through three stages: data reduction, data display, and concluding/ verification (Miles & Huberman, 1994). The researchers reduced data obtained from various sources by classifying the findings from the appropriate data. The data was then displayed in a matrix table or coding based on its categorisation. The implications of applying the design thinking-STEAM-PjBL model to develop transferable skills for pre-service chemistry teachers were then analysed.

Credibility criteria were used to test the trustworthiness as a data validity technique (Guba & Lincoln, 1989), including prolonged engagement, persistent observation, progressive subjectivity, and member checking to verify data for inferring conclusions (Miles & Huberman, 1994). Prolonged engagement involves researchers understanding the research context, exploring student experiences, and implementing the design thinking process in basic chemistry courses in specific class periods. At the same time, eight external observers helped to explore multiple phenomena in more depth. Meanwhile, progressive subjectivity was carried out to monitor research results based on the researcher's notes obtained during the research based on the empowerment of students in the design thinking process to develop their transferable skills. Member checking was done to ensure the accuracy of the data involved in the analysis process by confirming ambiguous data with the research participants. Researchers closely guarded all files produced during the research process to maintain student confidentiality.

Results and discussion

The implementation of design thinking-STEAM-PjBL model

The lessons began by introducing the design thinking process using the issue of rising temperatures occurring in Jakarta. Contextual issues encourage students to integrate 'chemical thinking' and their literacy skills to understand and explain real-life phenomena. This stage is vital as the basis for raising awareness of community issues and to motivate them to take part in helping the wider community face the challenges of global warming.

> Global warming is increasing the average temperature of the Earth's atmosphere, oceans, and land. It is one of the main environmental issues Jakarta faces as a densely populated city, and it has even become a global issue. Global warming is related to increasing the average temperature of the Earth's surface. We know that all energy sources on Earth come from the Sun. Most of this energy is in short-wave radiation, including visible light. When this energy reaches the Earth's surface, it changes from light to heat that warms

> the Earth. Earth's surface will absorb some heat and reflect the rest. Some of the heat is in the form of long-wave infrared radiation into outer space but is trapped by greenhouse gases in the Earth's atmosphere, which causes the Earth's temperature to increase. Greenhouse gases are mainly CO_2, CH_4, and NOx. The major contribution that results in the accumulation of these chemical gases in the atmosphere is human activities, such as the result of burning motor vehicle fuels, production activities in factories, and daily human activities. Therefore, we need to participate in solving this problem. Through the integration of design thinking, I hope to gain new insights and exchange understanding to create an innovative and useful solution in life.
> *(Participant 1, reflective journal, 12 December 2021)*

The use of contextual issues in chemistry education highlights the relevance of the content to real-life and encourages motivation to find solutions (Suryawati & Osman, 2018), provides opportunities for students to construct their own knowledge, and enhances positive learner attitudes through social learning (Andina et al., 2019). Once the participants understand the issues, empathy is introduced in the design thinking process by leading them to identify or engage emotionally in the exact problem (Veerasinghan et al., 2021). At the empathise stage, participants collect information related to the challenges and needs of the community and stakeholders related to the issues raised as material for their project assignments. Students will use various techniques such as interviews, observations, and online surveys to gather information. They arrange interview questions by sharing their thought and writing them on the Jamboard.

Participant 25	How about we ask the informant's opinion on the issues, like "Do you think the temperature in Jakarta will continue to rise in the following years?"
Participant 20	Good question, but I think it is necessary to first ask about the cause of the temperature rise (reflective question). So, we can include your proposal question in the following list.
Participant 25	I agree. I have a suggestion for the second question, "How do you feel about the increase in temperature in Jakarta?"
Participant 39	I think it would be more appropriate if it were like, "Do you feel that the temperature in Jakarta is increasing." Thus, number 3 is according to the suggestion, "What do you think is the cause of the temperature increase in Jakarta?"
Participant 20	Well, can we ask questions like this "In your opinion, how to deal with rising temperatures?"
Participant 25	Of course, you can, but maybe it's right for the last question.
Participant 20	Yes, my suggestion for the fourth question 4 will be related to the respondent's answer to the third question about the cause of the temperature rise. Well, the next question we can ask "Why do you think it can cause a temperature rise?" (clarifying question)
Participant 39	Good question, but we also need to ask whether the increase in temperature affects their activities or not? (exploratory question) *(Observer 8, observation sheet, 17 December 2021)*

Participant 21	This activity can bring participants to be more active. In addition, this activity can hone participants' thinking to regulate the flow of obtaining information by compiling questions to conduct interviews, observations, and utilise digital platforms to conduct online surveys. *(reflective journal, 17 December 2021)*

Discussions in the eight groups showed that participants paid attention to various types of questions to obtain information. They formulated questions by integrating the dimensions of the problems faced, causes and effects, feelings, and users' needs. Furthermore, participants were instructed to analyse the data collected through the define stage to have a better and deeper insight into users' emotions, experiences, and expectations. During the second stage in the design thinking process, participants extracted and clustered data to focus on which challenges and needs demanded an urgent response (Figure 2).

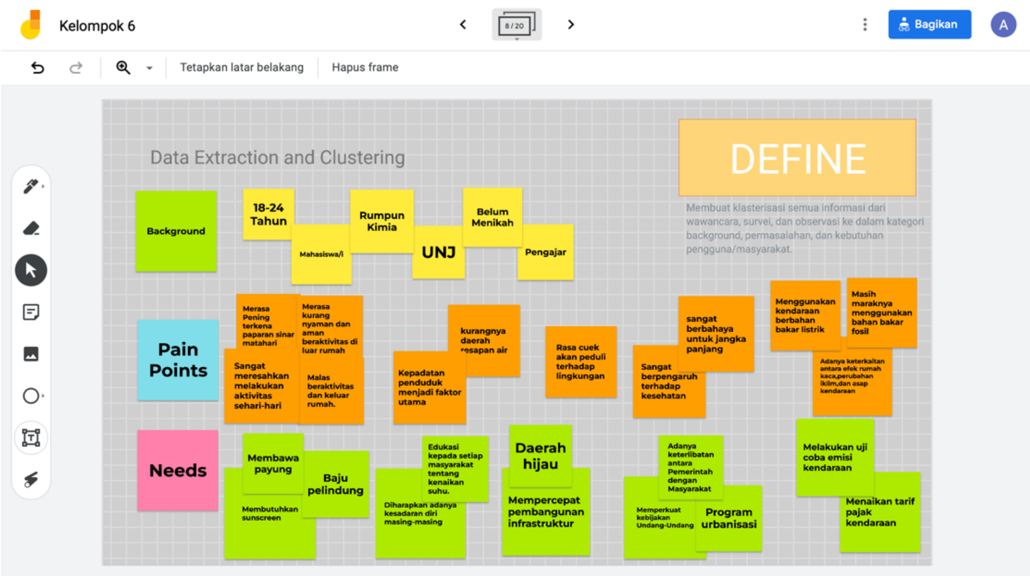

Figure 2: Data extraction and clustering
(Group 6, Jamboard worksheet at define stage, 28 December 2021)
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Participant 9	If you look at the clustering results, which do you think are the main challenges?
Participant 14	From the list of pain points, it seems clear that an increase in temperature disrupts activities and health.
Participant 19	I think so, and this seems to be closely related to the needs, which something that can protect the user from sun exposure.
Participant 9	Yes, I agree; it means we will focus on how to help Fasha as our persona, so that she feels comfortable doing outdoor activities, right?
Participant 14	Yeah, but maybe it's better to add a design statement like this "How can we help Fasha feel comfortable doing outdoor activities by increasing the effectiveness of sun protection technology?" *(Researcher's note, 28 December 2021)*

Throughout the define stage, participants provided clarity and focus on the entire design process. The main objective of this stage is to develop a meaningful problem statement from the designer's point of view, which results in a guide that focuses in on user insights and needs (Simeon et al., 2022). Then, at the ideate stage, participants in each group are encouraged to generate ideas. They brainstorm to share ideas and are challenged to develop creative responses, as did the participants in group 6. With the 3-3-3 technique, they are challenged to come up with three ideas and explain them to their peers every three minutes. Figure 3 is an example of an idea generated by participant 14.

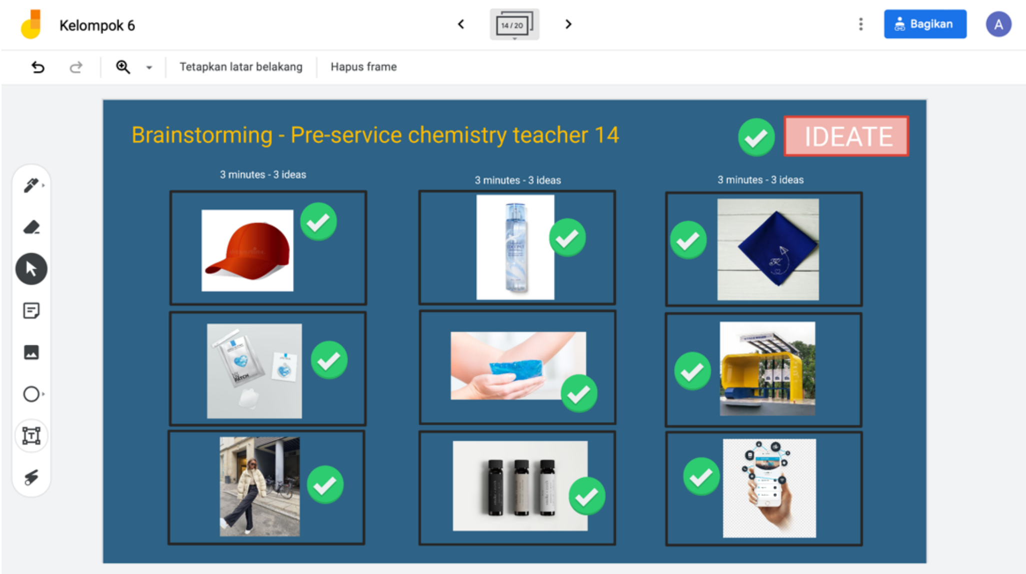

Figure 3: Generating ideas by participant 14
(Participant 14, Jamboard worksheet at brainstorming activity, 28 December 2021)
[Use web page or PDF reader 'zoom in' function to view details]

> First, the idea that I just proposed is a hat product that can block UV rays. The second picture is a product that already exists; I once knew there was a product called my UV patch, so it can be affixed to the skin that is connected to the application on the cellphone. Therefore, we can monitor whether the UV exposure is extreme and what kind of condition our skin is in. Here we can innovate with sunscreen, so whether the sunscreen is still effective can be monitored through the application so that the exposed part of the skin can be more protected. For the third idea, we know that people overseas usually wear a coat when it's winter to warm up. Now I think if there is one for winter, why don't we make one for summer too? It looks like a hoodie but is equipped with cooling sensation technology.
> *(Participant 14, the first round of group 6's brainstorming, 28 December 2021)*

The idea generation that has been carried out reports that the design thinking process motivated participants to develop their creativity as a problem-solving competency through design (Calavia et al., 2021). An insight that aligns with the Guaman-Quintanilla et al. (2022) study that reported the implementation of design thinking in the higher education curriculum promotes critical skills needed by the job market, such as problem-solving and creativity. The results obtained from the ideate stage lead the participants to agree on an idea that will be further developed into a prototype. Model development is the fourth stage of the design thinking process. The models developed in this research are digital images and interactive videos. A prototype helps convey design ideas quickly to users (Simeon et al., 2022). Figure 4 is an example of a prototype developed by group 6.

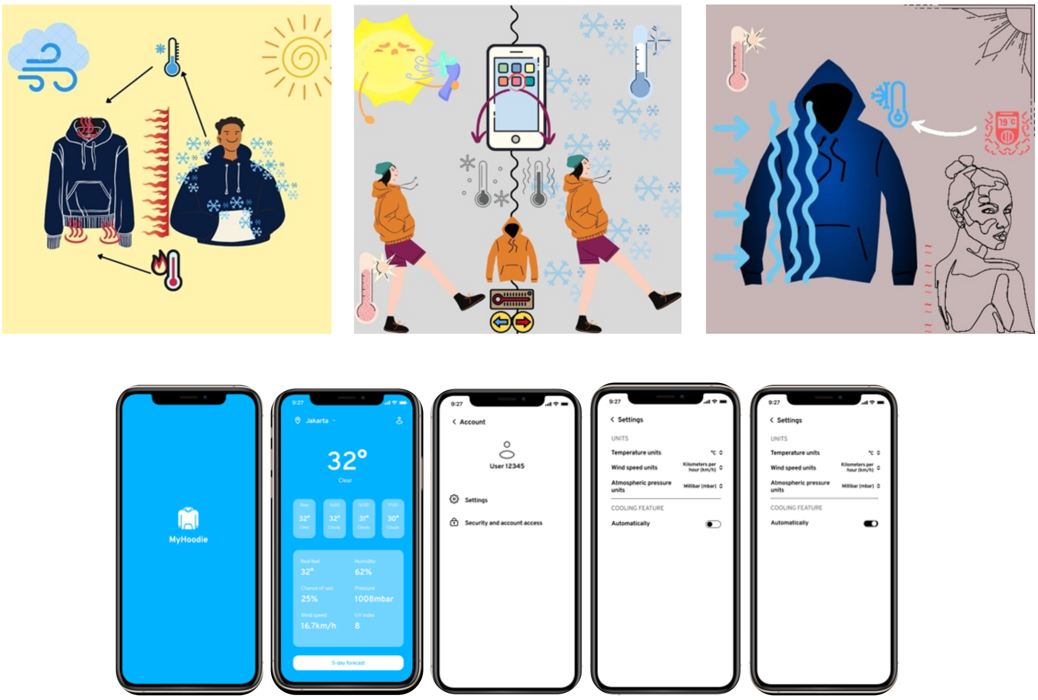

Figure 3: Prototype developed by group 6

In developing the prototype, participants integrate their understanding from various disciplines: science, technology, engineering, arts, and mathematics (Table 1).

Table 1: STEAM Discipline mapping on *My Hoodie Project*

Science	Technology	Engineering	Arts	Mathematics
Thermodynamics concept	Technology of temperature sensor	Design	Video making	Measurement product dimension
Electricity	Mobile apps development	Construction	Creativity in project development	Cost and benefit analysis
Critical thinking skills and science literacy	Problem solving and innovation	Creativity and design thinking	Emotions, ethical values and creativity	Logical and analytical thinking

In addition to the innovative ideas offered by group 6, the rest developed various exciting ideas based on the focus of the challenge from the empathise process that had been carried out. The following is a summary of the projects developed.

Table 2: Prototype summary

Group	Project name	Description
1	Biofuel and cooling helmet	The fuel comes from biomass, and the cooling helmet project is from empty oil palm fruit bunches equipped with cooler gel to be more environmentally friendly.
2	Corn-based plastics	Utilisation of corn starch as a basic material for making biodegradeable plastics to reduce carbon dioxide gas emissions from conventional plastic combustion.
3	Peltier air conditioning	Environmentally friendly air conditioning products utilise Peltier elements that do not produce chloro fluoro carbon (CFC) gas as in conventional air conditioners.
4	Portable mini fan with nanospray technology	The handy fan is equipped with a battery as a storage source of energy for portable use. This product is fitted with nanospray technology to spray water droplets to maximise the cooling effect.
5	Environmental-friendly building with stopray glasses and outdoor spaces	The design of buildings using stopray glass can reduce heat and the adverse effects of UV rays. The design incorporates a green area on the building's rooftop.
6	My hoodie	A hoodie has a body temperature sensor connected to cooling technology that will activate when needed and can be controlled via a smartphone.
7	Aornic's seed paper	Innovation of paper product that combines recycled paper with plant seeds inserted in it.
8	Fern vertical garden	An alternative to clearing green land amid dense Jakarta is using fern as a plant that can absorb more CFCs than other plants, with vertical planting techniques.

After the participants developed the prototype, they tested the model design to obtain feedback that would be used as material for improvement. In addition to improving the prototype, this stage also allowed the students to learn more about user needs and increase the point of view understanding of conditions (Lee, 2018).

User 1 — I think this idea is fascinating and innovative. This temperature sensor hoodie is quite helpful so that we feel comfortable when doing outdoor activities. Moreover, an application can be connected to sensors embedded in the hoodie material, which will make it easier for us to know the ambient temperature and body temperature. Then, how to make sensors that are planted into the hoodie? And are there any downsides to this temperature sensor hoodie?

Participant 19	Thank you for the question and the feedback. Related to the sensor, it will be embedded in the fabric thread used to make the hoodie. As for the weaknesses, we realised that the mobile apps will not work if there is no Internet connection. So, the hoodie user cannot set the desired temperature of the hoodie automatically through the apps.
User 2	I do agree that the product will be beneficial, but you need to build up how it can work too in offline, maybe for the next innovation. *(Observer 6, classroom observation sheet, 5 January 2022)*

During testing of the prototype, group 6 above found that the model created met the user's wishes. However, if the test results show that the offered solution is not acceptable to users, students need to return to the previous iteration process to make modifications. The testing phase is part of the iteration process that provides feedback to learn what works and what doesn't from the developed solutions and prototypes (Simeon et al., 2022). In the design thinking process, participants work creatively to find solutions to the problems at hand, they test ideas that fail and try to understand why a specific design fails as an effective way for students to learn and understand more deeply (Peppler & Hall, 2016).

Pre-service chemistry teacher experience in transferable skills development

This study reports on the practice of the STEAM-PjBL design thinking model in a chemistry education course to develop students' transferable skills. The research data was analysed using the transferable skills rubric developed by the State of Vermont (2020), which includes the following aspects: clear and effective communication, creative and problem-solving, informed and integrative thinking, responsible and involved citizenship, and self-direction.

For the entire design thinking process that was implemented in this study, participants were trained to exchange information effectively between two or more individuals (Brink & Costigan, 2015). As pre-service teachers, this experience was vital to convey learning clearly and effectively and to prevent misconceptions (Yusof & Halim, 2014). The ability to communicate well using evidence and appropriate logic is shown by students when testing the prototype that their group developed.

> Did you know that currently, Jakarta is experiencing an increase in temperature, one of which is caused by the many high-rise buildings? The survey results that we have conducted show that 56.3% of respondents agree that a drastic increase in temperature can have an impact on themselves and the environment. Therefore, we designed the building using stopray glass, which provides the advantages of: (1) thermal insulation performance ideal for all climates; (2) superior selectivity (ratio between light transmittance and solar factor) of up to 2.0, low shading coefficient of up to 0.24; (3) has a u-value or thermal transmission low to 1.6, as well as local processing to create shorter lead times and efficient supply. The cost needed to build a building, for example, measuring 20 m x 35 m with the price per square metre is Rp. 450,000, is a bit expensive, but it has a good impact on building owners and the environment, so the required cost is Rp. 315,000,000. And for the profit if we sell it about Rp. 500,000 then the selling price for the size of 20 m x 35 m is 350,000,000 so for one building the profit that will be

> obtained is Rp. 35,000,000. That's all from our group, thank you. *(Participant 23, classroom observation sheet at the test stage, 11 January 2022)*

The explanation provided by participant 23 shows that he was able to integrate the needs analysis, data, and cost and benefit calculations to convince stakeholders of the urgency of their problem and the importance of choosing their prototype. These results indicate that the design thinking-STEAM-PjBL model can support participants to use interdisciplinary understanding to create a complete and meaningful prototype. Correspondingly, STEAM education promotes self-expression, observation, communication skills (Hsiao & Su, 2021), and practical skills (Chen & Lin, 2019). This finding accords with Zharylgassova et al. (2021) who held that practice-oriented learning effectively influences various skills such as interpreting and evaluating arguments, making deductions, and drawing conclusions that are useful in developing psychological and pedagogical skills in future teachers.

The design thinking-STEAM-PjBL model influences the ability of participants to find creative and innovative solutions (Rahmawati et al., 2019). Creative problem-solving skills are essential for future teachers to effectively solve complex practical problems through repeated convergent and divergent thinking (Kelley & Kelley, 2013; Lim & Han, 2020). This study reports that participants were able to use analytical strategies to find creative ways to solve problems and to present innovative prototypes of solutions through an analysis of their strengths and weaknesses.

> The big challenge in design thinking-STEAM-PjBL is to create something that has never existed and answer all audience responses. To create something that has never existed before, it is necessary to analyse the purpose of innovation, community problems, what the community needs, the economic side, the ease of use, and the invention's negative impact. Then, to answer the audience's response, we need to properly understand the product innovations made, starting from how it works, capital, selling price, profits, losses, SWOT (strengths, weaknesses, opportunities, threats), and of course the product’s lifetime. *(Participant 36, semi-structured interview, 18 January 2022)*

The participants' statements above reflect that this ubiquitous, practice-oriented learning encouraged them to tackle tasks of any complexity by applying their content knowledge through design process (Psycharis, 2018; Zharylgassova et al., 2021). In practice, participants were trained to accumulate knowledge from multiple disciplines to become problem-solvers (Chai et al., 2020; Priatna et al., 2020). Regarding self-development as an attribute of a problem-solver, participants also needed to use informed and integrative thinking. Collaborative thinking is required to solve complex problems that occur in real life. Integrative thinking is characterised by a person's ability to combine various concepts into new, creative, and innovative forms by considering their values and priorities (Hartz-Karp & Marinova, 2020).

> Each participant in the group actively gives their ideas. They come up with new ideas or develop ideas that have been previously expressed. At the end of the ideate stage, they discuss choosing which view is the most appropriate to answer user needs. They analysed that Participant 14's idea (a hoodie with a cooling sensation) and Participant 4's idea (mobile apps for monitoring body temperature) could be combined into an exciting

> solution. The agreed idea is to develop a hoodie product equipped with a body temperature sensor connected to the user's cellphone. They try to apply the concept of thermodynamics into the project to be developed. They used two reputable articles as primary references in developing ideas (DOI: 10.3390/s17010130 [Majumder et al., 2017] and DOI: 10.3390/s18082414 [Dias & Silva Cunha, 2018)]). *(Observer 6, classroom observation sheet at ideate stage, 28 December 2021)*

The participants' experiences illustrated above reflect that problem solving, as a driving force in the design thinking process, can promote thinking skills and effectively improve products (Li et al., 2021). This transformation of achievement signals that the implementation of design learning has strong support in education for creating a favourable atmosphere of teaching and fostering positive interactions through cooperation and the exchange of ideas among learners (Tu et al., 2018).

Contextual issues raised in the design thinking-STEAM-PjBL model involves learners' emotion as citizens who have the responsibility to encourage theoretical problem solving (Adriyawati et al., 2020; Sheffield et al., 2018). Previous research by Rahmawati et al. (2022) shows that STEAM interdisciplinary learning practices empower learners to engage in sustainability education. Learners become involved in value learning that places them as agents of change for a sustainable environment. Therefore, as future teachers, participants need to understand their responsibilities as citizens to participate and contribute to maintaining the health of the natural environment. Participants in this study demonstrated ethical behaviour and moral courage in identifying ways to resolve conflicts by promoting equality of stakeholders' role in problem-solving.

> All elements of society must support efforts to preserve the environment and natural resources and law enforcement. This effort must be carried out comprehensively and across sectors. For example, to overcome the greenhouse gas emission due to the increase in the number of vehicles in Jakarta, there's the need to collaborate with its surrounding areas such as Bogor, Depok, Bekasi, and Tangerang. Because workers who live in these four cities use motorised vehicles every day enter the city of Jakarta. *(Participant 39, reflective journal, 12 December 2021)*

In the semi-structured interviews, participant 27 reflected on his experience in integrating his understanding of chemical content to participate in solving environmental problems as a form of his contribution as a good citizen.

Researcher	How do you apply the concept of chemistry to your problem-solving?
Participant 27	I first identified that the problem was related to the factors that caused the temperature rise in Jakarta, one of which was the result of burning plastic. So my friends and I agreed to create biodegradable plastic as one of our contributions to the environment. By understanding the polymer concept, we can choose which materials will be more easily decomposed by microorganisms in the soil so that it does not produce exhaust gases like conventional plastic combustion products. *(Participant*

27, semi-structured interview, 18 January 2022)

The two pieces of evidence above reflect that the practice of the STEAM-PjBL design thinking model encouraged students to participate as citizens through the process of finding innovative solutions to problems. As a central dimension of the design thinking process, the human-centred approach has engaged participants to ponder issues of mutual concern (Schliwa, 2019). The development of a sense of belonging and responsibility through the active involvement of learners is significant at various levels of education, especially in higher education. Therefore, universities have a mandate to encourage individuals and communities to develop a deep conceptual understanding of the problems that beset their environments (Arvanitakis & Hornsby, 2018).

As future teachers, participants need to realise that science continues to develop. Learning is a dynamic process (Mbagwu et al., 2020), so it is necessary to encourage participants to have strong internal motivation for learning. The following semi-structured interview excerpt reflects Participant 36's initiative and responsibility to learn through good time management and self-advocacy.

Researcher	How do you work in a team and manage time so that the projects you make can be completed on time?
Participant 36	We actively communicate via WhatsApp, and we consistently report the progress of each individual's work so that all members can monitor the progress of group projects. I often motivate friends to provide input and ideas actively. For the project to be done on time, we make a timeline that we mutually agree on. Usually, we will combine the results of individual work a few days before the specified deadline. *(Participant 36, semi-structured interview, 18 January 2022)*

Self-direction is a critical skill in the 21st century that requires learners to think more flexibly and find their own way of exploring deeply their understanding and the development of various other essential skills (Chin et al., 2019; Goldman et al., 2014).

The practice of the design thinking-STEAM-PjBL model brought positive implications for developing transferable skills for pre-service chemistry teachers. In line with that, they also appreciated the learning design process because of its usefulness for them as prospective educators.

> Various skills developed from the experience of design thinking in basic chemistry course will benefit us as pre-service chemistry teachers, such as innovative and creative thinking skills and mastering technology as learning support. In addition, the skills to issue ideas, argue, and present something so that the meaning conveyed can be clearly accepted. (*Participant 16, reflective journal, 11 January 2022)*

The reflection above suggests that the design thinking-STEAM-PjBL model succeeded in encouraging prospective chemistry teachers to see this journey as a meaningful experience to improve their competence as future professional educators.

Conclusion

This qualitative study demonstrated that implementing the design thinking-STEAM-PjBL model, which integrates the design thinking process in interdisciplinary project development, can promote the active involvement of pre-service chemistry teachers in developing their transferable skills. In particular, the results describe how participants engage in analytical and creative processes within the framework of a human-centred approach to design solutions so as to contextualise problems that afflict their local environment.

This study identified that involvement in finding solutions can support the deepening of understanding and development of various skills. Collaborative activities lead participants to improve their ability to communicate clearly and effectively. Problem-solving is an essential dimension in the design thinking process and encourages participants to be creative in generating ideas by involving informed and integrated thinking. The environmental values involved can promote a sense of responsibility by contributing to their ecological context. Thus, this process encouraged participants to use internal motivation to become independent learners.

These sets of skills are significant for pre-service teachers to expand their competence as future professional educators. Since this study involved only pre-service chemistry teachers at Universitas Negeri Jakarta, the findings cannot be reliably generalised beyond certain environmental and disciplinary contexts. However, this study indicates that further research is worthwhile to test the efficacy of the design thinking-STEAM-PjBL model to empower learning by pre-service teachers, in a diverse range of subjects in addition to chemistry.

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