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Enhancing entrepreneurship project-based learning for vocational schools with human-centered design and 3D printing

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ABSTRACT

Background: Project-Based Learning (PBL) is vital for equipping Vocational High School (SMK) students with entrepreneurial skills to reduce unemployment. However, many schools face challenges in its effective implementation, particularly in integrating Industry 4.0 technologies.
Contribution: This program introduced consumer-focused entrepreneurial thinking using Human-Centered Design (HCD) and 3D printing technology to teachers at SMKN 1 Pacet, Cianjur.
Method: The initiative included workshops and a mini product development project. Effectiveness was evaluated through pre- and post-tests, prototype assessments, and reflective questionnaires.
Results: Teachers' knowledge improved by 31%, with significant gains in skills and understanding.
Conclusion: The program enhanced teachers' understanding of entrepreneurship PBL integrated with HCD and 3D printing, fostering innovative teaching approaches.

1. Introduction

Vocational High Schools (SMK) in Indonesia play an important role in preparing skilled graduates for specific fields of work. In the academic year 2022/23, approximately 5 million

students were enrolled in SMK, a number comparable to that of regular high schools (SMA). Recent data indicates a rising trend in SMK graduates. In the academic year 2020/2021, there were approximately 1.63 million SMK graduates, compared to 1.58 million in 2019/20 and 1.47 million in 2018/19 [1]. The Directorate of Vocational High Schools (2021) has streamlined and consolidated 149 diverse curriculum spectrums into 10 fields encompassing 50 expertise programs [2]. This diversity highlights SMK's vast potential to cater to various industries' needs.

However, SMK's are facing a challenge of relatively high open unemployment rate among the graduates, approximately 9.4% as of August 2022 [3]. This statistic suggests challenges in graduates' integration into the workforce. Preparing SMK graduates for a career in entrepreneurship can be regarded as a viable path, thereby mitigating open unemployment rates. However, a number of obstacles may hinder this effort. First, learning facilities in many SMKs have not met quality standards. Furthermore, curricula and learning atmospheres are yet to align with rapidly evolving industries to enhance graduates' quality. Addressing these challenges is vital, given Indonesia's relatively low entrepreneur-to-population ratio (around 3.47% in 2021) compared to other countries like Malaysia (4.74%), Thailand (4.26%), and Singapore (8.76%) [4].

Several approaches have been attempted to address these challenges, including implementing programs linking education with the business world, teaching factory models following industry standards, industry practitioners teaching in SMK, grant programs for educational infrastructure rejuvenation, university mentoring programs, SMK Centers of Excellence, and implementing prototype curricula based on Project-Based Learning (PBL). Among these approaches, PBL implementation is an internal step, deeply tied to a school's development vision, mission, and distinctive characteristics, whereas the other six are external, relying on external factors (such as grants, collaborations, etc.). Hence, SMKs can take full control, strategically empowering their teachers to apply the most suitable PBL methods aligned with the school's character and development direction. Moreover, PBL is known to have a positive impact on academic achievement, motivation, and interest of students [5]. It also improves students' creativity, frequency of attendance, independence, attitude of responsibility, and access to learning with diverse culture [6]. Through PBL, students are also more likely to value sharing ideas and thinking skills [7], which also underlines its importance in learning environments. Within the context of entrepreneurship learning in vocational schools, it was demonstrated that embedding entrepreneurship model in PBL could improve learning achievement [8].

Our program partner, SMKN 1 Pacet in Cianjur Regency, has integrated entrepreneurship and PBL into their curriculum. However, they seek a more optimized learning framework in sync with rapid technological trends to enhance students' capacity and competitiveness in entrepreneurship. Additionally, there were identified gaps in teaching materials and learning

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patterns related to design and technology. Currently, design content in the curriculum is limited, despite the desire of the school to implement basic design subjects combined with entrepreneurship learning. Furthermore, 3D printing technology (3DP) is particularly appealing to the school, not only in terms of its technological aspect, but also opportunities for prototype production in various departments or study programs, such as Culinary Arts (for food and beverage models) [9], [10], Hospitality and Tourism (for room decoration and souvenirs) [11], [12], Computer Network Engineering (for enclosures of electronic devices) [13], and Agriculture (farming tools and models) [14], [15]. Strengthening PBL implementation and addressing these gaps are fundamental to the entrepreneurship learning framework, which positively impacts students' entrepreneurial skills development.

Entrepreneurial skills are intricately linked with proficient design skills. According to the World Design Organization (WDO), design has evolved from mere visual aesthetics into a strategic problem-solving process essential for driving innovation, ensuring business success, and enhancing overall quality of life through innovative products, systems, services, and experiences [16]. Demonstrated correlations between robust design performance and economic success highlight the pivotal role of design in corporate success [17]. At the level of Small and Medium Enterprises (SMEs), effective design and design management constitute prerequisites for gaining competitiveness, stimulating innovative product development, and ensuring sustained business success [18]. Within educational institutions, the integration of design principles and entrepreneurial skillsets has proven exceptionally conducive to Project-Based Learning (PBL) methodologies [19], [20].

Human-Centered Design (HCD) represents a problem-solving design paradigm that prioritizes human needs throughout the design process. Rooted in a profound understanding and empathy of human requirements, desires, and behaviors, HCD strives to craft solutions tailored to end-users. This approach requires extensive understanding of user needs and contexts, followed by iterative cycles of idea generation, prototyping, and testing, with continual feedback that shapes the final design [21]. HCD as a framework guides the development of solutions that are not only relevant but also beneficial and satisfying for users. HCD has found applications across diverse domains, including software development, medical devices, and public policy.

Furthermore, 3D Printing Technology (3DP) has revolutionized design and manufacturing. In product development, prototyping assumes a central role, which highly depends on manufacturing technologies. 3DP has gained substantial traction, allowing designers in conveying their ideas tangibly, offering a cost-effective, flexible, and user-friendly alternative to conventional manufacturing methods [22]. The technology's affordability and adaptability, especially through desktop-scale 3D printers, have made it increasingly accessible to entrepreneurs and educational institutions. 3DP thus empowers designers to create flexible digital 3D models, allowing seamless design modifications. By enabling real-time visualization

and on-the-fly adjustments, 3DP enhances the iterative design process. 3DP use in educational institution facilitates production of artefacts that support learning [23]. Its integration within PBL methodologies not only augments student engagement but also enriches the overall learning experience [24]. The incorporation of 3DP at vocational schools will potentially enrich educational practices. Students can develop various skills while working on 3D printing projects, including 3D modeling, creativity, technology literacy, problem-solving, self-directed learning, critical thinking, and perseverance, which prepare them well for the digital age [25].

While HCD has been widely recognized and applied in professional design and engineering fields, its integration into vocational education is less explored. Most existing studies focus on higher education or professional training, leaving a gap in how HCD can be effectively adapted and implemented in vocational settings to enhance pedagogical approaches. This study contributes to filling the gap by developing and implementing a program that integrates HCD principles into the professional development of vocational school teachers. By adapting HCD methodologies to the context of vocational education, through the use of 3D printing, the study provides a framework for how teachers can apply user-centered problem-solving approaches within their teaching practices. This not only enhances the teachers' pedagogical skills but also introduces students to HCD principles early in their education.

Our current hypothesis is that the combination of HCD and 3DP could pave the way for a transformative vocational education approach, hence chosen as specific methodology adopted in our community development program. The rationale behind adopting this combination is mainly the potentials it brings, which include: (1) enhancing problem-solving and critical thinking skills; (2) promoting innovation and creativity; (3) bridging theory and practice through Project-Based Learning (PBL); (4) developing digital and 3D literacy; (5) facilitating iterative learning, among the participants. By introducing such combination to SMKN 1 Pacet teachers, our community development program aims to: (1) Provide fundamental knowledge to teachers about entrepreneurship based on Human-Centered Design applied in student Project-Based Learning (PBL); (2) Offer basic knowledge and skills to teachers regarding 3D printing to enhance students' PBL experiences; (3) Foster empathy among teachers in PBL and enhance their understanding of creativity and innovation; and (4) Improve teachers' knowledge about PBL planning.

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2. Method

The methods implemented in the program are illustrated as a flow chart in Figure 1. The methods will be explained in Figure 1.

Figure 1. A flow chart illustrating the methods implemented in program

In the preparation stage, our team coordinated with SMKN 1 Pacet through several meetings. First, we prepared the sequence of programs through online discussion, focusing on the overall goals, specific objectives, scheduling, and workshop content and rundowns. Moreover, the discussion also ensured that the infrastructures and logistics needed in the program and workshop are well prepared. Second, following the online discussion, our team visited SMKN 1 Pacet to survey the workshop site. The visit also followed up on the important check list before the workshops kicked off. The school managed to admit 6 groups of teachers (total 21 teachers), coming from 6 different study programs. An online chat group was also set up to connect the team with the teachers (workshop participants) prior to the workshop. After coordinating with SMKN 1 Pacet, our team focused on preparing the workshop, including the training materials and the equipment. To achieve the objectives in this community development program, the workshop was conducted in 2 phases, namely HCD and 3DP at the first phase, and PBL at the second phase. The training materials included presentation slides, training modules, and an online platform for pre-test, post-test, and reflection/evaluation. The equipment ranged from 6 units of desktop 3D printers, print filament rolls (Polylactic acid, PLA), to stationaries for onsite group activities. The selected 3D printer was of Fused Deposition Modeling (FDM) type, Creality Ender-2 Pro (Figure 2). This printer was selected in consideration of price (complying with the allocated budget), quality based on user reviews, ease of use, and maintenance.

Figure 2. 3D printer and PLA filament roll used in the program

The materials presented in this workshop focus on explaining entrepreneurship, design, creativity, innovation, introduction to Human-centered Design, Value Proposition Canvas, explanation of 3D printing (covering basic prototyping), and experiment with 3D Printing. The presentation was designed to provide teachers with an understanding of entrepreneurship based on Human-centered design and 3D Printing as one way to enrich students' experiences later in their Project-Based Learning. Therefore, the 1st workshop on HCD and 3DP was designed as a one-day program, mainly covering training activities in two main sessions as summarized in Table 1. Before the training, teachers sat in an initial assessment to evaluate their pre-workshop understanding and knowledge. After completing all sessions, teachers participated again in a final assessment (post-test) to evaluate their knowledge related to the provided materials. The average score and success rate in pre-test and post-test were then calculated and compared with each other.

Table 1. Activities of the 1st workshop on entrepreneurship, human-centered design, and 3D printing

Morning session	
Activities	- Opening - Pre-test - Workshop on entrepreneurship, design, creativity, innovation, introduction to Human-centered design, Value Proposition Canvas
Afternoon session	
Activities	- Workshop on 3D printing, covering basic prototyping, 3D modeling/CAD, slicing software, tool introduction, 3D printer setup, 3D printing techniques using FDM - Printing experiments - Post-test

The 1st workshop was followed by a collaborative mini project of product development. In this activity, teachers worked collaboratively in groups to apply the knowledge acquired from the training and engaged in hands-on creative exploration of product development oriented towards Project-Based Learning (PBL). This mini project lasted around 1 month, during which the community development team supervised the groups remotely. Each group designed their flagship product using HCD approach and developed the prototypes using 3D printing. Judging and evaluation took place at the end of the project, where each group presented their design outcomes. The presentation was held on the same day as the PBL workshop.

By directly engaging in Project-Based Learning as "students" in the mini project, teachers are expected to develop greater empathy toward their students. This experience is central to the PBL planning. In addition to empathy, practical knowledge in crafting PBL plans is also crucial. In the 2nd workshop, the community development team organized an open discussion with the teachers on how to build practical and relevant learning plans or syllabus that integrates PBL. Table 2 summarizes the activities of PBL workshop and project presentation.

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Table 2. Activities of the 2nd workshop on project-based learning

Morning session	
Activities	- Opening - Group presentation on the mini project of product prototyping - Q&A session
Afternoon session	
Activities	- Awarding of best prototypes - Discussion on Project-based Learning - Reflection and evaluation session

In the end of the program, teachers reflected upon their experience throughout the program. Based on the reflection, the effectiveness of the program was evaluated, and possible room for improvements were identified. The program sustainability was also evaluated through discussions with the school management board and teacher representatives, considering the program results and possible future opportunities.

3. Results and Discussion

The following subsections outline the results obtained from four core activities in the program: workshop of entrepreneurship, HCD and 3DP; mini project; workshop of PBL; reflection and evaluation. The discussion on each activity will also follow.

3.1. The 1st Workshop (Entrepreneurship, HCD and 3DP)

The participants in this activity were 21 teachers from SMKN 1 Pacet. These teachers came from various study programs, as initially planned: Computer Network Engineering (5 teachers), Food Crops and Horticulture Agribusiness (4 teachers), Agricultural Processing Agribusiness (3 teachers), Hospitality (3 teachers), Tourism Services Business (3 teachers), and Culinary Arts (3 teachers).

Figure 3. Activities in the morning session of the 1st workshop

In the morning session (Figure 3), the workshop focused on knowledge transfer on entrepreneurship and human-centered design through presentation by two members of the community development team. Discussions and open interactions with the participants proceeded smoothly. During the afternoon session (Figure 4), the content involved both knowledge and hands-on skills, covering Computer-aided Design (CAD), 3D thinking, an introduction to 3D printing, assembling 3DP machines, tool introduction, printing setup, and printing experiments.

Figure 4. Activities in the afternoon session of the 1st workshop

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Participants' understanding of entrepreneurship, human-centered design, and prototyping using 3D printing was monitored through pre-training and post-training test evaluations. This was done to assess the extent of participants' understanding and to determine the effectiveness of the training in enhancing their knowledge. The questions in the test are tabulated in Table 3.

The test results are given in Figure 5. Evaluation of score result (Figure 5a) shows an average score improvement of 31%, from 41% (pre-test) to 72% (post-test). Thus, it can be quantitatively demonstrated that the training was effective in enhancing participants' understanding of the materials provided.

We also calculated the success rate of the tests, i.e., the ratio of correct answers to the number of participants. Mapping the success rate (Figure 5b) to the scope of question (Table 3) shows that significant understanding was mostly demonstrated for the subjects related to 3D printing (question 11 – 15). A significant improvement is also indicated in the subjects related to design (question 6 and 7) and Value Proposition Canvas (question 9 and 10). Topics related to entrepreneurship (question 1 – 5), on the contrary, show only a minor increase of success rate. On the one hand, this observation can be attributed to the prior knowledge of the participants about subjects related to entrepreneurship and innovation in general. Subject on HCD, Value Proposition Canvas, and 3DP, on the other hand, are entirely new to them, which explains why pre-test scores on these subjects were low, but significantly improved in post-test.

The main challenge faced during the first phase of training was the limited time to explain 3D modeling / CAD materials and the low specification of available computer for installation of Autodesk Fusion 360 software. This turns out to have a consequence on the mini project, as will be explained in the following subsection.

Table 3. List of pre/post-test questions in the 1st workshop

Number	Question	Type of answer	Scope	
			Entrepreneurship & HCD	3D printing
1	What is the outlet of an innovation?	Short answer	v	
2	Why does someone buy a product?	Short answer	v	
3	What needs to be done to understand consumer needs?	Short answer	v	
4	Successful products in the market are those with high technology.	True or False	v	
5	List the functions of innovation.	Short answer	v	
6	What is meant by Design Thinking?	Short answer	v	
7	Name one pattern of Design Thinking.	Short answer	v	
8	Name one characteristic of Human-Centered Design.	Multiple choice	v	

9	State one reason why we need to use the Value Proposition Canvas.	Short answer	v	
10	How many main components make up the Value Proposition Canvas?	Short answer	v	
11	What is meant by Computer-Aided Design (CAD)?	Short answer		v
12	In product manufacturing, why is creating a three-dimensional model using a computer important?	Short answer		v
13	What are the advantages of the 3D printing process?	Short answer		v
14	What steps are needed to prepare for the 3D printing process?	Short answer		v
15	Explain the principle of 3D printing using the Fused Deposition Modeling (FDM) type of printer!	Short answer		v

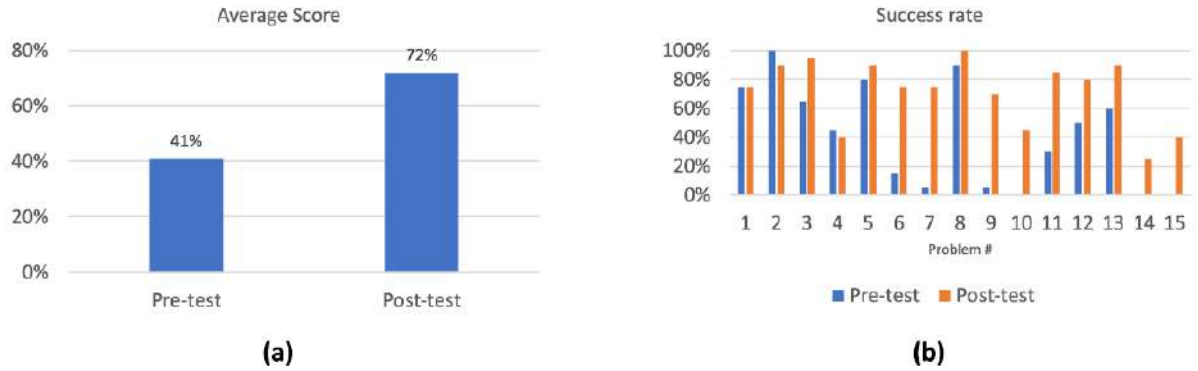

Figure 5. Pre- and post-test results of the 1st workshop: (a) Average scores; and (b) Success rate

3.2. Mini project of product development

In this phase, the teachers worked in groups to design and prototype their products using 3D printers. The 6 groups, each representing a study program, applied the knowledge and skills acquired from the 1st workshop into the project. It must be noted that due to the time limitations, the 1st workshop was obviously not sufficient to cover all the detailed technicalities of 3D modeling and 3D printing, which may be required to build the desired prototypes in the mini project. Therefore, the community service team set up a virtual helpdesk through online chat application that remotely directed the group project works as well as helped the groups by answering their questions.

With regards to the limited time on 3D modeling training and unsuccessful installation of 3D modeling software as mentioned above, a few groups took initiative to learn an alternative 3D modeling software, Autodesk TinkerCAD. This software can run on an internet browser,

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and it does not necessarily demand a high computer specification apart from stable internet connections. In addition, two teachers have had previous experience with 3D modeling, allowing them to help other teachers when building 3D CAD models of the design.

Figure 6 illustrates the prototypes built by the teachers. At the presentation session, all groups showcased their prototypes and explained their ideas. Based on the observation by the community service team, the teachers have successfully applied the basic skills and knowledge obtained from the 1st workshop, combined with their creativity, to build simple prototypes. They were able to work independently, while occasionally asking questions to the team when encountering technical problems with the 3D printing. The products that the teacher built include keychains, logos or badges, toy car display stand, figurine, furniture model, coin, and fruit model. It must be underlined, though, that these prototypes were combination of original ideas of the teachers themselves and models taken from free 3D libraries on the internet. The latter was mainly used as test products for the printing process, where the teachers could focus more on the technical aspects and practical elements of the 3D printing process, rather than on the 3D design and modeling.

Figure 6. Prototypes 3D-printed by the teachers in mini project: keychains (1 & 2); logos/badges (5 – 8); toy car display stand (9 & 10); figurine (11); furniture model (12); mobile phone cover (13); coin (14); and fruit model (15)

3.3. The 2nd Workshop (PBL)

The 2nd workshop was preceded by the group presentation on the mini project (Figure 7). In the main agenda of the workshop, an open discussion with the teachers was directed to how to PBL can be strengthened with HCD and 3DP (Figure 8). The teachers expressed several insights regarding the integration of these principles into PBL activities, emphasizing the transformative impact on how they will adjust their teaching approaches.

One overarching theme that resonated among the teachers was the shift in their perspectives on project-based activities. They articulated a newfound understanding of the importance of empathy-driven innovation in PBL. The HCD principles, with its emphasis on understanding and meeting the needs of end-users, resonated deeply with them. They recognized that PBL could no longer be only about completing projects but should evolve into a dynamic process that prioritizes customer satisfaction.

Furthermore, the integration of 3DP into PBL was met with enthusiasm. The teachers saw 3D printing not just as a technological tool but as a gateway to turning conceptual designs into tangible prototypes. The practical application of 3DP within PBL activities was considered invaluable, providing students with hands-on experiences in product development.

The program was seen as a catalyst for enhancing PBL. Teachers highlighted the importance of cultivating creativity, problem-solving skills, and teamwork among students. The emphasis on innovation and creativity within the PBL framework was considered a key outcome of the workshop.

Moreover, the impact of the program extended beyond the technical aspects. Teachers acknowledged the development of entrepreneurial skills as a crucial component of PBL. The shift from a focus solely on product manufacturing to a more holistic understanding of market needs and customer preferences became evident. This mindset was considered very important, with teachers expressing a commitment to imparting these skills to their students.

Figure 7. Activities in the morning session of the 2nd workshop (mini project presentation)

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Figure 8. Activities in the afternoon session of the 2nd workshop (discussion on PBL)

Table 4. List of reflective questions

Number	Question	Type of answers
1	By undertaking a mini product development project for approximately 1 month using HCD and 3D printing, you had the opportunity to be a learner and build empathy towards learners. Has this empathy been developed?	Yes - No
2	How much has your ability to empathize improved (comparison between before and after training)?"	Likert scale 1-5 (1 – not at all; 5 – significantly improved)
3	How much has your understanding and ability to create and innovate improved (comparison between before and after training)?	Likert scale 1-5 (1 – not at all; 5 – significantly improved)
4	How relevant are the themes of Human-Centered Design (HCD) and 3D printing for implementation as Project-Based Learning (PBL) in the learning process of your students?	Likert scale 1-5 (1 – not at all; 5 – highly relevant)
5	How much has your understanding improved in designing practical and relevant Project-Based Learning lesson plans?	Likert scale 1-5 (1 – not at all; 5 – significantly improved)
6	How significant are the benefits or impact of HCD and 3DP training activities?	Likert scale 1-5 (1 – not at all; 5 – significant)
7	How significant are the benefits or impact of mini product development project activities?	Likert scale 1-5 (1 – not at all; 5 – significant)
8	How significant are the benefits or impact of presentation and discussion activities in Project-Based Learning (PBL)?	Likert scale 1-5 (1 – not at all; 5 – significant)
9	Please provide your reflection and evaluation on the learning process during the activities and the improvement in your understanding after the program.	Open-ended, in 200-500 words
10	Please provide suggestions and feedback for the community development team	Open-ended, in 200-500 words

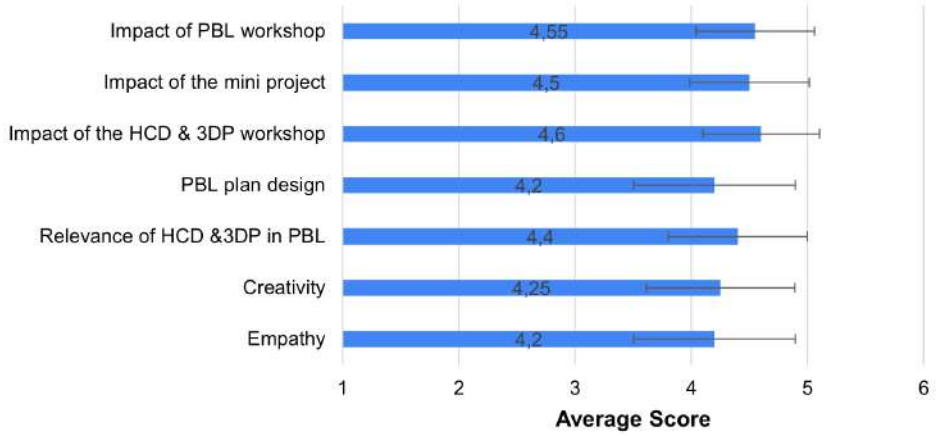

Figure 9. Average score of the reflective questionnaire (questions 2 – 8)

3.4. Reflection and evaluation

After the 2nd workshop, the team opened the session of reflection, in which the teachers answered 10 questions as summarized in Table 4. Among these questions, questions 2 – 8 were numerically answered on a 5-point Likert scale. The average score of these questions is shown in Figure 9, covering the aspect of empathy (question 2), creativity (question 3), relevance (question 4), PBL plan (question 5), and impacts (questions 6 – 8). All aspects are marked with an average score of 4.2 – 4.6, indicating that the teachers felt that significant improvement has been made.

Questions 9 and 10 are more of qualitative nature, the answers of which were analyzed in terms of emerging themes. After reviewing the reflections from the teachers in responding to question 9, several key themes and findings could be identified, as elaborated in Table 5. In addition, suggestions and feedback obtained from question 10 will be summarized as recommendation in the Conclusion section.

The themes and findings in Table 5 collectively reflect a positive impact of the program and workshop on the teachers, emphasizing not only the acquisition of technical skills and new knowledge but also a shift in mindset towards human-centered approaches and innovative Project-based Learning teaching methods. Furthermore, evaluation of the program sustainability through discussions with the school management board and teacher representatives led to a conclusion that the program was successful, and some potential projects have been identified, both as an integrated theme or approach in PBL and as elements to support the implementation of teaching factory in SMKN 1 Pacet. The teachers are also eager to learn more about 3D modeling, which was not fully covered in the workshop.

To address the limitations found in the workshop, particularly with regards to the 3D modeling training, several potential strategies can be implemented in future studies. One

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effective approach is to extend the training duration and adopt a modular learning system, which allows participants to gradually develop their skills in 3D design and printing. By breaking down the curriculum into smaller, more focused modules, participants can dive deeper into complex topics with enough time for practice and mastery. This strategy can be complemented by providing pre-workshop preparation materials, such as self-paced online courses, instructional videos, and practice exercises, which could enable participants to familiarize themselves with foundational concepts before the hands-on sessions.

Table 5. Key themes and findings from teachers' reflections

Key Themes & Findings	**Elaboration**	**Verbatim response from teachers (in Bahasa Indonesia)**
Increased openness to innovation and empathy	Participants expressed openness to innovation after being introduced to HCD. They acknowledged the importance of empathy in the innovation process and the necessity of aligning design with consumer needs. This indicates a shift in mindset towards user-focused thinking, which is a crucial element in HCD.	"Saya merasa semakin berpikiran terbuka terhadap inovasi yang harus dibuat setelah dijelaskan mengenai Human Center Design dimana inovasi membutuhkan empati dan harus sesuai dengan kebutuhan konsumen."
Enhanced knowledge and skills in HCD and 3D printing	Many participants reported a significant increase in their understanding of HCD principles and 3D printing technology. They appreciated the new knowledge, indicating that it was beneficial and relevant to their teaching practices. The feedback suggests that the program successfully introduced participants to the concepts of 3D design and printing.	"Saya semakin paham mengenai HCD dan pembuatan design 3D serta proses 3D Printing."
Application and practical learning	The participants valued the hands-on, practical nature of the training. They noted that learning about 3D printing was not just theoretical but also included practical elements such as 3D modeling and printing experimentation. This practical approach helped them see the direct application of these skills in their teaching and product creation.	"Selama proses pembelajaran digital printing ini, memberikan pengetahuan dan pengalaman baru bagi saya, terutama ketika sudah proses cetaknya, dengan hasil yang sangat menarik."
Need for additional learning time and support	Despite the positive feedback, some participants identified challenges, particularly the need for more time to master design applications. They found that understanding and implementing the design tools required additional practice and support, indicating the complexity of integrating new technologies into their existing skill set.	"Evaluasi dalam kegiatan tersebut adalah perlunya tambahan waktu pembelajaran dalam hal menguasai aplikasi design karena hal tersebut merupakan hambatan terbesar dalam menghasilkan suatu karya design."

Renewed enthusiasm and motivation	The program reignited participants' enthusiasm for learning and teaching. Some teachers expressed that the training had rekindled their passion for design and innovation, leading them to explore new ideas and approaches. The positive impact on their motivation was evident.	"Saya mendapatkan kembali semangat saya yang sudah terkubur setelah lulus kuliah dahulu dimana saya kembali membuka halaman-halaman tentang perancangan 3D modeling."
Implications for future teaching and student learning	Participants noted that the skills and knowledge gained from the program would benefit their students. By incorporating 3D printing and HCD into their curriculum, they felt they could offer more innovative and practical learning experiences, equipping students with valuable skills for future careers.	"Peserta didik akan bertambah wawasan dengan adanya alat 3D printer ini."

Continuous support and follow-up sessions are also crucial for reinforcing learning. A system of periodic virtual check-ins, Q&A sessions, and peer mentoring can offer participants the opportunity to seek clarification and share experiences, which would enhance the overall learning experience. In view of the diverse backgrounds and skill levels of participants, future workshops can benefit from tailored training programs. Offering multiple difficulty levels or elective sessions focusing on specific aspects of 3D design and printing can cater to individual needs, making the training more accessible and effective.

4. Conclusion

The community service program reported in this article aims to introduce consumer-oriented entrepreneurial thinking and innovation based on Human-centered Design and 3D printing technology, to be implemented in Project-based Learning activities in SMKN 1 Pacet, Cianjur. Through organization of two workshops and a 1-month mini project, the main target of the program is an improvement of the knowledge and skills of the teachers in entrepreneurship learning framework integrated with HCD and 3D printing technology, as well as enhanced creativity and ability to empathize. Through the evaluation of test scores, diversity and quality of generated ideas and prototypes, observed skills on prototyping using 3D printers, ideas and plans on PBL generated in the discussion session, and reflections on their experience during the program, it was indicated that the target was well achieved. Therefore, the program has successfully improved the knowledge of teachers of SMKN 1 Pacet Cianjur about entrepreneurship learning framework based on PBL, integrated with HCD and 3D printing technology. It is anticipated that this success will motivate teachers to apply their new knowledge in future PBL activities, thereby promoting student-centered learning while helping students develop important skills for the future, including problem-solving, adaptability, and communication. By engaging students in hands-on, technology-driven

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projects, PBL not only improves learning outcomes but also equips students with the practical abilities and confidence needed to tackle real-world challenges, thus enhancing their future competitiveness in entrepreneurship.

Based on the feedback from the reflective questionnaire and the team evaluation, two main areas for improvement were identified. First, more learning time for 3D modeling / CAD software is needed. This is in fact the most frequent suggestion occurring in the response to the questionnaire. The team evaluation also suggested that the materials on 3D modeling in the 1st workshop were indeed too limited due to time constraints and insufficient PC specifications to run the software. Second, it was highly recommended that the program be continued further to maintain its sustainability and ensure a long-term impact. This notion was also supported by the input from the school management board.

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