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The Impact of the Fuzzy Delphi Technique on Technology Methods Based on Design Thinking

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ABSTRAK

Ketika teknologi menjadi penting dalam kehidupan masyarakat, ada seruan untuk mengintegrasikan teknologi ke dalam pendidikan. Oleh karena itu, penelitian ini bertujuan untuk melihat unsur-unsur yang diperlukan untuk mengintegrasikan teknologi sebagai wadah pembelajaran berbasis pemikiran desain. Penelitian ini merupakan penelitian kuantitatif dengan menggunakan teknik Fuzzy Delphi. Pendekatan yang digunakan untuk mengumpulkan data penelitian adalah dengan menggunakan instrumen kuesioner. Jumlah ahli yang terlibat sebanyak 18 orang, dari bidang Pendidikan 8 orang, teknologi Pendidikan 5 orang, dan design think 5 orangs. Hasil penelitian menunjukkan bahwa kedelapan unsur tersebut diterima oleh para ahli dengan persentase konsensus di atas 75% dengan nilai ambang batas (d) ≤ 0,2. Kesimpulan kedelapan elemen tersebut yaitu menggunakan teknologi atau internet, memilih alat atau sumber daya teknologi, menilai kredibilitas dan relevansi sumber, menggunakan teknologi untuk menganalisis informasi, menggunakan teknologi untuk mendukung kerja tim, menggunakan teknologi untuk membantu siswa berbagi informasi, memanfaatkan teknologi untuk memantau tugas, memanfaatkan teknologi untuk berinteraksi langsung dengan pakar, diperlukan dalam mengintegrasikan teknologi sebagai wadah pembelajaran berbasis design thought. Implikasi penelitian ini adalah para guru dan siswa sudah mulai menerapkan delapan elemen ini dalam proses pembelajaran dalam kelas.

ABSTRACT

As technology becomes important in people's lives, there is a call to integrate technology into education. Therefore, this research aims to look at the elements needed to integrate technology as a learning platform based on design thinking. This research is quantitative research using the Fuzzy Delphi technique. The approach used to collect research data is to use a questionnaire instrument. The number of experts involved was 18 people, 8 people from the field of education, 5 people from educational technology, and 5 people from design thinking. The research results show that the eight elements are accepted by experts with a consensus percentage above 75% with a threshold value (d) ≤ 0.2. The conclusions of these eight elements are using technology or the internet, choosing technological tools or resources, assessing the credibility and relevance of sources, using technology to analyze information, using technology to support teamwork, using technology to help students share information, utilizing technology to monitor assignments, utilizing technology to interact directly with experts is necessary for integrating technology as a learning platform based on design thinking. This research implies that teachers and students have started to apply these eight elements in the classroom learning process.

1. INTRODUCTION

Industrial Revolution 4.0 requires countries to make changes along with digital transformation to remain competitive. Even though the rapid development of technology is changing the way we think, work, play and relate to each other, but many of us are still in our comfort zone and still apply old ways of thinking (Oke & Fernandes, 2020; Saarikko et al., 2020). Likewise with the scenarios that occur in the world of education where the world of education is still not fully aware of how technology actually affects every day learning (Beaunoyer et al., 2020; Iivari et al., 2020). Previous study expressed his concern by calling on teachers to prepare students not only to face the world today but also the world of the future, where at that time the use of technology was one trillion faster than today's technology (Markauskaite et al., 2022). Seeing the expectations of this phenomenon, teachers need to prepare themselves with the necessary technology skills. It is even more worrying when the findings of research conducted by other study shows that technology has made teachers' lives more difficult (Halomoan, 2022). This problem stems from the lack of skills possessed by teachers in integrating technology in education. Correspondingly, study have conducted research exploring barriers to integrating technology among elementary

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school teachers (Chen et al., 2020). The research results found four main obstacles, namely lack of training and technical support, lack of priority and support from administrators, lack of resources and facilities and teacher workload (Lumbantoruan, 2022; Lytras et al., 2022),. A study conducted found that teachers' perceptions, roles, and responsibilities regarding technology integration by schools with intensive technology programs were positive (Ejaz et al., 2022). This study highlights three important themes regarding technology integration in education, namely barriers to integration, the importance of technology training, and the learning environment. In conclusion, the findings of these two studies clearly show that an important component in the successful integration of technology in education is the application of technology skills to teachers in professional development courses.

Aspects of 21st century learning include providing independent learning, fostering a collaborative classroom environment and promoting information and communications technology (ICT) literacy (Agustini et al., 2019; Gessler et al., 2021; Kikon, 2023). Thus, technology in education can have a positive impact on the development of students' 21st century skills such as increased motivation, collaborative learning, critical and creative thinking. Correspondingly previous study suggests that academic experts develop ICT-related skills, where the curriculum should be designed to increase the use of ICT in schools with a pedagogical orientation that encourages habitual and creative use (Fernández-otoya et al., 2022). Looking at the recommendations put forward, this research will highlight the following research questions: 1) Based on expert views, WHAT elements are needed to integrate technology as a forum for design thinking-based learning? 2) Based on expert views, what is the position of the elements needed to integrate technology as a forum for design thinking-based learning?

The integration of technology in the classroom cannot be ignored by teachers. This argument is based on perspective which states that the use of technology is one way for teachers to obtain more innovative and creative thinking practices and to better integrate design thinking practices into teaching and learning. Learning design (Mansor et al., 2020). In line with this, teachers can increase the level of innovation, creativity and design thinking by including the use of technology in their teaching and learning processes (Calavia et al., 2021). Seeing technology solely as a burden on teachers in preparing material and accessing material is an unfounded view. This is because the use of technology in the 21st century is increasingly widespread and exclusive, where students' mastery of technology is more than just the technological skills of teachers and parents, and at this level the teacher's role is more as an active facilitator. Guiding students to apply technology in more complex and creative learning (Haleem et al., 2022; Khakimov, 2019). This shows that current technology integration focuses more on creativity, collaboration and project-based learning. Therefore, to implement technology integration like this, it is necessary to provide support to teachers to design good creative learning. Therefore, design thought-based learning can provide guidance in supporting this view of technology integration.

Basically, design thinking is defined as a problem solving methodology by constructing innovative strategies to adapt to human needs that can be implemented with technology. Recently, discussions about design thinking and its potential in the teaching and learning process have become increasingly debated. Among them is the ability to think design which is placed as a theoretical lens in education, and complex problem solving methods (Andrews-Todd & Forsyth, 2020; Urdan & Kaplan, 2020). The reason for choosing this model as the basis for the study is because this model highlights the use of technology in design thinking. This is because good technology can help the design thinking process and further increase the level of innovation and creativity (Crites & Rye, 2020; Pande & Bharathi, 2020). In short, technology is the most important vehicle for integrating learning based on design thinking. Effective use of technology can only be realized by teachers who are equipped with these skills. Thus, looking at the requirements mentioned, it is important to know the elements needed in the technology domain as a forum for design-based learning.

A Model for Guiding Students in 21st Century Design Thinking. This model was founded by previous study which provides clear guidelines on how to integrate technology in learning based on design thinking through the Five episodes that have been highlighted (Cantú-Ortiz et al., 2020). Other study emphasizes that design thinking-based learning involves several creation episodes starting from the initial stage of designing a problem to a concrete solution (Hainora Hamzah et al., 2022). The reason researchers chose this model as the basis for research is because this model emphasizes the use of technology in design thinking. This is in accordance with the aim of this research which is to see the views of experts regarding the elements needed to integrate technology as a forum for design thinking-based learning. The uniqueness of this model is that in each episode guiding questions have been prepared that can trigger students' thinking to frame the design process. This episode is divided into five parts, namely cognitive, socio-cultural, technical, productivity and meta-cognitive. Meanwhile, in the socio-cultural episode, students need to understand the socio-cultural context of a society before carrying out empathy activities. For example, as Malaysians who live in various races, students should know the sensitivity of a religion before carrying out empathy activities. Including WHAT can and cannot be eaten according to religious beliefs, such as Hindus cannot eat beef while Muslims cannot eat pork. Here students need to be sensitive to the sensitivity of a competition so as not to ask questions that could cause tension in the target group. This is based on the role of the designer who is more concerned with social involvement and the design process than solving the problem itself (Ryan et al., 2020; Smutny & Schreiberova, 2020).

Many studies reveal how the use of technology can increase the level of creativity, innovation and design thinking in the next guiding question, allowing students to consider technologies that could be leveraged to work on the project more efficiently (Pacheco-Velázquez et al., 2023; Rafiq et al., 2023). This includes videos, tutorials, and self-study sites to gain a deeper understanding before solving a problem. This is related to the theory put forward where students use existing and current knowledge to make deeper connections to their learning (Behnamnia, Kamsin, & Ismail, 2020; Caldevilla-Domínguez et al., 2021). Utilizing the use of technology allows students to explore further and build new experiences. Therefore, the use of technology in design-based learning can support constructivism theory in increasing the level of innovation, creativity and design thinking (Rafiq et al., 2023; Tapingkae et al., 2020). In this question, students also need to consider appropriate technological resources to complete the assignment. This can expose students to the different types of technology available through experiential learning and further help increase levels of creativity, innovation and design thinking (Jahnke & Liebscher, 2020; Schreck et al., 2020).

Previous study ask questions aimed at students' consideration of the reliability of the data they obtain (Fromm et al., 2021). This is because the internet offers a variety of information that continues to increase. Therefore, students need to be aware that all information displayed on the internet is not all true and students need to assess the credibility and validity of information obtained online before using it as a reference. Therefore previous study describes five skills that must be possessed to obtain information via the internet, namely evaluating skills in terms of (1) accuracy, (2) authority, (3) objectivity, (4) recognizability and (5) coverage of information contained on the Internet (Huang et al., 2021). According to other study in this episode students also need to consider how they can express their opinions clearly and represent the knowledge they generate throughout the planning process using computers as a cognitive tool (Zabolotna et al., 2023). This includes the use of technology to support and monitor Team work such as the use of email and the WhatsApp application. Utilizing this technology is a sharing medium to improve communication with group members and stakeholders in the design process (Kandel et al., 2020; Milara et al., 2020; Salmerón et al., 2020)

This research is urgently carried out because there are differences between theory, the opinions of previous researchers, and the reality in the field. The theory says that the presence of Fuzzy Delphi aims to analyze the efficiency and effectiveness of work processes and 21st-century skills related to accessibility and flexibility. However, the reality in the field of the learning process is that its use is still relatively low. Therefore, it needs to be researched to know how to deal with problems throughout the artifact design process, find out the adjustments that need to be made and the social and emotional reactions to the design work process, find out evaluations, and the novelty of this research consider how self-efficacy can be improved and further enable someone to succeed in achieving external and internal goals as described in the 21st-century learning framework.

2. METHOD

This research uses the Fuzzy Delphi technique. Researchers use techniques based on (Spranger et al., 2022). Previous study state that the Fuzzy Delphi technique can be used to obtain expert consensus on a problem (N. Liu et al., 2020). Therefore, to answer the research questions that have been raised, the researcher developed a questionnaire consisting of five points. In the questionnaire, experts acted to determine the elements needed to integrate technology as a learning vehicle based on design thinking. This questionnaire was adapted from the 21st Century Teaching and Learning Survey (Herrera-Franco et al., 2020) which has good reliability values (standard Alpha >0.90, correlation 0.58). According to previous study, the number of experts in research does not need to be large because there is no strong relationship between the number of experts and the quality of results that can be produced from discussion groups (Kipper et al., 2020). In line with this, researchers have selected a total of 18 experts based on recommendations, the appropriate number of experts is between 10 to 15 people, if there is high uniformity among the selected experts. Whereas other study suggests the number of experts is 10-50 people (McWilliams et al., 2019). In addition, the selected experts must have a background or experience in a field related to the research being conducted, this selection can support their opinion on research needs and can revise their initial assessment to reach consensus among experts (Beiderbeck et al., 2021; Moskalewicz & Oremus, 2020). This is because adding more inexperienced experts may weaken the accuracy of the results. The selected expert must meet the following criteria: 1) Have extensive knowledge in the field being studied, that is, at least have a Master's degree in education, educational technology, or a field related to design thinking, 2) Experienced in the field being studied and have a minimum of five years' experience in the related field, 3) Able to fully commit until the study is completed, and 4) Have no personal interest in avoiding biased research (P. Liu et al., 2020). The profile of experts involved in this study is presented in Table 1.

Tabel 1. Profile of Experts Involved

Expert	Graduation	Expertise	Experience
P1	Bachelor's Certificates	Pedagogy expert teacher at national schools	10 years
P2	Bachelor's Certificates	Pedagogy expert teacher at national schools	11 years old
P3	Doctor of Philosophy	Pedagogy expert Curriculum expert Language expert brilliant lecturer at the Institute of Teacher Education (IPG)	26 years
P4	Doctor of Philosophy	Pedagogy expert Curriculum expert Munshi language expert, Language and Library Council (DBP) and brilliant lecturer at IPG	24 years old
P5	Bachelor's Certificates	Expert in design thinking Expert training consultant in design thinking at the Institute Tad Biran Awam Negara	21 years
P6	Bachelor's Certificates	Design thinking expert Design thinking expert practice consultant	10 years
P7	Doctor of Philosophy	at INTAN	20 years
P8	Bachelor's Certificates	Lecturer technology and education expert at the Aminuddin Baki Institute	16 years
P9	Doctor of Philosophy	Pedagogy expert teacher at national schools	25 years
P10	Doctor of Philosophy	Curriculum expert Lecturer study method expert at Public Universities	29 years
P11	Bachelor's Certificates	Curriculum expert Deputy Dean of Higher Education Universities	10 years
P12	Bachelor's Certificates	Technology and education expert Assistant Director in the Educational Resources and Technology Division	12 years old
P13	Bachelor's Certificates	Technology and education expert Main trainer in Information Technology and Communication Learning (ICTL)	14 years
P14	Doctor of Philosophy	Pedagogy expert teacher at national schools	30 years
P15	Bachelor's Certificates	Pedagogy expert Curriculum expert brilliant lecturer at IPG	20 years
P16	Bachelor's Certificates	Technology and education expert ICTL lead trainer	23 years
P17	Bachelor's Certificates	Technology and education expert ICTL lead trainer	17 years
P18	Bachelor's Certificates	Pedagogy expert teacher at national schools	10 years

Data analysis. The data obtained were analyzed using Microsoft Excel software according to the steps suggested (Lin et al., 2000). The steps are as follows: Step 1: Assume K experts are invited to determine the importance of the variable evaluation criteria measured using linguistic variables is show in Table 2.

Table 2. Five-Point Scale of Linguistic Variables

Linguistic changeability	Fuzzy scale
Strongly Disagree	(0.0, 0.0, 0.2)
Don't agree	(0.0, 0.2, 0.4)
Simple Agree	(0.2, 0.4, 0.6)
Agree	(0.4, 0.6, 0.8)
Strongly agree	(0.6, 0.8, 1.0)

Then the step 2 is converting all linguistic variables into fuzzy triangular numbering (triangular fuzzy numbers). And the step 3 for each expert, use the vertex method to calculate the distance between them. Moreover (m,n) obtained must be less than or equal to the value 0.2. The distance between two fuzzy numbers or better known as the threshold value is calculated using a formula: d (*m*, *n*) = $\sqrt{\frac{1}{3}}$ [] *m1* - *n2*g^2 +] m2 - *n2*g^2 +] m3 - *n3*g^2]. Step 4: In step 3, m x n experts, if the percentage reaching group consensus is more than 75% Govindasamy et al., (2023) then proceed to Step 5. Otherwise, a second round of Fuzzy Delphi Technique should be conducted. In step 6, for each alternative choice, the fuzzy evaluation is defuzzied with a formula: *ai* = $^1_4$] ai 1 + 2*ai*2 + *ai*3g. Alternative ranking options can be determined according to the AI value. To guarantee the acceptance of the expert consensus, the next condition must be met where the α-cut value obtained must be equal to or exceed 0.5.

3. RESULT AND DISCUSSION

Result

Data were synthesized from questionnaires distributed to obtain group consensus before the first research question was answered. In the context of the Fuzzy Delphi technique, the criteria used to evaluate group consensus are based on the terms of agreement, namely the group percentage must exceed 75%. Before group consensus is obtained, the threshold value is calculated using the following formula: d (*m*, *n*) = ⅓ [] *m1* - *n*2g^2 +] m2 - *n*2g^2 +] m3 - *n*3g^2]. In this context, the condition that needs to be met is that the threshold value d (m, n) obtained must be less than or equal to the value 0.2. Based on the analysis data, the threshold value d (m, n) in the eighth element is less than 0.2 with a percentage agreement value exceeding 75% (Table 3). Therefore, the first research question has reached group consensus. Survey Analysis Defuzzification Process: An Important Element in Integrating Technology as a Container in Design Thinking Based Learning. As explained in the research methodology, the defuzzification process functions to determine the position of an element based on expert consensus. This process was carried out after the researcher succeeded in obtaining group consensus. Table 3 shows the results of the analysis based on expert consensus. The defuzzification value translated also meets the next requirement where the α-cut value obtained must be equal to or exceed 0.5. So, all the elements presented have been accepted by all experts.

Table 3. Analysis Results Based on Expert Consensus

No	Items/Elements	Terms of Triangular Fuzzy Numbers		Defuzzification Process Terms						
				Score				Consensus expert	Elements Accepted	Position
		Threshold Value, d	Percent Consensus	*m1*	*m2*	*m3*	*Fuzzy* (A)			
1	Using technology or the Internet for self-instruction (such as videos, tutorials, self-instruction websites)	0.127	80.0%	0.704	0.912	0.992	0.869	Accept	0.869	1
2	Select appropriate tools or technology resources to complete tasks	0.115	83.3%	0.704	0.904	1.000	0.869	Accept	0.869	1
3	Assess the credibility and relevance of online sources	0.123	80.0%	0.664	0.872	0.992	0.843	Accept	0.843	3
4	Using technology to analyze information	0.101	83.33%	0.664	0.864	1.000	0.843	Accept	0.843	3
5	Using databases, spreadsheets, graphics programs to analyze information	0.111	80.00%	0.648	0.856	0.992	0.832	Accept	0.832	6
6	Using others programs/technologies to analyze information	0.101	83.33%	0.664	0.864	1.000	0.843	Accept	0.843	3
7	Using technology to help students	0.113	76.67%	0.624	0.840	0.984	0.816	Accept	0.816	8
8	Share information (example: multimedia presentations using sound or	0.111	80.00%	0.648	0.856	0.992	0.832	Accept	0.832	6

The position of each element can be seen based on the defuzzification value in Table 3. Thus, the researcher looks at the defuzzification score value in the elements "use of technology or the internet for independent learning (such as videos, tutorials, self-taught websites)" and "selection of appropriate technological tools or sources suitable for completing the task" was ranked first with a defuzzification value of 0.869. Then there are three elements at the third level, namely "assessing the credibility and relevance of online resources", "using technology to analyze information (eg databases, spreadsheets, graphics programs, etc."), and "using technology to analyze information. Supports team collaboration (e.g. shared workspace, email exchange, giving and receiving

feedback, etc.)" with a defuzzification value of 0.843. The next element is the element "using technology to help students share information (for example, multimedia presentations using sound or video, software presentations, blogs, podcasts, etc.)" and "using technology to monitor assignments" with a defuzzification value of 0.832. Finally, the last element on the ladder is "using technology to interact directly with experts or members of the local community or global community" which is 0.816. If the position of each element is in order, then the findings of this research have answered the second research question, namely "based on the opinion of experts, what is the position of the elements needed to integrate technology as a forum for design thought-based learning.

Discussion

The findings in this research are in line with previous research that the use of Fuzzy Delphi has an influence on the use of technology. This research found the position of each element based on the agreement provided by the experts (Radbruch et al., 2020; Agha et al., 2020). The positions of the elements are as follows: 1) Using technology or the Internet for self-teaching (such as videos, tutorials, self-teaching websites), 2) Selecting the right technology tools or resources to complete the assignment, 3) Assessing the credibility and relevance of online resources , 4) Using technology to analyze information (e.g. databases, spreadsheets, graphics programs etc.), 5) Using technology to support teamwork (e.g. co-working spaces, email exchanges, giving and receiving feedback, etc.), 6) Use technology to help students share information (for example multimedia presentations using sound or video, software presentations, blogs, podcasts, etc.), 7) Use technology to monitor assignments, and 8) Utilize technology to interact directly with experts or members local/global community(Capson-Tojo et al., 2020; Kumar et al., 2021).

Based on the defuzzification score analysis carried out, the researchers saw two elements that had high defuzzification score values, namely first; using technology or the internet for self-teaching (such as videos, tutorials, self-teaching websites) and secondly; selecting appropriate tools or technology resources to complete tasks. According to researchers, the explosion of information technology means that teachers are now faced with students consisting of generations Y and Z who are generally digitally literate. As a result, this group has a more self-oriented learning style where smart students access online learning media that are more interesting and easier for them to understand and then make their own decisions about the appropriate technological devices to complete assignments well. With modern technology continuing to develop, it turns out that the skills needed by students in the 21st century are also different from those of previous generations. This is because the form of learning for 21st century students is more self-oriented by utilizing technology to work on projects more efficiently (Afanasyev et al., 2019; Dawood et al., 2021). The use of technology gives students the advantage to explore and create new experiences. The findings of this research support constructivism theory which uses existing and current knowledge to make deep connections to learning (Okonkwo & Ade-Ibijola, 2021). Elements that assess the credibility and relevance of online resources are in third place. This element is considered very important in the opinion of experts because in the era of modern technology, information can be conveyed and shared quickly. This information is obtained from various sources available on the internet. Therefore, researchers believe that emphasizing strategies and skills in finding, collecting, analyzing and evaluating information wisely are very important skills for students to obtain meaningful information that is authentic and appropriate to the desired context. This element is considered important because not all information displayed on the internet is true and students need to assess the credibility and validity of information obtained online before using it as a reference (Pal & Vanijja, 2020; Sailer et al., 2021). Elements that use technology to analyze information (e.g. databases, spreadsheets, graphics programs, etc.) are also in third place. These skills make design thought-based learning activities more competitive in an effort to increase student engagement in class. Previous study suggests that students consider several elements such as language, graphics and multimedia before analyzing information (Shin et al., 2020).

The element of using technology to support Teamwork (e.g. shared workspaces, email exchange, giving and receiving feedback, etc.) also takes third place with the two previously mentioned elements. Talking about teamwork, the collaboration aspect cannot be ignored. In design thinking when students interact with their peers, they not only practice social skills that can resolve conflicts or learn how to respect the rights of others and how to protect their own rights but also acquire advanced technical skills related to problem solving, design, and outcomes. According to researchers, teachers need to guide students in utilizing technology with a focus on cultivating students' skills, knowledge and attitudes for lifelong learning. Students need to be given the opportunity to utilize technology to support teamwork. This can be done through email exchanges, sharing information via Google Drive and so on. Furthermore, the element that is in sixth place is "the use of technology to help students share information (for example, multimedia presentations using sound or video, software presentations, blogs, podcasts, etc.)". This element is very important because according to previous study the main reason why design thought-based learning needs to be implemented in schools is because students need to know how to convey their ideas to others and explain the processes involved (Ghani et al., 2022). This is because students have problems presenting ideas in the assignments they do. The element “using technology to monitor tasks” also ranked sixth.

These skills are related to cognitive processes that provide students with the opportunity to build their own appropriate platforms for monitoring assignments effectively. The use of this technology is a sharing medium to improve communication with group members and with stakeholders in the design process (Behnamnia, Kamsin, Ismail, et al., 2020; Mitter et al., 2020; Pranckutė, 2021). Finally, the element of "using technology to interact directly with experts or members of the local/global community" is in last position. In 21st century learning, student collaboration with experts or with members of local and global communities is highly recommended. This directly gives students the opportunity to talk and make choices by utilizing technology. This knowledge element can improve students' metacognition as well as serve as a medium for sharing with stakeholders and group members involved in the design process (Tapingkae et al., 2020; Tuzun, 2020). Therefore, referring to expert assessments, technology plays an important role in design thinking-based learning patterns. Because obey, The most effective tool that can be provided in integrating technology is the ability to think creatively like a designer.

The implications of this research provide a complete picture of the benefits and how to use front elements in Fuzzy Delphi. The teachers have implemented eight 1) Using technology or the Internet for self-teaching (such as videos, tutorials, and self-teaching websites), 2) Selecting the right technology tools or resources to complete the assignment, 3) Assessing the credibility and relevance of online resources, 4) Using technology to analyze information (e.g. databases, spreadsheets, graphics programs, etc.), 5) Using technology to support teamwork (e.g. co-working spaces, email exchanges, giving and receiving feedback, etc.), 6) Use technology to help students share information (for example multimedia presentations using sound or video, software presentations, blogs, podcasts, etc.), 7) Use technology to monitor assignments, and 8) Utilize technology to interact directly with local experts or members /global community in the learning process. This research has several limitations. First, this research guides teachers on how technology can be used in designing thinking-based learning for students. The results would be different if this research targeted high school students, or students who are more experienced in using technology. Second, the number of respondents who participated was small. Therefore, it is recommended to conduct further research by repeating this research using more respondents who can determine the extent to which the findings can be generalized. Finally, this research is limited to learning based on design thinking only. Therefore, further research is needed to study other learning that uses the same technological context.

4. CONCLUSION

Research shows that technology is the most important tool in integrating design thinking-based learning, especially technology that can be used effectively. In addition, two elements located at the third and sixth levels indicate the need for students to master intermediate-level technological skills; using technology to analyze information (e.g. databases, spreadsheets, graphic programs; using technology to help students share information (e.g. multimedia presentations using sound or video, software presentations, blogs, audio broadcasts, etc.), while the teacher as a facilitator guides students to apply technology more complex learning in design thought-based learning. Therefore, teachers should develop students' technology skills by increasing the effectiveness of design thinking-based learning through intensive interaction to stimulate student involvement in using technology. This is because students who are weak in contemporary learning are unable to compete in digital learning due to not being able to master the basic skills and technology to manage today's world. Therefore, it is important for school curricula to equip students with skills that enable them to use technology routinely and educational policies need to develop measures to reduce new gaps in student learning. Thus, the elements provided in this research can be used as guidelines for teachers in utilizing technological aspects in education, specially design thought-based learning.

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