EVALUATION OF STEM MAKERSPACE WORKSHOP USING KIRKPATRICK'S MODEL

Penilaian Bengkel STEM Makerspace Menggunakan Model Kirkpatrick

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ABSTRACT

The integration of makerspace principles presents a promising avenue for educators to implement impactful STEM project-based learning initiatives. To this end, a three-day workshop entitled "Introductory STEM Makerspace Workshop – Learning Through Making" was conducted for lower secondary science teachers, with a particular focus on electric circuits. Throughout this workshop, educators were furnished with the basic knowledge and skills to facilitate maker-centered project-based learning experiences in science education. Furthermore, participants were challenged to conceptualise and develop lessons incorporating maker-centered learning in both classroom settings and extracurricular activities. This study evaluated the effectiveness of this workshop for 18 teachers employing three of the four levels of Kirkpatrick's Evaluation Model. At the first level, encompassing participants' reactions, data were collected through an online evaluation form and direct observation during the workshop sessions, revealing a predominantly positive response from the participants.. Subsequently, at the second level, which pertains to learning outcomes, participants' acquisition of skills was evaluated via examination of photographs and reflective submissions on Google Drive subsequent to each workshop session. Findings indicated that educators attained proficiency in fundamental tasks such as soldering, 3D printing design, and fabrication of basic electrical devices, exemplified through their application of parallel circuit concepts. As for the third level, concerning behavioural change, was assessed through voluntary feedback solicited from participants. Notably, four respondents reported implementing acquired knowledge and skills within their educational contexts at the time of data collection. Thus, this evaluation determines whether and to what extent the workshop's effectiveness is for the participants. Additionally, it aids in identifying strengths and shortcomings and serves as a decision-making tool for future improvements.

Keywords: STEM makerspace, teachers' training, evaluation, Kirkpatrick's Evaluation Model

ABSTRAK

Integrasi konsep 'makerspace' menawarkan satu cara untuk pendidik melaksanakan pembelajaran berasaskan projek STEM yang bermakna. Sehubungan itu, satu bengkel selama 3 hari bertajuk 'Introductory STEM Makerspace – Learning Through Making' telah dijalankan untuk guru sains menengah rendah yang memfokuskan kepada litar elektrik. Dalam bengkel ini, guru dilengkapkan dengan pengetahuan dan kemahiran untuk melaksanakan pembelajaran berasaskan projek dalam sains. Selain itu, guru merekabentuk dan menghasilkan pengajaran yang menggabungkan pembelajaran 'maker-centered' dalam dan luar bilik darjah. Kajian ini menilai keberkesanan bengkel *ini untuk 18 orang guru menggunakan tiga daripada empat tahap Model Penilaian Kirkpatrick. Bagi tahap satu, data reaksi peserta telah dikumpul melalui borang penilaian dalam talian dan pemerhatian semasa bengkel. Keputusan menunjukkan bahawa peserta memberikan reaksi positif untuk bengkel tersebut. Dalam tahap dua, pembelajaran peserta dinilai melalui foto dan refleksi yang dimuat naik dalam 'Google Drive' selepas setiap sesi. Mereka memperoleh kemahiran asas pematerian, reka bentuk percetakan 3D, dan membuat produk elektrik mudah dengan menggunakan konsep litar selari. Bagi tahap ketiga yang melibatkan perubahan tingkah laku, data dikumpul melalui maklum balas sukarela daripada peserta. Empat peserta telah memberikan maklum balas bagaimana mereka mengaplikasi pengetahuan dan kemahiran bengkel ini di sekolah pada masa penulisan. Justeru itu, penilaian ini dapat menentukan sejauh mana keberkesanan bengkel untuk para peserta. Selain itu, ia membantu dalam mengenal pasti kekuatan dan kekurangan serta membantu membuat keputusan untuk penambahbaikan untuk pelaksnanaan bengkel ini di masa depan.*

Kata Kunci: *STEM Makerspace, penilaian, latihan guru, Model Penilaian Kirkpatrick*

INTRODUCTION

In education, the quality of teaching is one of the crucial factors in improving students' achievement. As educators confront significant challenges in subject content changes, new instructional methods, advances in digital technology and students' learning needs, they must continually expand their knowledge and skills to implement the best educational practices (Mizell, 2014). To improve and update one's knowledge, skills and abilities for better performance, training and development are very important as they will enhance the overall effectiveness and performance of the organisation (Rafiq, 2015). Professional development in education refers to any formal and informal process that offers learning opportunities for teachers. It can be a course, conference, seminar, workshop, collaborative learning among teachers, or informal professional development such as discussion among colleagues, observations, self-reading, and research (Mizell, 2014).

Makerspace is often referred to as a physical place where people can create and co-create knowledge and physical or digital products (Martinez & Stager, 2019). It is a space with common resources that can be shared for projects of interest with the support of a maker community (Han et al., 2017; Oliver, 2016). Individuals may explore tools, materials, concepts, learning experiences and disciplines that they may not have experienced before as makerspaces provide multiple entry points into creating, combining disciplines that have been traditionally separated (Mersand, 2021). As people engage in various hands-on activities in makerspace, they develop problem-solving, critical thinking, and creativity (Kurti et al., 2014). It is also a place that supports technology innovation and entrepreneurship that prepares individuals to face new global challenges (Hatch, 2014).

However, in many cases, the idea of a physical makerspace is limited by physical resources of space, money and time. In reality, many makerspaces can often be exclusive places, predominantly occupied by the technically inclined and many not welcoming people unfamiliar with those kinds of environments or technologies. This also highlighted the unfolding questions of equity and inclusion in the 'maker movement' (Kim et al., 2018; Vossoughi et al., 2016). (Oliver, 2016b) argues that a makerspace is more about learning and activity than the physical space itself. It is about the making mindset applied to classrooms, homes or other places. The concept of a 'makerspace mindset' provides the potential for making and learning to grow creative, curious individuals through life-changing learning experience (Culpepper & Gauntlett, 2020). Therefore, the focus is not on converting a room into a designated makerspace but on a making environment that provides the potential for cross-curricular connections, collaboration, creativity, innovation, and learning (Martinez & Stager, 2019). Thus, makerspace can also be described as a making environment within the learning of science, mainly project-based learning, that integrates and connects relevant concepts and skills from other disciplines to promote meaningful learning, creativity, innovation and collaboration (Blackley et al., 2017). It can be a specialised STEM project-based learning as it allows cross-curricular connections, collaboration, innovation and creativity in solving real-world problems through the making environment. In short, integrating makerspace offers one way for educators to implement meaningful maker-centered project-based learning in science.

This study evaluated the effectiveness of this workshop for 18 teachers, which determines to what extent the workshop's effectiveness is for the participants. It aids in identifying strengths and shortcomings and serves as a decision-making tool for future improvements. Additionally, it justifies whether to continue or discontinue this training workshop in the future.

LITERATURE REVIEW

The evaluation of training is crucial as it can assist in identifying training needs, evaluating effectiveness, and figuring out whether the training has the intended impact. It helps to make data-driven decisions and serves as a guide to improve any future training programmes. There are several evaluation models for training or workshop programs that can help to assess the effectiveness of any training and workshop programs (Table 1). For example, Kirkpatrick's Four-Level Model (Kirkpatrick & Kirkpatrick, 2007), Phillips' ROI Model (Philips, 2003), Brinkerhoff's Success Case Method (Brinkerhoff, 2005) and Kaufman's Five Levels of Evaluation (Kaufman & Keller, 1994). However, there is no one-size-fits-all answer to which evaluation model is the best for evaluating training and workshops, as each model has its strengths and weaknesses. The choice of evaluation model for a training or workshop program depends on the specific goals and objectives of the program, as well as the resources, participants, and context of the training programme (Andales, 2024).

Table 1
Evaluation Models for Training or Workshop Programs

Training Evaluation Model	Description
Kirkpatrick's Four-Level Model (Kirkpatrick & Kirkpatrick, 2007)	Measures the impact of training at four levels: reaction, learning, behavior, and results.
Phillips' ROI Model (Philips, 2003)	Evaluates the return on investment (ROI) of a training program by measuring the monetary benefits and comparing them to the cost of the program
Brinkerhoff's Success Case Method (Brinkerhoff, 2005)	Focuses on identifying successful outcomes and analysing the factors that led to those outcomes. It helps to identify the factors that can be replicated in future training programs. It is more suitable for evaluating programs that involve a small group of highly skilled participants
Kaufman's Five Levels of Evaluation (Kaufman & Keller, 1994)	Assesses the effectiveness of training programs at five levels: inputs, reaction, learning, behavior, and results. It emphasises the importance of evaluating the inputs and resources required for a training program

Kirkpatrick's evaluation model, developed in 1959, is an approach to evaluating the effectiveness of training in an organisation. It delineates four training outcome levels: reaction, learning, behaviour and results (Kirkpatrick & Kirkpatrick, 2006; Nawaz et al., 1982). The levels are in sequence that progress in difficulty in the evaluation process. The first level measures how participants react to the training program, which implies their overall satisfaction with it. In practice, it assesses the participants' affective response to the implementation quality and the relevance of the training through surveys, interviews or observations (Andales, 2024; Dewi & Kartowagiran, 2018; Farjad, 2012).

The second level is learning, which can be characterised as the degree to which participants' attitudes, knowledge, and/or abilities change due to attending the training session (Kirkpatrick & Kirkpatrick, 2006). It can be quantifiable evidence of the learning that has taken place during the training, such as quizzes, tests and examinations (Bates, 2004; Dewi & Kartowagiran, 2018). The level of behaviour measures the extent to which the participants' behaviour changed due to the training program (Kirkpatrick & Kirkpatrick, 2006). This evaluation takes place after the training workshop in the participants' workplace and requires time to gather the data from the participants (Rafiq, 2015). The fourth level is the result which refers to the outcomes of the participants attending the training program (Kirkpatrick & Kirkpatrick, 2006). For instance, increased production, improved quality, cost reduction, sales increase and higher profits. In education training, it can also refer to the students' outcomes in the formative and summative assessments. This stage may require a longer time of 6 months or 1 year to obtain the evaluation data (Rafiq, 2015).

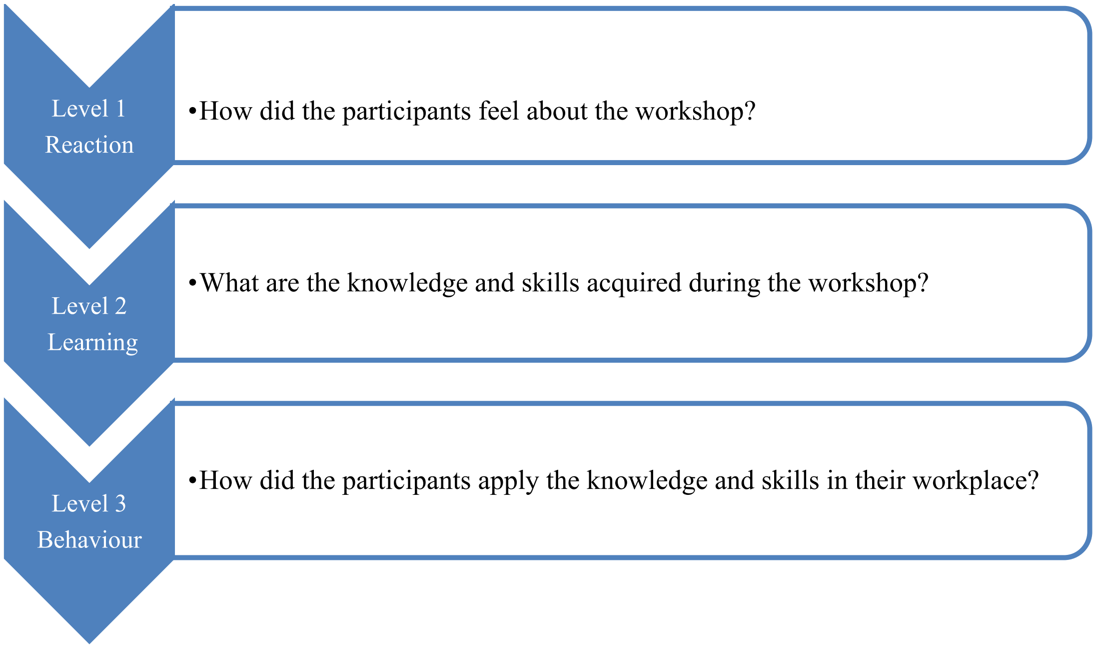
Figure 1
Kirkpatrick's Evaluation Model

In many organisations, the Kirkpatrick model has been the main underpinning for training evaluations (eg. (Dewi & Kartowagiran, 2018; Farjad, 2012; Rafiq, 2015). It is a systematic way of evaluating training and addressing the needs of the participants. The model simplifies the complex training evaluation process and presents a straightforward guide about the questions that should be asked for each level. The outcome data for the four levels are generally collected upon the completion of the training. Thus, pre-training performance measures are not essential for determining training effectiveness. Instead, it is solely based on outcome measures that reduce the number of variables with which evaluators need to be concerned (Bates, 2004).

On the other hand, Cahapay (2021) also highlighted a few of the model limitations. This model may present an oversimplified view of training evaluation that does not consider the contextual or individual influences in the evaluation process. Factors such as the organisation's work culture, goals, values, interpersonal support for skill acquisition and behaviour change in the workplace, and the availability of material and resources may influence the training process and outcomes. Secondly, Kirkpatrick's model seems to indicate that the levels of evaluation have a direct causal relationship with each other. For example, for learning to occur, there must be positive reactions. However, Kirkpatrick and Kirkpatrick (2006) mentioned that positive reactions might not guarantee learning, but negative reactions are indications that individuals are not motivated to learn. Despite the limitations, this study will utilise Kirkpatrick's model as a guide to evaluate the effectiveness of the training workshop. This is because it describes the characteristics of each level and provides systematic tools and methods to evaluate the training programme's impact. However, only 3 levels of the model will be utilised. The fourth level which is result, is not reported in this study as the data has not been obtained at the time of writing. Specifically, it will answer these few research questions:

1. Reaction: How did the participants feel about the workshop?
2. Learning: What are the knowledge and skills acquired during the workshop?
3. Behaviour: How did the participants apply the knowledge, skills and attitude in their workplace?

Figure 2
Research Questions According to the Four Levels of Kirkpatrick's Evaluation Model

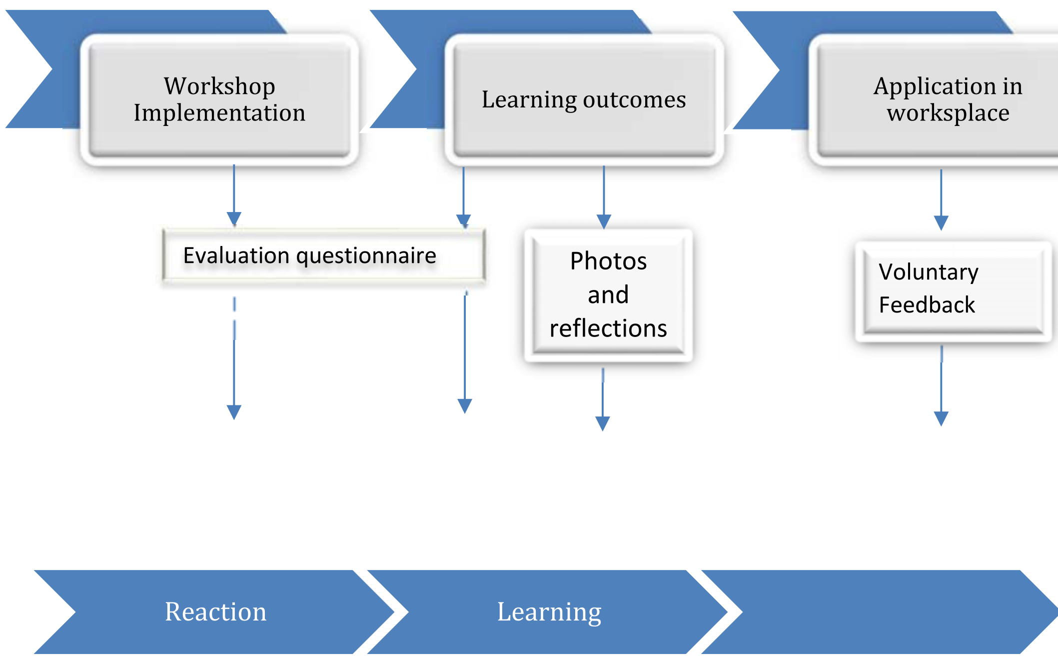


METHODOLOGY

This study is an applied research project aimed at evaluating the effectiveness STEM makerspace workshop using Kirkpatrick's model. It was a 3-day workshop entitled Introductory STEM Makerspace Workshop – Learning Through Making, a professional development workshop whereby teachers were equipped with knowledge and skills to carry out maker-centred project-based learning in science. Besides, teachers were challenged to design and produce lessons incorporating maker-centred learning in the classroom or after-school activities. The 3-days workshop aimed to help teachers better understand blending maker- centered projects into the science classroom or extracurricular activities. Teachers also acquired basic skills in some maker activities related to science learning to enhance the implementation of project-based learning with the students. Among some skills were soldering, connecting simple electric circuits and introduction to 3D printing. Lastly, teachers will design and plan a science project-based learning lesson based on a selected maker activity.

Data were collected using a combination post-workshop surveys, observations and document reviews. There were 18 participants comprising a mixture of secondary and primary science teachers and officers from the education department from a few districts. Participation in this workshop is upon the interest and willingness of the participants to respond to the promotional brochure on social media and invitation letters through the State Education Department. There were seven sessions in the workshop that aimed to equip teachers with basic knowledge and skills to carry out maker-centred project-based learning in science. Each participant was assigned to a folder in the Google Drive with all the session notes, allowing them to add notes, photos and reflections. The data for the evaluation of this workshop were mainly from the photos and reflective notes from the participant's assigned folder and the workshop evaluation form. There are 25 items in the workshop evaluation form, rated using the five-point Likert type response, namely 1 = strongly disagree, 2 = disagree, 3 = not sure, 4 = agree and 5 strongly agree. Apart from that, there are three open-ended questions in the evaluation form. The questionnaire was converted into Google From and disseminated at the end of the 3rd day through a link posted through the Group Whatsapp. 16 out of 18 participants filled in the evaluation form. Figure 3 summarises the data collection process in relation to the Kirkpatrick's evaluation model.

Figure 3
Summary of Data Collection Process in Relation to the Kirkpatrick's Evaluation Model



FINDINGS

The presentation of findings will be categorised by the research questions related to the first three levels of Kirkpatrick's evaluation model.

Level 1: How did the participants feel about the workshop?

All the participants agreed that they enjoyed the making process during the workshop. Item 23 "I enjoyed the making process" scored a mean of 4.93 which is the highest among the 25 items. 15 out of the 16 responses strongly agreed with the statement.   There were also comments in the open-ended questions that reflect the positive reactions of the participants:

- *Its perfect for a beginner course*
- *The content of the workshop is clear, and it is applicable. Everything is well-organised. Good job for the team.*
- *All are good and comfortable.*
- *I am happy with the organising of this workshop.*
- *A great workshop! Beneficial to all of us.*
- *Congrats to the whole team. It was fun and I learned a lot. Looking forward to joining more of your programmes.*

Level 2: What are the knowledge and skills acquired during the workshop?

All the participants learned what was intended to be learned as listed in the objectives of each session. This is indicated by the agreement of the items in the questionnaire that relate to the objectives of the sessions. This was also supported by the observatory notes by the researcher, reflective notes and photographs of the output of each participant were recorded in the designated Google Doc. The data are summarised and presented in Table 2.

Table 2

Data Summary From the Output of the Workshop

Session	Objectives	Items in the questionnaire	Output
Introduction to Makerspace Maker-centered project-based learning	Gain better insight into makerspace and maker-centred project-based learning in Science and Mathematics education	Item 1: I understand what is a makerspace. Item 2: I understand the characteristics of maker-centered project-based learning.	The participants shared some feedback on how to implement maker-centred learning in their classroom through the Google Doc
Soldering Skill	To gain more insights about soldering To acquire basic skills in soldering	Item 3: I understand the basic steps in soldering. Item 4: I acquired skills in soldering	1. All the participants could solder the LEDs on the PCB successfully at a different paces. 2. All the participants could join 2 wires through soldering and cover the exposed joint with a heat shrink tube.
Design and produce a simple, functional electrical product	Design and produce a simple, functional electrical product by applying the concept of the parallel circuit and using recycled material	Item 5: I am able to design and produce a simple electrical product.	All the participants could produce a simple electrical product by applying the parallel circuit and using the available recycled material. They were given the choice of doing it in a group or individually. 6 participants did it individually and the rest did it in groups. There were a total of 5 group projects and 5 individual projects.
Introduction to 3D printing	1. Gain an understanding of the basics of 3D printing 2. learn the basic steps in 3D printing	Item 6: I understand the basic steps in 3D printing. Item 7: I know how to download the available online designs for 3D printing.	All the participants were able to download the existing 3D design from one website (Thingiverse) and slice the 3D design using Ultimaker Cura and understand some of the vital information The screenshots were pasted into the Google Doc
Designing and 3D printing	Design and produce a 3D-printed item	Item 8: I know how to design simple objects for 3D printing through Tinkercad	All the participants were able to design a personalised 3D design of a key tag using Tinkercad All the designs were printed in stages using the Creality Ender 3 printer
3D printing and electric circuit	Produce a functional electrical product from 3D-printed designs		All the participants could assemble a simple circuit into a 3D-printed tea light casing
Integrating maker-centered	Design a maker-centered project-based learning lesson	Item 9: I know how to integrate a maker-centered	• One group presented their comprehensive action plan on

learning to enhance the learning of science	plan or action plan in the classroom learning or as after-school/ co-curricular activities	project-based learning into a science lesson. Item 10: I know how to integrate a maker-centered project as extracurricular activity.	incorporating makers activities in their school STEAM festival. • Two groups of teachers presented lesson plans on maker-centered activities in science respectively (a)Making organic enzymes from fruit and vegetable waste (b)STEM challenge to produce a prototype boat that propels using elastics (potential energy) • One group presented a proposal of their plans for their district • One group shared their ideas on the application of maker activities in their upcoming projects

All the participants have acquired new knowledge about the concept of makerspace, 3D printing and basic electrical projects. They also acquired useful skills in soldering and 3D designs using Tinkercad. For example, for the 2 hours of basic soldering skills, the objectives are for the participants to gain more insights and acquire basic soldering skills. All of them agreed that they understood the basic steps (item 3) and acquired the skills in soldering (item 4) as indicated in the survey in Appendix 1. During the hands-on session, all the participants could successfully solder the PCB LEDs at a different pace. Besides, they could join 2 wires through soldering and cover the exposed joint with a heat shrink tube. Some of their output is presented in Appendix 2. In their reflection, some mentioned that it was their first time doing soldering and was an eye-opening experience for them. Some mentioned shaky hands, and some fears, but were able to overcome them.

Participant H: *This is my first experience with soldering. Great experience.*

Participant I: *Today is my first time soldering. It trains me to be meticulous and focused on my task.*

Participant K: *It was messy at first. Hands were shaky, the solder didn't stick to the circuit. However, after a while, I got the hang of it and my soldering became better and neater.*

On the other hand, there is another group of participants who had experience in soldering through the Living Skill subject during secondary school but admitted they have not put it into practice for a long time. This group of participants seem to be able to pick the skill very fast and their soldering output was clean and neat. It was their first time doing the soldering. The excerpt of their reflection is as below:

Participant P: *It has been so long since I did soldering. I think the last time I did this was in secondary school for Kemahiran Hidup. I enjoyed doing it today even though it looks a bit messy.*

Participant Q: *I used to do soldering during my degree time. So, this is my second time doing soldering since 6 years ago. Excited and enjoy the moments here.*

Most importantly, participants were guided to integrate the newly acquired knowledge and skills into their classrooms and schools. They developed and presented detailed plans for incorporating maker-centered learning approaches, which are designed to foster hands-on, experiential learning in science education. These plans highlighted creative and practical strategies for engaging students in the learning process through activities that promote critical thinking, problem-solving, and collaboration based on their respective school context. The participants' enthusiasm and innovative ideas demonstrate a significant potential for transforming traditional science teaching methods and inspiring a more dynamic and interactive learning environment. The promising outcomes of these presentations suggest that maker-centered learning could play a pivotal role in enhancing science education and motivating students to develop a deeper interest in scientific inquiry.

Level 3: How did the participants apply the knowledge and skills in their workplace?

The data for this level was collected through voluntary participant feedback and communication after a few months. While only four teachers out of a workshop with 18 participants voluntarily provided feedback and participated in communication channels after a few months, this limited response may be due to their willingness, busy schedules and unclear expectations for post-workshop engagement. Table 3 summarises the application of the knowledge and skills of participants in their workplace.

Table 3
Summary of Application of Knowledge and Skills of Participants in Their Workplace

Participant	The period after the workshop	Application of knowledge and skills
B	1 month	- Purchased a personal 3D printer to explore and self learning - Promote the usage of the existing 3D printer in the school for the students - Printed exhibition artefact for the school open-day - Trained students in the STEM club to print exhibition items - Trained students to design customised items to be printed and sell to raise funds for the STEM club . The fund is to purchase another set of 3D printer for the club. - (Participant B's output is showcased in Figure 1 Appendix 3)
C	3 months	- Worked together with participant B in exploring and self learning about 3D printing - Designed and printed a simple tool to examine the properties of ray for Year 5 Science (Figure 2 Appendix 3)
P	6 months	- Conducted simple electrical project with her students in the classroom (Figure 3 Appendix 3) - Coordinator of STEAM movement in her school- a maker initiative of the school that launched 6 months after the workshop -
D	4 months	Coordinated STEM exhibition in the school that encouraged students participation in innovative science projects

The table showcases how participants from the workshop applied their knowledge and skills after the program. Participant B stands out for his enthusiasm, going above and beyond by investing by purchasing a personal 3D printer for further exploration. He also promoted the use of the existing school printer and integrating it into student projects, training them to design and print items for exhibitions and fundraising, demonstrating the technology's potential. Participant C collaborated with Participant B in self-directed learning and even designed a tool for science lessons (Figure 2 in Appendix 3). Participant P, after six months, incorporated a simple electrical project using 3D-printed elements into her classroom activities (Figure 3 in Appendix 3). Notably, she also became the coordinator of her school's STEAM movement, a maker initiative launched shortly after the workshop. This suggests a potential wider impact on the school's approach to learning. Participant D, within four months, organised a STEM exhibition, encouraging student participation in innovative science projects. While the specific use of 3D printing isn't mentioned, this initiative aligns with the workshop's goals of promoting STEM education. Overall, these post-workshop activities showcase the positive impact the program had on these participants, inspiring further learning, integration into teaching practices, and potentially influencing broader school-wide initiatives.

DISCUSSION

The workshop evaluation indicated positive participant reactions, reflected in their written comments and enjoyment of the training. Their positive affective response to the relevance of the training was reflected in their written comments and reflections. It's important to note that while positive reactions can be an indication of engagement and motivation to learn, they don't necessarily guarantee learning outcomes (Kirkpatrick & Kirkpatrick, 2006). Participants can enjoy a workshop and feel positive about it without actually retaining the information or applying it in their lives or work. On the other hand, negative reactions to a training session can indicate that participants are not engaged or motivated to learn (Zhuang et al., 2017). If participants are not interested in the content, they may not pay attention, which can hinder their ability to learn and retain information. Overall, it's important to consider both positive and negative reactions when evaluating the effectiveness of a training program. While positive reactions are encouraging, it's important also to assess whether participants have learned and applied the information in their lives or work. Therefore, it is crucial to consider the subsequent levels in the Kirkpatrick model in evaluating the impact of any training

This study effectively assessed learning at the Kirkpatrick model's second level, focusing on knowledge and skill acquisition. This evaluation level helps determine whether the training program has achieved its intended learning objectives (Kirkpatrick & Kirkpatrick, 2006). Both questionnaire and qualitative data were used to assess participants' learning. The qualitative findings revealed that all the participants have acquired new knowledge about the concept of makerspace, 3D printing and basic electrical projects. They also acquired useful skills in soldering and 3D designs using Tinkercad. Prior research has predominantly employed quantifiable assessments, such as quizzes and examinations, to evaluate learning outcomes following a training (Dewi & Kartowagiran, 2018).

In contrast, this workshop utilised performance tasks that required participants to actively demonstrate their acquired knowledge and skills by completing designated tasks after each session. The photos of the completed task and written reflections were uploaded in the Google Doc. Unlike traditional tests, which often only measure a participant's ability to recall information, performance tasks require them to apply their knowledge and skills to solve problems or complete tasks that are similar to what they would encounter in real life (Stobart & Gipps, 2010). Participants used critical thinking, problem-solving, creativity, and communication skills to complete the tasks successfully. Participants may also have to work collaboratively with others, which is a platform for developing teamwork and collaboration skills. Therefore, performance tasks provide a more authentic and meaningful way to assess participants' learning. However, implementing performance tasks posed challenges such as data management and time consumption. The use of Google Docs for each participant to upload their photos and reflection after each session resulted in large amount of qualitative data that need to be analysed manually. It was a time-consuming process as compared to the traditional pen and paper tests.

The study aimed to assess the third Kirkpatrick level (behaviour change) but faced limitations. Shen et al. (2017) emphasise the importance of evaluating knowledge transfer to the workplace. Here, only four participants reported applying their learning to improve student learning. This limited response highlights the complexity of measuring behavior change, as noted by Waruwu (2021). External factors like school culture, leadership support, and individual motivation (Bell et al., 2017) significantly impact teachers' ability to implement new practices. Schools with supportive leadership and resources for STEM makerspace activities, as reported by some participants, can facilitate successful knowledge transfer. These factors align with best practices for evaluating training effectiveness at the behavior level.

There is a gap between level 2 and level 3 which may imply the ineffectiveness of this workshop. Thus, for future evaluation studies, some recommendations can be made to improve the evaluation further and of any training or workshop.

1. To use a more comprehensive survey to assess the reaction of the participants in the implementation of the workshop
2. Implement the use of a rubric to assess the output of the performance tasks for each session for systematic analysis.
3. To follow up systematically through e-portfolios from the participants on how the participants applied their knowledge and skills in their workplace

Future workshops could address limitations in assessing behaviour change by employing structured follow-up methods and exploring preferred communication channels for teachers. Collaboration with schools could also encourage a supportive environment that promotes learning practices. By addressing these aspects, future workshops can achieve a more holistic evaluation of their effectiveness.

A notable limitation of this research lies in the absence of traditional methods for establishing data reliability and validity commonly employed in basic research. Practical contextual constraints impeded a formal assessment of reliability and content validity. This evaluation study faced complexities in controlling variables to ensure reliability and validity as it was conducted in a real-world setting, unlike the controlled conditions of basic research. The presence of numerous confounding variables in natural environments can affect data integrity. Furthermore, the primary objective of this study was to provide immediate insights into strengths and shortcomings, serving as a decision-making tool for future improvements. This pragmatic focus often requires a balance between rigorous psychometric testing and the practical application of findings.

Nonetheless, practical measures were implemented to ensure data credibility. Multiple data sources, such as surveys, observations, and document analysis, were utilised to corroborate findings and enhance result credibility. Detailed documentation was maintained, with participants providing thorough reflections and photographs after each session, uploaded to a shared Google Drive folder. These self-reported data ensured consistency and transparency throughout the study.

CONCLUSION

This workshop assessed participant reactions and learning outcomes using traditional and innovative methods. Future studies should aim to incorporate more rigorous methods for assessing reliability and validity, even within real-world settings. This could involve employing mixed-methods approaches to triangulate data further, using longitudinal designs to track changes over time, and integrating advanced statistical techniques to control for confounding variables. Additionally, future research could explore the development of adaptable frameworks that balance the need for immediate practical application with the rigour of psychometric evaluation. This would enhance the robustness and applicability of findings, ultimately contributing to more effective decision-making and continuous improvement in educational practices.

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REFERENCES

Andales, J. (2024). *Training Evaluation_ Benefits & Process _ SafetyCulture*. Safety Culture. https://safetyculture.com/topics/training-evaluation/

Bates, R. (2004). A critical analysis of evaluation practice: The Kirkpatrick model and the principle of beneficence. *Evaluation and Program Planning*, *27*(3), 341–347. https://doi.org/10.1016/j.evalprogplan.2004.04.011

Bell, B. S., Tannenbaum, S. I., Kevin Ford, J., Noe, R. A., & Kraiger, K. (2017). 100 years of training and development research: What we know and where we should go. *Journal of Applied Psychology*, *102*(3), 305–323. https://doi.org/10.1037/apl0000142

Blackley, S., Sheffield, R., Maynard, N., Koul, R., & Walker, R. (2017). Makerspace and reflective practice: Advancing pre-service teachers in STEM education. *Australian Journal of Teacher Education*, *42*(3), 22–37. https://doi.org/10.14221/ajte.2017v42n3.2

Brinkerhoff, R. O. (2005). The Success Case Method: A Strategic Evaluation Approach to Increasing the Value and Effect of Training. *Advances in Developing Human Resources*, *7*(1), 86–101. https://doi.org/10.1177/1523422304272172

Cahapay, M. (2021). Kirkpatrick Model: Its Limitations as Used in Higher Education Evaluation. *International Journal of Assessment Tools in Education*, *8*(1), 135–144. https://doi.org/10.21449/ijate.856143

Culpepper, M. K., & Gauntlett, D. (2020). Making and learning together: Where the makerspace mindset meets platforms for creativity. *Global Studies of Childhood*, *10*(3), 264–274. https://doi.org/10.1177/2043610620941868

Dewi, L. R., & Kartowagiran, B. (2018). An evaluation of internship program by using Kirkpatrick evaluation model. *Research and Evaluation in Education*, *4*(2), 155–163. https://doi.org/10.21831/reid.v4i2.22495

Farjad, S. (2012). The Evaluation Effectiveness of Training Courses in University by Kirkpatrick Model (Case Study: Islamshahr University). *Procedia - Social and Behavioral Sciences*, *46*, 2837–2841. https://doi.org/10.1016/j.sbspro.2012.05.573

Han, S. Y., Yoo, J., Zo, H., & Ciganek, A. P. (2017). Understanding makerspace continuance: A self-determination perspective. *Telematics and Informatics*, *34*(4), 184–195. https://doi.org/10.1016/j.tele.2017.02.003

Hatch, M. (2014). The Maker Movement Manifesto. In *The Maker Movement Manifesto*. McGraw Hill Education.

Kaufman, R., & Keller, J. M. (1994). Levels of evaluation: Beyond Kirkpatrick. *Human Resource Development Quarterly*, *5*(4), 371–380. https://doi.org/10.1002/hrdq.3920050408

Kim, Y. E., Edouard, K., Alderfer, K., & Smith, B. K. (2018). *MAKING CULTURE: A National Study of Education Makerspaces*. https://www.researchgate.net/publication/336530623_Making_Culture_A_National_Study_of_Education_Makerspaces

Kirkpatrick, D., & Kirkpatrick, J. D. (2006). *Evaluating Training Programs* (3rd ed.). Berrett-Koehler Publishers, Inc.

Kirkpatrick, D., & Kirkpatrick, J. D. (2007). *Implementing The Four Levels. A Practical Guide for Effective Evaluation of Training Programs*. Berrett-Koehler Publishers, Inc.

Kurti, R. S., Kurti, D. L., & Fleming, L. (2014). The Philosophy of Educational Makerspaces. *Teacher Librarian*, 8–11.

Martinez, S. L., & Stager, G. (2019). *Invent To Learn. Making, Tinkering, and Engineering in the Classroom*. Constructing Modern Knowledge Press.

Mersand, S. (2021). The State of Makerspace Research: a Review of the Literature. *TechTrends*, *65*(2), 174–186. https://doi.org/10.1007/s11528-020-00566-5

Mizell, H. (2014). Why Professional Development Matters. *Journal of Contemporary Criminal Justice*, *30*(4), 360–361. https://doi.org/10.1177/1043986214541602

Nawaz, F., Ahmad, W., Khushnood, M., & Ahmed, W. (1982). *Kirkpatrick Model and Training Effectiveness: A Meta-Analysis 1982 To 2021*. https://doi.org/10.22547/BER/14.2.2

Oliver, K. M. (2016a). Professional Development Considerations for Makerspace Leaders, Part One: Addressing "What?" and "Why?" *TechTrends*, *60*(2), 160–166. https://doi.org/10.1007/s11528-016-0028-5

Oliver, K. M. (2016b). Professional Development Considerations for Makerspace Leaders, Part Two: Addressing "How?" *TechTrends*, *60*(3), 211–217. https://doi.org/10.1007/s11528-016-0050-7

Philips, J. J. (2003). *Return on Investment in Training and Performance Improvement Programs* (2nd ed.). Routledge. https://doi.org/https://doi.org/10.4324/9780080516257

Rafiq, M. (2015). *Training Evaluation in an Organization using Kirkpatrick Model : A Case Study of PIA Journal of Entrepreneurship & Organization Management*, *4*(3), 152-162. https://doi.org/10.4172/2169-026X.10001

Shen, N., Yufe, S., Saadatfard, O., Sockalingam, S., & Wiljer, D. (2017). Rebooting Kirkpatrick: integrating information system theory into the evaluation of web-based continuing professional development interventions for interprofessional education. *The Journal of Continuing Education in the Health Professions*, *37*(2), 137–146. https://doi.org/https://doi.org/10.1097/CEH.0000000000000154

Stobart, G., & Gipps, C. (2010). Alternative assessment. *International Encyclopedia of Education*, 202–208. https://doi.org/10.1016/B978-0-08-044894-7.00307-9

Vossoughi, S., Hooper, P. K., & Escudé, M. (2016). Making through the lens of culture and power: Toward transformative visions for educational equity. *Harvard Educational Review*, *86*(2), 206–232. https://doi.org/10.17763/0017-8055.86.2.206

Waruwu, M. (2021). Evaluation of the online mode-based the candidate of headmaster training program by using the Kirkpatrick Evaluation Model. *Jurnal Pendidikan Dan Pengajaran*, *54*(3). https://doi.org/10.23887/jpp.v54i3.35482

Zhuang, Y., Feng, W., & Liao, Y. (2017). Want more? Learn less: Motivation affects adolescents learning from negative feedback. *Frontiers in Psychology*, *8*, 76. https://doi.org/https://doi.org/10.3389/fpsyg.2017.00076

Appendix 1

Analysis of the items in the questionnaire

No	Items	Average
1	I understand what is a makerspace.	4.75
2	I understand the characteristics of maker-centered project-based learning.	4.88
3	I understand the basic steps in soldering.	4.88
4	I acquired the skills in soldering	4.56
5	I am able to design and produce a simple electrical product.	4.5
6	I understand the basic steps in 3D printing.	4.56
7	I know how to download the available online designs for 3D printing.	4.81
8	I know how to design simple objects for 3D printing through Tinkercad	4.69
9	I know how to integrate a maker-centered project-based learning into a science lesson.	4.44
10	I know how to integrate a maker-centered project as extra curricular activities.	4.56
11	During the making process, I face problems	4
12	During the making process, I did my research to understand and solve the problem.	4.19
13	During the making process, I collaborated with others to solve the problem.	4.5
14	During the making process, I think creatively to develop my product	4.56
15	During the making process, I applied the engineering design process	4.25
16	During the making process, I applied of Science and/or Mathematics concepts	4.5
17	During the making process, I learned new Science and/or Mathematics concepts .	4.31
18	During the making process, I was able to work in a team.	4.63
19	During the making process, I was able to act as a lead	4.06
20	During the making process, I was able to help others	4.63
21	I presented my product.	4.81
22	I managed to complete all the required products for the workshop.	4.88
23	I enjoyed the making process.	4.94
24	I have confidence in making process.	4.75
25	I need more time to tinker and complete my project.	4.19

Appendix 2

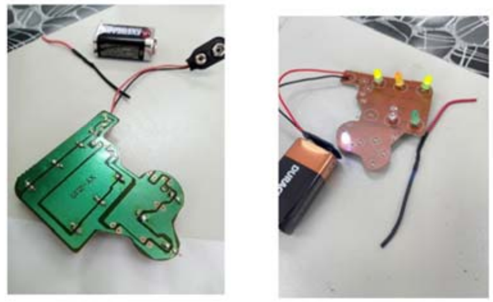


Figure 1: Hands-on soldering practice during the workshop and soldered products by the participants

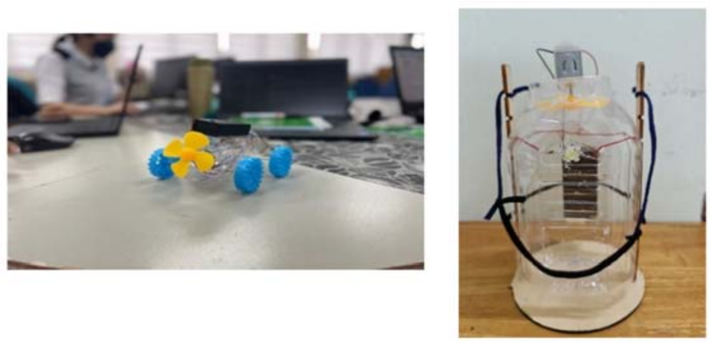
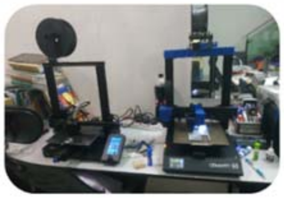


Figure 2: Hands-on makers' activity - designing and producing an electrical product applying the parallel circuit from recycled material

Figure 3: Samples of participants' 3D designs and printed product and 3D Printing demonstration

Appendix 3



Participant B purchased a personal 3D printer at home

Printed a set of rockets for the school open day exhibition

Incorporated LED lights in the 3D printed model

Printed a set of rockets for the school open day exhibition

Printed figurine for school exhibition

Printed figurines for school exhibitoin

Figure 4: Output from Participant B

Participant C designed and printed a simple ray diagram tool

Using the tool to study the light reflection

Figure 5: Output from participant C

Sample of participant C's primary student science project

Sample of participant C's primary student science project

Sample of participant C's primary student science project

Launching of the "STEAM Engine" in the school

Diagram 3: Output of Participant P