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Building a Positive Future for Science Education through Teacher-Researcher Partnerships

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Abstract. As a science education researcher and the director of a large online science education resource – The New Zealand Science Learning Hub – I am really interested in the intersection between science education research and practice. I often find myself wondering how teachers and researchers can be supported to work together to think about, and shape, the future of science education. In this paper, I draw on examples from two projects to showcase the benefits that can arise when teachers and researchers work proactively together, and to demonstrate opportunities for extending impact in the digital age. My hope is to inspire all of us to seek out opportunities to collaborate and learn together to enhance the science education experiences of learners in our early childhood centres, schools, tertiary institutions, and informal learning settings. This paper was first presented as a keynote address at ISET (International conference for science educators and teachers) 2023 in Phuket, Thailand.

Keywords: Curriculum resources, research-practice nexus, teacher-Researcher Partnership

INTRODUCTION

There are likely to be many reasons why some science educators pursue science education research – an innate curiosity, a desire to enhance their own practice, the social mobility of a higher (research) degree, the appeal of an academic career, serendipity and ‘falling into’ academia, a drive to make a difference beyond the walls of their own classroom. In coming to this paper, I invite readers to consider their own motivations and goals, and how these motivations and goals influence their research programs.

My own research trajectory has been significantly shaped by my role leading the ongoing development of a large online resource based in New Zealand – The Science Learning Hub | Pokapū Akoranga Pūtaiao (sciencelearn.org.nz). As a result, I am particularly interested in curriculum ergonomics (Chopin et al., 2018) and teacher-researcher partnerships (Coburn & Penuel, 2016).

The theme of the ISET 2023 conference was Science Education 2030 – Need for new solutions in a rapidly changing world: Rethinking our future together. Collaboration is centrally positioned in this: it’s a call for us to rethink our future together. This inspired me to think about the important role of collaborating as we conceptualise and undertake science education research that will lead to new solutions. Below, I share examples from my own work by way of demonstrating the value of teacher-researcher partnerships for science education research that positively impacted on practice.

ON 2 SCIENCE: MULTIPLE AFFORDANCES FOR LEARNING THROUGH ONLINE CITIZEN SCIENCE

The first project that I would like to use to exemplify an effective teacher-research partnership is a three-year project funded by the Teaching and Learning Research Initiative (TLRI) of New Zealand's Ministry of Education. The TLRI is one of New Zealand's few funds for 'blue skies' education research, and it is highly competitive. The primary objective of the TLRI fund is "to enhance the links between educational research and teaching practices to improve outcomes for learners" (TLRI, n.d.). In other words, teacher-researcher partnerships are central of successful proposals. Additionally, there needs to be a focus on the individuals in the team using their collective expertise, and on all team members having the opportunity to learn from each other.

Forming a teacher-researcher partnership

The project On2Science: Multiple affordances for learning through online citizen science was funded from 2020-2023 and extended an earlier pilot project, funded in 2018 by the TLRI: Citizen scientists in the classroom: Investigating the role of online citizen science in primary school science education. Across both projects, we investigated the affordances of online citizen science projects to enhance science teaching and learning.

Consistent with the intention of the TLRI funding, the research questions, methodologies, and findings were co-constructed across the project team – but first, a team needed to be established. In our case, the story begins with a researcher in computer science, Dr Markus Luczak-Roesch being curious about possible partnerships with education researchers. After contacting and meeting science education researcher Dr Dayle Anderson, the two brought in two others to help identify possible inter-disciplinary research projects: information systems researcher Dr Cathal Doyle and science education researcher Dr Azra Moeed, all at Victoria University of Wellington. This group of four then brought in four primary school teachers from four different primary schools, two research assistants, and two project advisors (of which I was one), and together the group co-constructed the first of the TLRI research projects - Citizen scientists in the classroom.

Citizen science projects invite volunteers to contribute to science projects, for example, by collecting data and/or analyzing data. Online citizen science (OCS) projects were defined as

> … an extension of citizen science, where the tasks to be completed are aided, or completely mediated, through the Internet. Engagement can occur in different ways such as providing larger datasets to be analysed; making tools available to support engagement from citizen scientists that are geographically distributed; enabling new ways of communication between citizen scientists; and providing a wider reach to a broader audience of potential participants.

This research was embedded within a Communities of Practice (CoP) model (Townley, 2020) and our research design was guided by an interpretivist research paradigm (Norwich, 2020). The four teacher-researchers chose the OCS project they would use and co-designed their classroom plans with the wider team. Each unit was implemented in the teacher's classroom, making up individual case studies. Research data included a combination of teacher-researchers' planning documents; teachers' verbal reports at project team meetings; teachers' pre- and post-intervention questionnaires; classroom observation notes by researchers and research assistants; copies of student work; focus group discussions with students; and student questionnaires. Case studies were co-constructed, with cross-case analysis illuminating both common and unique aspects across the cases (see Doyle et al., 2019). The different contributions across the research collaboration are outlined in Figure 1.

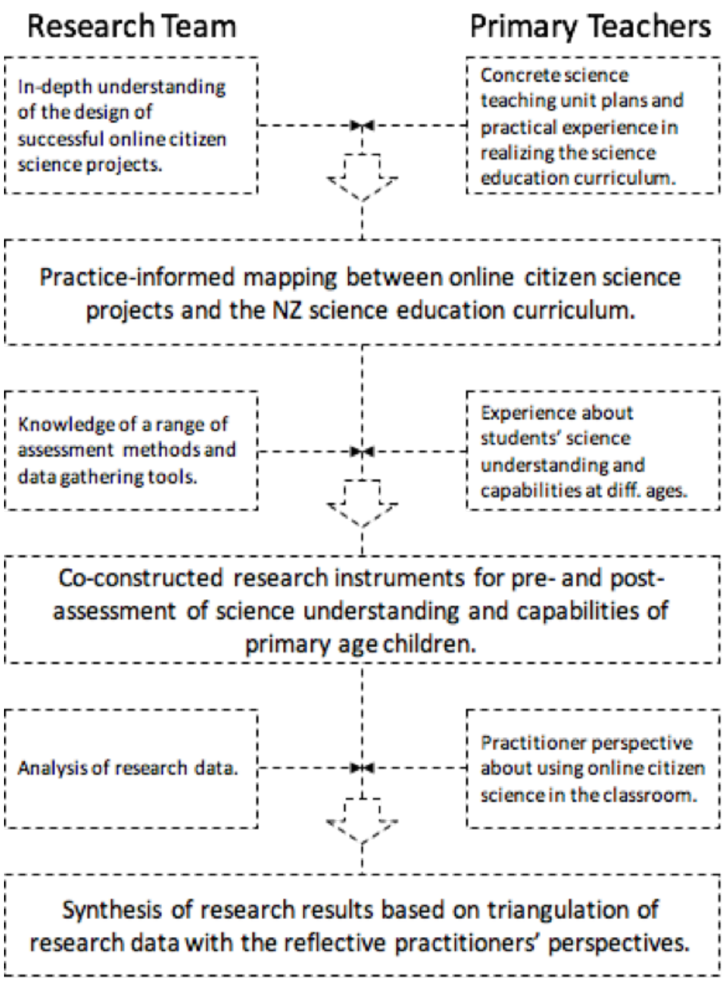

Figure 1. The research-practice nexus underlying the co-constructive partnership within the Citizen scientists in the classroom project (from Doyle et al., 2018)

Building from the 2018 project, the project team invited a wider group of teachers and researchers, including researchers in digital technology education, to co-design a three-year project – On2Science – that brought together three lines of inquiry: OCS and science education, OCS and Digital Technology (DT) education, and OCS and human-computer interactions (HCI). The development of these interweaving lines of inquiry was made possible by the interdisciplinary nature of the partnership (Buntting et al., 2020). Over the course of the three year project, 10 teacher-researchers contributed to 16 case studies across 10 schools, with teachers working in pairs in some cases. From the analysis of the multiple data sources, we were able to describe the rich learning undertaken by the children in each case study class, what individual teachers learned, and how the collaboration enriched the researchers' experiences and understandings of the complexity of science teaching, learning and research in each case.

The impacts of working together

For the purpose of this article, the point is the value of the 'cold call', conversations to find common ground, and the collaborations that can be established when people say 'yes'. In the On2Science project, we specifically investigated the impacts of the teacher-researcher partnership by asking all members of the research team to provide written responses to a series of prompts:

1. Cast your mind back to when you were first invited to join this project . . . What was it that made you say 'yes'? What impact did you think being involved might offer to your practice?

2. How has participating in this project influenced your professional practice? Please give some specific examples.

3. What has been the impact on student learning?

4. Have there been ripple effects? In what ways has your involvement in this project spread beyond your practice, to others?

5. This project brings together teachers and researchers. What have been the benefits of this collaboration?

6. What challenges have you encountered as part of this project? Please comment on how you have adapted to these (if appropriate).

7. What about being involved in this project has surprised you?

Responses were received from six teacher-researchers, three science education researchers, one DT education researcher, two professional learning providers, and two research assistants (PhD students in information systems). From the responses, three key themes emerged relating specifically to the partnership approach. First, it was anticipated that collaborating would be inherently beneficial.

Participants were drawn to the partnership because they anticipated that there would be inherent value in collaborating with others, including in relation to their own learning. Indicative comments included:

> I loved the idea of a partnership which included teachers of students at various levels, universities, and professional learning providers. (Teacher-researcher 1)
> I believed it would improve my practice in the classroom. […] I also wanted to model to my students positive learning dispositions, by talking to them about what I was doing and why – learning is lifelong and I am always trying to develop as a teacher (Teacher-researcher 2)
> I hoped to develop my own understanding of citizen science, to work with other teachers who are passionate about science and to learn more about research in education. (Teacher-researcher 3)
> I thought the experience would really help me develop professional/scholarly skills, working on a project different than my thesis, with a group who were clearly excited about the project. It presented as an opportunity to learn and develop both research and interpersonal skills. (Research Assistant 1)
> Bringing together teacher's practical wisdom and researchers' more theoretical insights is always powerful. (Science education researcher 1)

Second, participants reports that the partnership had positive impacts on their practice, as demonstrated by the following indicative comments. (Impacts on students' learning are reported elsewhere, for example, Buntting et al. (2022).)

For teachers:

> Participating in this project has made me a much better science teacher. The unit plans I have created as part of my participation in this research are far more considered and in depth than units I had planned previously. (Teacher-researcher 3)
> My planning has improved. Having a focussed cross-curricular plan that can be used to guide the learning but still be a stepping stone for student input and direction. (Teacher-researcher 4)

> It has changed the nature of my science teaching by further developing my ability to focus on the nature of science and science skills. It has also helped me develop my confidence to share my work, upskill other teachers, and step into school leadership. (Teacher-researcher 1)
>
> It has got me thinking about how I can/could use digital curriculum ideas in science and in other aspects of my work. (Teacher-researcher 2)
>
> When I first became passionate about teaching science, I was doing a lot of one-off lessons with exciting science experiments etc. This was great but didn't develop students' skills or knowledge sufficiently. Now, through these projects, students have been scaffolded through a project where they are developing their learning and understanding in an authentic context over the course of weeks. They are engaged and excited about science learning and don't want the lessons to end. (Teacher-researcher 5)

For teacher educators:

> In many ways, getting stuck into the OCS has legitimised my teaching discussions of links with DT and science - I can talk from first-hand experience - as well as conversations with teaching students about classroom practice based on observations of experienced teachers. (DT education researcher and lecturer 1)
>
> I have been able to share teacher stories in the schools I work at to give them further contexts for learning with science and/or DT curriculum. (DT professional learning provider 1)
>
> I certainly have a much better understanding of the DT curriculum now. I can see opportunities for DT integration and understand how and where they fit into that curriculum. (Science professional learning provider 1)

For researchers:

> I have been more thoughtful and critical in my data analysis and drawing evidence based conclusions. (Science education researcher 2)
>
> This was my first instance of collaborative research and so it's really set the tone for me. It was cross-disciplinary and practitioner oriented. I think this has certainly supported and complemented my own sensibilities and research focus to never let the practitioner or community be too far away from what I'm doing. The value of community within research, when it's possible, creates a powerful opportunity to explore phenomena deeply and create new and meaningful knowledge. I hope I can do that one day. (Research assistant 1)

Finally, there was a strong sense of valuing being part of a professional community where participants experienced mentoring from others with different levels and areas of expertise:

> The team members all brought different skills and ideas to the collective and this provided a fabulous learning opportunity for me. My DT skills are still developing but the OCS projects bring a wonderful opportunity to use cross curricular teaching in an innovative way with support from experts in the field. (Teacher-researcher 4)
>
> As a new academic, it was a wonderful 'way in' to contribute and be mentored by experienced and enthusiastic academics (DT education researcher and lecturer 1)
>
> In collaborating with colleagues, I believe my time with TLRI has impacted how I communicate and negotiate, i.e., consensus building. I recall working directly with [a more experienced researcher] to review codes between us before going to the entire team to review coding and build consensus. She modelled behaviour and communication to me that I

still use, particularly in consensus building. I find enduring value in this. (Research assistant 1)

Overall, the mutual respect for the expertise that each person brought to the partnership, an openness to learning, and time to connect personally and professionally all contributed to positive project outcomes. As a project team, we were also committed to sharing our findings as widely as possible with the teaching profession for the project to have wider impact. This included co-presenting at teaching and research conferences, nationally and internationally, and writing in academic and teacher-facing journals. This additional aspect was specifically mentioned by several teacher-researchers in their responses to the question about ripple effects listed above, for example:

> I have used my involvement in this project to upskill a number of teachers across the 3 schools I have worked at over the course of my involvement. It has also been the basis of presentations that I have made at a number of different conferences and events. (Teacher-researcher 1)
>
> Opportunities to present at conferences as part of the team. A publication record, which is important if you wish to apply for wider opportunities, e.g., Fulbright. (Teacher-researcher 4)

There was also valuable synergy with another project that I lead – this is described below in order to provoke thinking about how digital technologies might be harnessed in order for education research to have wider reach into the teaching profession.

THE SCIENCE LEARNING HUB – POKAPŪ AKORANGA PŪTAIAO

The Science Learning Hub – Pokapū Akoranga Pūtaiao (sciencelearn.org.nz) is a large online resource funded by New Zealand's Ministry of Business, Innovation and Employment. Its purpose is to enhance school science by making contemporary science and technology more visible and accessible to teachers and students. It was initially conceived in 2005, and sustained funding since then means that we have been able to develop a robust digital infrastructure, proven processes for multimodal story telling with wraparound educational resources, and a large and growing audience (nearly 6m users per annum). The Hub project team includes people with expertise in science, science education, science education research, culturally responsive pedagogies, resource development, multimedia development, teacher professional learning, social media outreach, and technical know-how – although the total number of staff is equivalent to only five full time people. Importantly, the team is in regular contact with teachers, helping to ensure that the resources are used and useful. Further, technical capability such as the Hub's collections tool (in which users can curate and annotate resources, for example, to develop unit plans), is an example of what Choppin et al. (2018) have called the "dissolution of boundaries between design and use" (p. 75).

In response to the findings emerging from the two TLRI projects, the Hub team developed a new section on the online platform to collate citizen science resources emerging from the TLRI projects as well as other CS initiatives. This section now features a range of content, including:

1. CS and OCS project pages – summaries of each project and what citizen scientists are asked to contribute, outlines of relevant science concepts and aspects of the nature of science, examples of possible learning outcomes, and links to additional information and activities. This collection is searchable by topic (e.g., animal classification, climate change, night sky, pollution) and science capability (identified by the New Zealand Ministry of Education as including gathering and interpreting data, using evidence, critiquing evidence, interpreting representations, and engaging with science).

2. Recorded webinars in which teachers share how they have used CS and OCS projects as part of their teaching and learning programmes – with the intention to inspire and support other educators.

3. A ‘tips for planning’ article that brings useful insights from the TLRI research and other initiatives to provide suggestions for teachers of aspects to consider when choosing a CS or OCS project and when planning to embed it within wider teaching and learning.

4. Case studies resulting from the TLRI projects. These case studies include insights into the teacher’s background, the inspiration for the unit, the unit plan, examples of student activities and responses, and teacher and researcher reflections. They support the other resources by providing deeper insights into aspects teachers should consider when planning to include CS and OCS projects in school science programmes.

In the year July 2022 – June 2023, the project pages were viewed more than 16,000 times. The most popular project pages were Wild Sourdough (1,396 views), Penguin Watch (1,178 views), and The Pieris Project (1,018 views).

CONCLUDING THOUGHTS

My intention with the keynote address at ISET 2023 was to provoke conversation around how education researchers can collaborate with educators to think about – and shape – the future of science and STEM education. This paper outlines some of the benefits of such collaborations for the professional learning of participants, as well as for generating research insights that can be shared through traditional academic forums. In sharing the TLRI projects, I was particularly interested in highlighting the value of having courage to initiate conversations with others that might lead to productive research partnerships. I also wanted to provoke conversation about the additional avenues we might explore as researchers to broaden the reach and impact of our work. In our case, the New Zealand Science Learning Hub provides a productive vehicle for sharing insights from science education research in multimodal forms with a large educator audience. Other avenues could include sharing findings at teacher-facing conferences and in teacher-facing journals and magazines, via social media groups and blogs, and with policy makers. It seems critical to explore these opportunities if our research is to make a difference to educational practice.

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STEM Learning Activity through Making Natural Paints from Plants Process

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Abstract. The paper will clarify STEM learning activities related to the natural paint-making process. The STEM education learning activity will be developed based on Sutaphan and Yuenyong's (2019) context-based STEM education learning approach. These learning activities aim to show the student teachers' learning through (1) how to make natural paint from flowers and plants and (2) producing natural paints are available for use, low-cost, and effective. The 7 stages of STEM education are used as the processes for making natural paints from flowers and plants (beetroot, red cabbage, butterfly pea, and turmeric) into useable paints. The results from the learning activity shown that beetroot, red cabbage, butterfly pea, and turmeric have the properties to synthesize color ink and use it for artist setting. The inks synthesized are eco-friendly, avoid biological waste, and avoid hazardous chemical. This paper will discuss how to provide students with a chance to apply STEM knowledge through these activities to encourage students and local people to conduct natural painting with natural ingredients for safety and health.

Keywords: STEM education, Natural Paints, Synthetic

Introduction

In the 21st century is the generation the Industrial Revolution 4.0 and it has created intense economic competition between countries. The development of science, technology, engineering, and mathematics has become a priority agenda for economic and social development through the declare of the Industrial Development Policy in Cambodia 2015-2025 (Moeys, 2016). STEM policy shown that Cambodia is a developing country, it is the most necessary to encouraged learning STEM activity in order to produce human resource in Cambodia. STEM education is a study model that provides opportunities to integrate the four key skills of science, technology, engineering, and mathematics to implement a combination of decision-making decisions or any problem.

Cambodia had just implemented STEM education in the education program one year after the policy. It aims to develop K–12 and higher education students in science, technology, engineering, and mathematics to meet the needs of the labor market and the ASEAN community. STEM education improves students' critical thinking skills and positive STEM perceptions, and it indirectly influences their understanding of their careers (Haciolu and Gulhan, 2021). STEM education helps students to improve behavior activity creative and innovate. STEM education learning activities have an effect on students' creative thinking skills (Sirajudin & Suratno, 2021; Sutaphan and Yuenyong, 2023).

The literatures suggest that STEM education pedagogy would be provided in the following aspects: (a) the content and practices of one or more anchor science and mathematics disciplines define some of the primary learning goals; (b) the integrator is the engineering practices and engineering design of technologies as the context; (c) the engineering design or engineering practices related to relevant technologies necessitate the use of scientific and mathematical concepts through design justification; (d) the development of 21st century skills is emphasized; and (e) the integrator is the engineering practices and engineering design of technologies as the context (Moore et.al., 2015; Sutaphan and Yuenyong, 2019).

The conceptualization of STEM education pedagogy should engage students to identify the real-world problems such as disasters (e.g. flooding, earthquake, tsunami etc.), pollutions, environmental issues, biotechnology, food, health, cosmetics, ecosystem, green energy, climate change, entrepreneurs' issues, and so on (Suparee and Yuenyong, 2021; Sutaphan and Yuenyong, 2019; Sutaphan and Yuenyong, 2023; Wongsila and Yuenyong, 2019). In order to regulate teacher's ideas of developing STEM education learning activities for engaging students' developing solutions for real-world problem, Sutaphan and Yuenyong (2019) suggested the practical idea of STEM education teaching approach which integration key concepts among problem based, project based, inquiry, design, and a real-world problem solving. The framework of stages of teaching included seven stages of teaching. These included (1) identification of social issues, (2) identification of potential solutions, (3) need for knowledge, (4) decision-making, (5) development of prototype or product, (6) test and evaluation of the solution, and (7) socialization and completion decision stage.

And, literature revealed that some studies adopted framework of Sutaphan and Yuenyong (2019) STEM education pedagogy to develop the STEM education units in different contexts in Asia (Adita and Yuenyong, 2021; Ebal Jr et.al., 2019; Fachrunnisa et.al., 2021; Koes-H et.al., 2021; Guarin et.al., 2021; Masita et.al., 2021; Nugraheni and Yuenyong, 2022; Sutiawan et.al., 2021; Theerasan and Yuenyong, 2019;Villaruuz et.al., 2019). This study, therefore, focused on applying STEM in learning process by using 7 step model of STEM education, which provided students with the opportunity to make natural paints from a plant process that, in recent years, many students have used in art class. Students can apply scientific knowledge or others to design a solution for making something new in their daily lives.

Development of Making Natural Paints STEM Education Unit

The STEM education learning activity will be developed based on Sutaphan and Yuenyong's (2019) context-based STEM education learning approach. In Cambodia, students usually use paint for their learning activities, especially in art class. Based on Sutaphan and Yuenyong's (2019) context-based STEM education learning approach, seven stages are provided: (1) identification of social issues; (2) identification of potential solutions; (3) need for knowledge; (4) decision-making; (5) development of a prototype or product; (6) testing and evaluation of the solution; (7) socialization and completion of the decision stage. Through this learning activity, students apply knowledge to create natural paints. Students apply knowledge in Chemistry, Mathematics, Engineering, Biology, and Economics to produce natural paints. In chemistry, students think about ingredients. In math, students calculate the proportions of ingredients in a production. Engineering is the study of packaging techniques, and biology is the study of the expiration of natural paints. In the economy, students think about the cost of ingredients in the production of natural paints. This lesson plan is shown in the table below.

Table 1: Lesson plan on natural paint from plant process STEM education learning process

STAGE	ACTIVITY
Identification of Social issues	Inspire students to think about making inks to use in the classroom, especially art classes. Synthetic paints which sale in the market are more popular than natural paints, however, due to their volatile organic compounds, which are harmful to nature and pose a threat to individuals who use them and harm the environment (V.A.R.Barao et al., 2022). Paints are a mixture of many substances such as resin, alcohol, carbon, pigments, lubricant, Synthetic Dye, aniline, dextrin, glycerin, fluorescents, and other materials (Wild, 2016). Lubricant is an oil that can affect human health and the environment, such as affecting water and soil sources (Madanhire et al., 2016) Synthetic dyes are toxic, causing disease to human health and also affecting the environment (Ngulube et al., 2017) Aniline is widely used as an intermediate chemical in the pharmaceutical and dye industries. These chemicals are of concern because they have an impact on public health and aquatic species in the environment to solve this problem, we need to: produce natural paints from flowers or plants; Learn how to make pigments from flowers or plants. Check raw materials, chemicals, budgets, and packaging for natural ink production (Chaturvedi & Katoch, 2020)
Identification of Problem Solution	To Solve this problem, we need to: 1. Produce natural paints from flowers or plants 2. Learn how to make pigments from flowers or plants. 3. Check raw materials, chemicals, budgets and packaging for natural ink production 4. Produce natural paints that are usable, low-cost. Organic paints are considered environmentally friendly as they are sourced from natural resources such as leaves, plants, roots, flowers, fruits, and minerals (Singh & Sharma, 2017).
Need for Knowledge	Find information on the internet and in books on knowledge related to the production of pigments from plants. Knowledge from research articles: ➢ Turmeric  Turmeric is a yellowish-brown tuber with a yellowish interior and small tubers growing in the ground. Turmeric is a plant used in spices is a mixture of bright yellow chemicals due to the presence of a specific substance, Curcumin, which can help fight oxidation and inflammation (Jiggi, 2012). ➢ Beetroot  Beetroot is a tuber vegetable that contains red pigment. The color of beetroot is red and pink because beetroot contain 75–95% betalains. The red pigment in beetroot betalains helps with antioxidant and anti-inflammatory properties.(Chandran et al., 2014). ➢ Coffee’s pulp  Coffee is a popular beverage in Cambodia, it is brewed with hot water for consumption, but its pulp is left behind. However, the coffee left behind loses its flavor, but its color does not change, and its color should be used for color synthesis.

Table 1: (Cont')

STAGE	ACTIVITY
	➢ Butterfly pea flower Butterfly pea flower contains anthocyanin, which gives it a dark blue or purple color (Mary et al., 2020).  ➢ The red cabbage The red cabbage is derived from a plant pigment known as anthocyanins, which is a compound that causes it to turn purple because of its pigment content. Also, for painting (Danilo & Alfaro, 2021).  ➢ Vinegar Vinegar is used as an additive in the production of pigments because it is acetic acid, and it is used with water as a solvent as an additive to make these dyes environmentally friendly and biologically damaging. Adding more vinegar to this natural ink helps preserve the ink and stabilizes the ink so it lasts longer on paper when it dries (V.A.R.Barao et al., 2022).  ➢ Cassava starch Cassava starch is used as a binder in the form of water-based paints (Udonne & Obiokwu, 2013).  ➢ Water Water acts as a solvent to break the polysaccharide bonds of glucose (Qian et al., 2019). ➢ Salt Salt is a substance that absorbs water or moisture. We add salt to make the mixture more viscous (Parvathy & Jyothi, 2012). The plants are heated in water, vinegar, salt to create a color extraction, then noodles are added as a binder in the production of natural paints. Plants + Water + Binder = Natural paints
Decision Making	Discuss and decide on an experimental process that produces ink from plants. The plants that we use in our process are turmeric, beetroot, butterfly pea flower, red cabbage, Coffee's pulp. These plants are very abundant and easy to find in Cambodia. So it is very easy for us to find raw materials for natural paints production.
Development and prototype or Products	Through STEM learning activities students development and prototype or Products started to think about: In chemistry, students think about ingredients. In math, students calculate the proportions of ingredients in a production. Engineering is the study of packaging techniques, and biology is the study of the expiration of natural paints. In the economy, students think about the cost of ingredients in the production of natural paints. Martial and Procedure

Table 1: (Cont’)

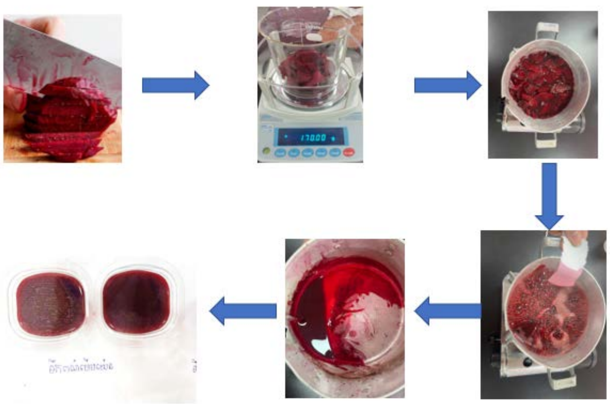
STAGE	ACTIVITY
Development and prototype or Products	Martial and Procedure Martial: Gas stove, spoon, pot, baker, knife Ingredients: Salt (NaCl), water, vinegar, Butterfly pea flower, Turmeric, Cassava starch, Red cabbage, Beetroot Procedure: The procedure of production is detailed for making color from beetroot, and other ingredients also have the same production pattern. The productions are following the steps below: The description of figure 1: Step 1: Split the beetroot into a small piece Step 2: Weighing 170 grams of beetroot Step 3: Measure 300mL of pure water Step 4: Mixed beetroot and water in the pot Step 5: Add a spoonful of vinegar Step6: Add a spoonful of vinegar and blend Step7: Heating for 30 minutes Step8: Test the color with white paper Step9: Filter the liquid pigments into a new pot Step10: Add two spoons of cassava starch and blend until it’s mixed. Step11: Leave until it’s cool and packaged.  Figure 1: the diagram of making color painting

Table 1: (Cont’)

<table>
<tr><th>STAGE</th><th>ACTIVITY</th></tr>
<tr><td>Test & Evaluation of the solution</td><td>
After the process of packaging, the researchers tested the quality of the paint by observing nine criteria for each product, such as:
C1: Flow ability
C2: Color
C3: Brightness
C4: Drying time (paper)
C5: Expiration period

Table 1: Physical properties of natural paints from plants
<table>
<tr><th></th><th>Beetroot</th><th>Turmeric</th><th>Red cabbage</th><th>Butter fly flower</th><th>Coffee</th></tr>
<tr><td>C1</td><td>Free flowing</td><td>Free flowing</td><td>Free flowing</td><td>Free flowing</td><td>Free flowing</td></tr>
<tr><td>C2</td><td>Pink</td><td>Yellow</td><td>Pistachio</td><td>Green</td><td>Brown</td></tr>
<tr><td>C3</td><td>Good</td><td>Good</td><td>Good</td><td>Good</td><td>Good</td></tr>
<tr><td>C4</td><td>5-8 second</td><td>5-8 second</td><td>5-8 second</td><td>5-8 second</td><td>5-8 second</td></tr>
<tr><td>C5</td><td>1 month</td><td>1 month</td><td>1 month</td><td>1 month</td><td>1 month</td></tr>
</table>
The physical properties of the natural paints produced from the, local ingredients such as: Beetroot; Turmeric; Red cabbage; Butterfly flower; and Coffee are interpreted in Table1. The color paints are Free flowing, brightness, stable for Permeance, easy to dry and long period of expiration day. The paint colors are pink for Beetroot; yellow for Turmeric; pistachio for red cabbage; green for Butterfly flower and Brown for Coffee. The synthesized paints do not easily to erase due to the properties of color paints and it indicated that the color paints have good quality. However, some color paint displaying some change, when left in room conditions for 2 weeks:

Table 2: Physical properties ’s variations of natural colors
<table>
<tr><th></th><th></th><th>Beetroot</th><th>Turmeric</th><th>Red cabbage</th><th>Butter fly flower</th><th>Coffee</th></tr>
<tr><td>Week1</td><td></td><td>No Color Change</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Week2</td><td>Day 1</td><td>Slight Change</td><td>No Change</td><td>No Change</td><td>No Change</td><td>No Change</td></tr>
<tr><td></td><td>Day 2</td><td>Slight Change</td><td>No Change</td><td>No Change</td><td>No Change</td><td>No Change</td></tr>
<tr><td></td><td>Day 3</td><td>Slight Change</td><td>No Change</td><td>No Change</td><td>No Change</td><td>No Change</td></tr>
<tr><td></td><td>Day 4</td><td>Slight Change</td><td>No Change</td><td>No Change</td><td>No Change</td><td>No Change</td></tr>
<tr><td></td><td>Day 5</td><td>Slight Change</td><td>No Change</td><td>No Change</td><td>No Change</td><td>No Change</td></tr>
<tr><td></td><td>Day 6</td><td>Slight Change</td><td>No Change</td><td>No Change</td><td>No Change</td><td>No Change</td></tr>
</table>
The Changes in natural color show in Table 2 that all colors do not change color within two weeks, except for the color of the Beetroot, which changes during the second week.
</td></tr>
</table>

Table 1: (Cont’)

<table>
<tr><th>STAGE</th><th>ACTIVITY</th></tr>
<tr><td></td><td>






</td></tr>
<tr><td>Socialization and completion decision stage</td><td>
1. Share what you get with other students and teachers or on social media.
2. Other students and teachers comment on their promotion.
3. Evaluate based on comments in the project (number of likes and dislikes), creativity, Acceptable creativity and complexity of innovation.

Presented in class

Posted Video on Facebook and you tube
Link: https://youtu.be/L9LbeBhPq7s
</td></tr>
</table>

Table 1: (Cont')

STAGE	ACTIVITY
	 Science Fair at Phnom Penh Teacher Education College

Conclusions

The paper will clarify STEM learning activities related to the natural paint-making process. The STEM education learning activity will be developed based on Sutaphan and Yuenyong's (2019) context-based STEM education learning approach.

According to the problem of paints, the learning activities of the 7 stages encourage students to practice knowledge and create something related to the production of natural paints from plants. After finishing the project, students gain some more knowledge about the way to produce natural paints from plant processes, they can develop their product and make the decision to produce it.

The test and evaluation student shows the quality of their product and shows it to their teacher and their friends. This paper shows how to provide students with a chance to apply STEM knowledge through these activities to encourage students and local people to conduct natural painting with natural ingredients for safety and health.

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Comparison of Fleming's Right-hand Rule and ijk-Notation in Determining the Direction of Magnetic Force

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Abstract. Fleming's Right-hand Rule (RHR) and ijk-notation are mnemonics that help students identify the direction of magnetic force. Literature has provided successes and limitations of each of these mnemonics, but no literature was found documenting the comparison of these mnemonics used in one Physics concept as these were normally used separately (i.e., RHR for electromagnetism and ijk notation for vectors in Math). This study employed a quasi-experimental one-group posttest-only design and the data were analyzed using Independent Samples t-test. This study underscores that Fleming's Right-hand Rule can better help students in identifying the direction of magnetic force than ijk-notation. The students emphasized that the use of ijk-notation is perplexing particularly when vectors differ in sign conventions, thus the low score using the said mnemonic.

Keywords: Physics Education, Right-hand Rule, ijk-notation, Electromagnetism

INTRODUCTION

Students always find Physics as one of the most challenging subject areas learned in school. The primary reason of their aversion is the fact that Physics entails complex solutions spoken by the intricate language of Mathematics. In the realm of Physics education, a lot of pedagogical innovations were already developed and tested to address this diffident attitude of students towards Physics.

Physics education research has shown that pupils struggle with the concept of magnetic force, which is extremely complicated and challenging (Onorato & Ambrosis, 2014). According to Scaife & Heckler (2010), traditional instruction is fairly effective in teaching magnetic force, but it still buds misconceptions particularly after the instruction. Another reason why students struggle with the concept of magnetic force is the lack of sufficient grasp of the vector algebra (Kustusch, 2016). Because of the previously mentioned learning predicament, teachers and researchers have attempted to innovate and test teaching approaches that would improve students understanding of the magnetic force.

One of the reliable approaches in teaching Physics is doing physical experiments (Trivedi & Sharma, 2013). According to their study, the employment of physical experiments in teaching Physics not only influences the students' attitude towards Physics but also allows them to appreciate its social implications. Ismail, Abu, Meng, Wang, & Zhou (n.d.) used the R&D model (ADDIE model) in teaching magnetic force. They found out that students understand the concept of magnetic force better by developing a visualization using power generator, tea leaves, two copper wires, two neodymium magnets, and an adjustable voltage source. If such materials are not available, drawing and mathematical representations can be used as an alternative. Savinainen & Nieminen (2019) emphasized that multiple representation models can effectively improve students' understanding. The same argument was underscored by Onorato & Ambrosis (2014) when they highlighted that effectiveness of multimedia in teaching magnetic force.

Fleming's Right-hand Rule (RHR) has been the staple of Physics teachers in teaching magnetic force. The RHR is a mnemonic that tells us the directions of magnetic force, magnetic field, and the charged particle. According to Deprez, Gijsen, & Deprez (2019), students perform significantly better while using RHR in the context of magnetic force. This mnemonic has been used in teaching, but it also has issues particularly in the student's side. According to Kustusch (2016), there is a direction error which is believed to be implicit. Students are unaware of the direction of the hand especially with reversed direction of one of the vectors. The error of students in using RHR is merely kinesthetic (Kustusch, 2016; Nguyen, 2005; Domelen, 1999).

Another method of identifying the magnetic force is the ijk-notation. This mnemonic is sporadically used in teaching magnetic force. This mnemonic is usually used in Mathematics. Heckler & Scaife (2015) highlighted that students perform typically excellent and often much better using ijk-notation that in the arrow format. They further argued that ijk-notation help students learn physics concepts involving vector addition and subtraction. Furthermore, Buncher & Ph (n.d.) underlined that ijk-notation was effective as their respondents scored higher in post-test than in pre-test.

This foregoing study aimed to compare the use of RHR and ijk-notation in determining the direction of magnetic force. This would examine the students' scores and their response time. Lastly, it is this study's hope to provide Physics teachers an idea of the students' preferences and the difficulties they have encountered using these two different mnemonics.

MATERIALS AND METHODS

This study employs a quasi-experimental one-group posttest-only design. The participants of the study were 17 students of a public secondary school in the province of Phetchaburi in Thailand. They are studying in a program that specializes in Science and Mathematics under a bilingual mode of instruction (English and Thai).

Fleming's Right-hand Rule and ijk notation were both comprehensively taught to the participants. Furthermore, both mnemonics were taught in English and Thai to rule out the possible effects of language barrier in the study's outcomes.

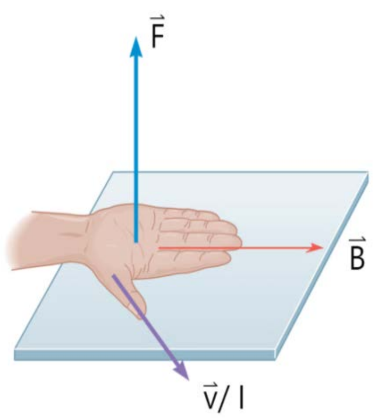


Figure 1. Fleming's Right-hand Rule

Fleming's Right-hand Rule can be used to determine the directions of the magnetic force on a moving charge in a magnetic field or a current in a magnetic field. The fingers point to the direction of the magnetic field. The thumb points the direction of the charge's motion or the current flow. Lastly, the palm of the hand points to the direction of the magnetic force. The ijk-notation and its sign conventions were taught using the illustration shown above. This mnemonic is deemed useful in determining the direction of a vector cross product.

The instrument used in this study is a 15-item test on determining the direction of the magnetic force. In the first part of testing, the participants were asked to identify the direction of the magnetic force using the Fleming's

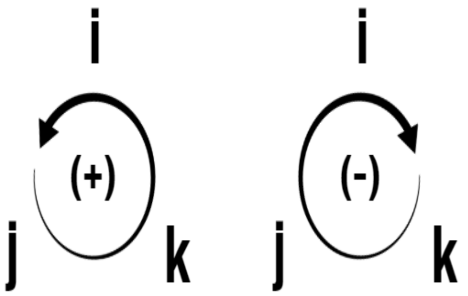
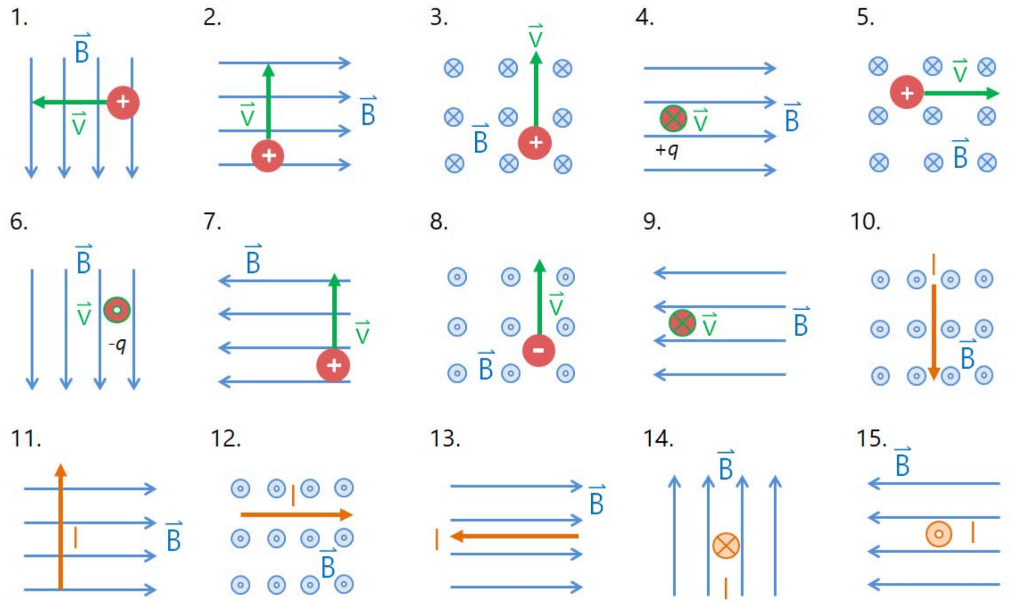


Figure 2. ijk-notation

Right-hand Rule. The respondents were also asked to submit their papers once done. The researcher recorded the time elapsed to answer the test. In the second part of testing, the same data collection method was employed but in this part the participants were only allowed to use the ijk-notation.

This study utilized descriptive statistics to analyze the data collected. The scores from two tested mnemonics were analyzed using Independent Samples t-test. The same statistical tool was used to analyze the time taken to complete each test using two different mnemonics.



RESULTS AND DISCUSSION

Table 1. Independent Samples t-test Result on the Mean Scores of Fleming's Right-hand Rule and ijk-notation

Mnemonics	Mean Score	SD	Statistic	df	p
Fleming's Right-hand Rule	9.71	1.86	8.71	32.0	< 0.001
ijk Notation	3.71	2.14			

*used α= 0.05

Table 1 shows the mean scores of students using Fleming's Right-hand Rule (RHR) and ijk-notation. The mean score using RHR is 9.71 while the mean score using ijk-notation is 3.71. There is a huge difference between the mean scores using the two mnemonics. Since $p < 0.001$, the null hypothesis is rejected. Therefore, there is a significant difference between the students' mean scores using Fleming's RHR and ijk-notation.

Table 2. Independent Samples t-test Result on the Time Spent using Fleming's Right-hand Rule and ijk-notation

Mnemonics	Mean Time (s)	SD	Statistic	df	p
Fleming's Right-hand Rule	438	227	-1.85	32.0	0.074
ijk Notation	559	148			

*used α= 0.05

Table 2 shows the mean time spent by the students in using Fleming's Right-hand Rule (RHR) and ijk-notation. The mean time spent using RHR is 438 s. On the other hand, the mean time spent by the students using ijk-notation is 559 s. Since p= 0.074 is greater than α= 0.05, the decision is to fail to reject the null hypothesis. Therefore, there is no significant difference between the time spent by students in using Fleming's Right-hand Rule and ijk-notation.

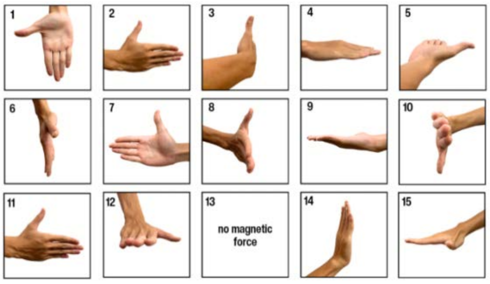


Figure 3. Direction of Magnetic Force using Fleming's Right Hand

v/I x B	Direction of magnetic force
1. $-\hat{\imath} \; x \; -\hat{\jmath} \; = +\hat{k}$	out of the page
2. $+\hat{\jmath} \; x \; +\hat{\imath} \; = -\hat{k}$	into the page
3. $+\hat{\jmath} \; x \; -\hat{k} \; = -\hat{\imath}$	left
4. $-\hat{k} \; x \; +\hat{\imath} \; = -\hat{\jmath}$	down
5. $+\hat{\imath} \; x \; -\hat{k} \; = +\hat{\jmath}$	up
6. $+\hat{k} \; x \; -\hat{\jmath} \; = +\hat{\imath}$	Right *(left for –q)*
7. $+\hat{\jmath} \; x \; -\hat{\imath} \; = +\hat{k}$	out of the page
8. $+\hat{\jmath} \; x \; +\hat{k} \; = +\hat{\imath}$	Right *(left for –q)*
9. $-\hat{k} \; x \; -\hat{\imath} \; = +\hat{\jmath}$	up
10. $-\hat{\jmath} \; x \; +\hat{k} \; = -\hat{\imath}$	left
11. $+\hat{\jmath} \; x \; +\hat{\imath} \; = -\hat{k}$	into the page
12. $+\hat{\imath} \; x \; +\hat{k} \; = -\hat{\jmath}$	down
13. $-\hat{\imath} \; x \; +\hat{\imath} \; =$	no magnetic force
14. $-\hat{k} \; x \; +\hat{\jmath} \; = +\hat{\imath}$	right
15. $+\hat{k} \; x \; -\hat{\imath} \; = -\hat{\jmath}$	down

Figure 4. Direction of Magnetic Force using

This is because when one of the two vectors differs in sign, the cross product should bear the opposite sign indicated by the ijk-notation.

Apart from the statistical findings, the students underscored that they were having difficulties using the ijk-notation. Their main problem is the sign conventions assigned to the vectors. Furthermore, they emphasized that the ijk notation only becomes convenient if the velocity of the particle, magnetic field, and current all have the same sign. The students found it difficult to identify the direction of the magnetic force using the ijk-notation especially when one of the two vectors differs in sign.

Figure 5 shows the comparison of RHR and the ijk-notation in determining the direction of magnetic force. For instance in item 10, RHR can immediately determine the direction of the magnetic force by looking at the direction at which the palm is facing. In this particular example, it is directed towards the left. If ijk-notation will be used in this item, it is confusing. In this item, I x B is counterclockwise ($\hat{j}$ x $\hat{k}$) in the ijk-notation, thus the direction should be positive (+): up; right; or out of the page. However, the current and magnetic field have different sign conventions: the current is going down (-$\hat{j}$) and the magnetic field is directed out of the page (+$\hat{k}$). In this condition, the sign suggested by the counterclockwise ijk-notation should not be followed. The sign of the cross product should be the opposite of the indicated sign convention by the ijk-notation. For illustration

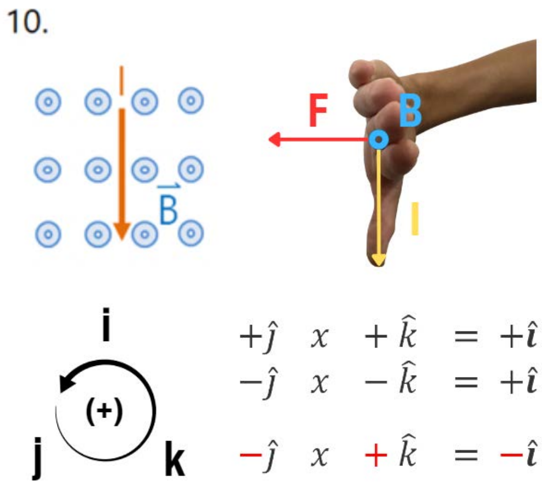


Figure 5. Comparison of RHR and ijk-notation in determining the direction of magnetic force in item 10

purposes, +j ̂ x +k ̂= +(i)̂, -j ̂x -k ̂= +(i)̂, but -j ̂x +k ̂ = -i ̂. The same should be observed in the clockwise ijk-notation.

The comparison of RHR and ijk-notation was inspired by the researcher's observation when his students were unaware of the direction of their hands. The ijk-notation was meant to solve the abovementioned problem. However, the data of this study revealed that the use of ijk-notation, as a mnemonic in determining the direction of magnetic force, entails a robust background in vector algebra.

CONCLUSION AND RECOMMENDATION

After deliberate analysis of results, this study strongly underscores the following:

1. Fleming's Right-hand Rule can better help students in identifying the direction of magnetic force than ijk notation ($p < 0.001$).

2. There is no significant difference between the time spent by students in using Fleming's Right-hand Rule and ijk Notation.

3. The main problem encountered by the students using the ijk notation is when vectors differ in sign conventions.

The magnetic force's direction can be determined using either mnemonic. Additionally, it is advised that both be introduced to the students. Students should be encouraged to practice RHR in order to prevent direction error. To identify the direction of magnetic force, vector algebra and sign rules should be taught as prerequisites for the use of ijk-notation.

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Cyberspace Metaverse Connected to Artificial Intelligence: Analysis of Merdeka Curriculum Interactive Multimedia Needs on Science Material

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Abstract. The independent curriculum utilizes technology as a digital platform that facilitates teachers and students in developing their potential. Using various existing learning platforms is less efficient and makes things difficult for students, so they need a platform that can accommodate multiple learning needs. The research method used is netnography, which is descriptive qualitative. The data collection technique in this research is observation of the use of digital media in the independent learning curriculum, in-depth interviews, and library research. The research results showed that as many as 53 percent of respondents did not agree with the existence of diverse learning platforms with different functions. The metaverse cyberspace platform can be an innovation relevant to the independent learning curriculum because it can provide a variety of media so that it does not take up student storage space. The metaverse cyberspace platform based on local wisdom can integrate technology with everyday life and support science learning. The metaverse cyberspace platform connected to artificial intelligence (AI) is a solution to the problems of the independent curriculum, namely the character education crisis and the need for learning technology.

Keywords: Cyberspace Metaverse, Articificial Intelligence, Merdeka Curriculum, Science Material

INTRODUCTION

The Minister of Education and Culture of the Republic of Indonesia emphasized simplifying the curriculum to restore the quality of education after the pandemic, called the independent learning curriculum (Kemdikbud, 2020). One indicator of an independent curriculum is creating flexible learning through digitalizing education (Pertiwi et al., 2023). The independent curriculum utilizes technology as a digital platform that facilitates teachers and students in developing their potential (Mustofa & Mariati, 2022). The digital platforms in the current independent curriculum are independent teaching and home learning (Wahira et al., 2023).

Independent teaching is a platform that focuses on developing teacher potential so that the platform contains the development of learning models, innovative learning methods, and other learning innovations that can encourage teachers to innovate (Marisana et al., 2023). Meanwhile, the learning house is a platform that focuses on developing student potential so that students can learn independently through the materials and materials available (Wahdani et al., 2023). Both platforms focus on developing the potential of students and teachers by utilizing technology to answer the challenges and needs of education in the digital era.

The independent learning curriculum has three objective indicators: developing soft skills and character, focusing on essential material, and flexible learning using technology. The independent curriculum applies a flexible learning concept to focus more on student development in achieving learning goals (Pertiwi et al., 2023). Therefore, the independent curriculum can carry out learning activities synchronously and asynchronously (Martani, 2023).

The currently available asynchronous-based learning platforms only carry out unidirectional learning, such as giving assignments or grades to students and collecting assignments without interaction, for example, Google Classroom (Kemdikbud, 2020). Meanwhile, synchronous learning platforms only occur via video conference (Zoom, Google Meet) or WhatsApp (Abdillah, 2021). This platform cannot produce visual effects that can depict the virtual world like the real world so that students and teachers can experience classroom learning through cyberspace (Pustikayasa, 2021).

The currently available platforms have limitations because teachers cannot monitor student activities during teaching and learning activities (Asmiyunda et al., 2023). If the teacher does not require students to be on camera, many students will leave the conference room and not pay attention to the lesson (Pustikayasa, 2021). The use of conference media is considered less effective in its implementation, so it requires innovation to optimize technology-based learning systems (Abdillah, 2021).

One of the breakthroughs that can be used in technology-based learning is the cyberspace metaverse. Cyberspace is a learning media that utilizes technology and is not limited by space and time so that learning can be done anywhere and anytime; this creates a more efficient learning concept (Anggoro & Sari, 2021). Meanwhile, the metaverse is a platform that can visualize the virtual world like the real world (Díaz et al., 2020). The cyberspace metaverse is a combination of platforms that creates a social network for teachers and students to interact virtually by replicating the actual learning experience in the classroom (Firdaus, 2023).

Implementing cyberspace metaverse in the education sector can create virtual classrooms so students can teleport virtually in the learning process (Hemmati, 2022). In addition, learning resources and learning processes can be integrated directly into one platform so that it does not require many applications as learning resources. The metaverse cyberspace platform allows users to feel sensations in a natural environment; this is needed in science learning, which requires interactive multimedia to provide students with experience in virtual scientific investigation activities (Nurcahyo, 2020).

Science learning that utilizes the metaverse cyberspace platform must be integrated with daily life to achieve the three indicators of an independent learning curriculum. Local wisdom is one aspect of daily life and can be integrated into the metaverse cyberspace platform (Firdaus, 2023). Local wisdom is a cultural concept in community life that is shared based on the formation of local culture in understanding the natural environment in which one lives and is hereditary (Setyawan, 2019).

Metaverse cyberspace needs to be improved in utilizing technology in learning. It can erode student character because there is no direct supervision by the teacher, making cheating possible (Alifiyah, 2023). Artificial intelligence (AI) in this platform uses sensors that can recognize faces, bodies, and human movements so that technology can supervise students in the learning process (Rathore, 2023).

Based on the problem description above, it is essential to carry out this research. This research creates an innovation, namely a cyberspace metaverse platform connected to artificial intelligence (AI), which can complement the shortcomings of the independent learning curriculum. Implementing the metaverse cyberspace platform connected to artificial intelligence (AI) in learning science material based on local wisdom creates meaningful and cultural learning.

METHODOLOGY

The method used in this research is a netnography method, which is descriptive qualitative. Netnography is a research method that utilizes information technology to obtain observation and interview data (O'Donohoe, 2010). The subjects of this research were 100 respondents consisting of college students teaching in Indonesia. The respondent sample selection technique uses random sampling by taking samples from each school.

The data collection technique in this research is observation of the use of digital media in the independent learning curriculum, in-depth interviews, and library research. The data analysis technique used in this research is interpretive analysis from observations and in-depth interviews. Interpretive analysis aims to analyze in depth and detail to obtain meaning from the respondents' real experiences to understand the research object (Smith et al., 2009).

RESULTS AND DISCUSSION

The existence of an independent learning curriculum with various platforms applied in the learning process has given rise to various kinds of responses. It has both negative and positive impacts in its implementation. Based on the research results, there are four main points of discussion, namely regarding the use of the independent learning platform, the implementation of science learning based on the independent learning platform, character formation through the independent learning platform, and innovation as a solution to problems that arise in implementing the independent learning curriculum.

Use of the Merdeka Belajar Platform

The research results through observation of the independent curriculum platform and in-depth interviews with teaching campus student respondents regarding the use of the independent teaching platform can be seen in Figure 1.

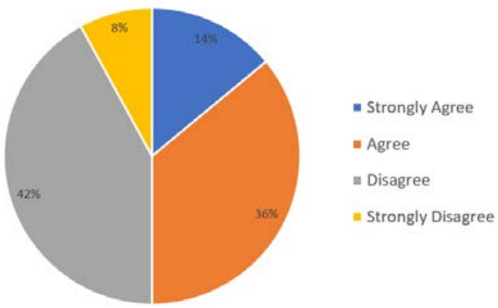


Figure 1. Teachers' use of the independent teaching platform

The diagram in Figure 1 shows that as many as 14% of respondents and 36% of respondents strongly agreed and agreed that the independent teaching platform made it easier for teachers to find and develop innovative learning methods. The independent teaching platform provides many features, such as assessments, teaching media, learning videos, and creative learning materials that teachers can apply during the teaching and learning process. It shows that the independent teaching platform can facilitate teachers to innovate in the learning process. An independent teaching platform supports the implementation of the independent curriculum, which aims to improve the quality of education in Indonesia (Iskandar et al., 2023).

42% and 8% of respondents stated that they neither agreed nor disagreed that teachers could utilize the independent teaching platform. Respondents stated that the actual situation was that many teachers needed to be made aware of the independent teaching platform. Apart from the need for more socialization of the use of the independent teaching platform, the age and internet network conditions in the 3T area also mean that teachers are unable to utilize the platform. The limited internet network in the 3T area is a challenge for the digitalization of education, which causes education in Indonesia to be unequal (Suryaningrum, 2023).

The independent learning curriculum focuses on learning patterns and developing students' competencies (Santoso et al., 2023). Flexible learning patterns utilize various platforms that can be accessed by students, such as home learning, Google Classroom, video conferencing (Zoom, Google Meet), WhatsApp, and other networking-based learning platforms (Siregar et al., 2023). The research results through observations of various independent learning platforms and in-depth interviews with respondents can be seen in Figure 2.

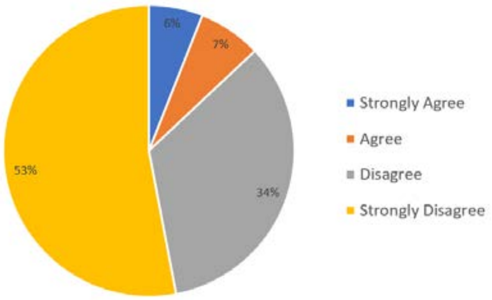


Figure 2. Use of various learning platforms that students can access

Based on the diagram in Figure 2, it shows that as many as 53% of respondents and 34% of respondents stated that they did not agree or disagree with the use of various learning platforms. The large number of diverse platforms with different functions means that teachers and students often need more memory space on smartphone devices. Using these various learning platforms also requires a strong internet network. Of course, it disrupts the implementation of learning because teachers and students must have smartphones that have ample storage capacity to access various learning platforms. Using various platforms will create a gap for students with low economic conditions because they need help to afford smartphones with large storage capacities, which are unsuitable for areas with weak internet networks (Ramadani et al., 2023).

As many as 6% of respondents and 7% of respondents stated that they strongly agreed and agreed because they felt that the benefits of the various platforms available made it easier for teachers and students to carry out distance learning so that learning could be carried out flexibly. Learning platforms with many types make it easier for teachers to choose a variety of platforms so that learning is not boring. It shows that the various learning platforms currently available can be utilized by users who have smartphones with ample storage space. However, the use of various platforms that have different functions could be more efficient and adequate for teachers and students who have smartphones with small storage capacities. So, we need an innovative platform that can accommodate various media types so that students can download only a few learning platforms.

Implementation of Science Learning Based on the Independent Learning Platform

The use of various platforms in implementing the independent learning curriculum influences the implementation of learning, one of which is learning science material. The research results through observation of the implementation of science learning based on the independent learning platform and in-depth interviews with respondents can be seen in Figure 3.

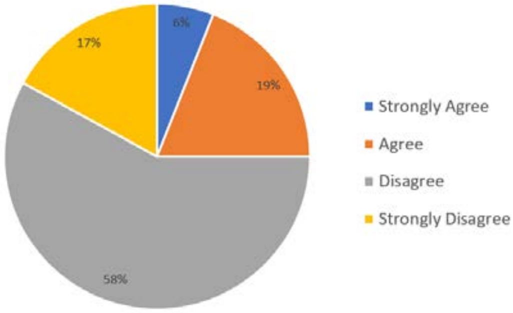


Figure 3. Teacher implementation in visualizing science material on digital platforms

The diagram in Figure 3 shows that as many as 58% of respondents and 17% of respondents stated that they disagreed and disagreed with implementing science learning on digital platforms because, currently, teachers cannot visualize science practicum on digital platforms. Hence, science learning is only limited to theory. Science learning based on digital platforms cannot provide real experiences such as direct practicums, so students must understand the concepts. Science learning, dominant with curriculum activities, aims to increase understanding of science concepts through experience. Therefore, a platform is needed that facilitates students to carry out online practicums (Indriyani et al., 2023).

As many as 6% of respondents and 19% of respondents stated that they strongly agreed and agreed with the implementation of science learning on digital platforms because teachers can use animations or practical videos so that students can understand concepts. It shows that the dominant science material with practicum can be implemented through a digital platform with practicum visualization through animation or other media. Currently, science learning has yet to be optimal because the implementation of learning on digital platforms cannot visualize science practicum, so innovation is needed in the form of a platform that can visualize practicum in a virtual space similar to the real world.

Character Building through the Merdeka Belajar Platform

An indicator of the independent learning curriculum is the development of student character (Nurdiana Sari et al., 2023). Therefore, observations are needed regarding the formation of student character when using the independent learning platform. The research results through observation of the formation of honest and disciplined character through the independent learning platform and in-depth interviews with respondents can be seen in Figure 4.

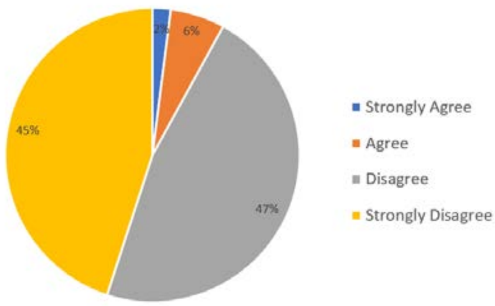


Figure 4. Formation of honest and disciplined character through the independent learning platform

The diagram in Figure 4 shows that 47% of respondents and 45 respondents stated that they neither agree nor disagree that the independent learning platform can shape students' honest and disciplined character. This is because digital-based independent learning platforms mean that students need more direct supervision, thereby allowing students to cheat in the learning process. In addition, with digital learning, students are laxer in their responsibilities and less disciplined, so digital learning can shape students' character. There is no supervision by teachers or parents in using technology, so that students generally misuse technology. Many students do not participate in synchronous or asynchronous learning because learning via digital platforms is only limited to providing material and assignments, so students get bored and prefer to play games.

As many as 2% of respondents and 6% of respondents stated that they strongly agreed and agreed because digital learning carried out at home could be directly supervised by parents so that it could shape students' character. Apart from that, there is a working time limit so that students can work in a structured and systematic manner. It shows that learning via digital platforms currently cannot shape students' honest and disciplined character due to the lack of direct supervision. Based on research by Alifiyah (2023), using digital platforms as learning media causes a crisis in character education. Therefore, innovation is needed in the learning platform to supervise students even though they carry out learning independently.

Innovation as a Solution to Independent Learning Curriculum Problems

The independent teaching platform has yet to be utilized optimally. Many teachers need more facilities and infrastructure to implement the learning methods found on the independent teaching platform (Arnes et al., 2023). The existence of the metaverse cyberspace platform can facilitate teachers to implement innovative and creative learning methods. The metaverse cyberspace platform provides centralized learning media, making it easier for teachers to operate it (Díaz et al., 2020).

Apart from that, using the metaverse cyberspace platform in learning is a solution to the many independent learning platforms on one device, causing storage space to be full and inefficient. Using the metaverse cyberspace platform is an excellent opportunity to complement implementing an independent curriculum focusing on independent learning (Muslim, 2023). The advantage of metaverse cyberspace is that it can create a centralized platform that makes it easier for students and teachers to carry out learning (Indarta et al., 2022). It is supported by data on the development of metaverse discussion topics and popular searches on YouTube and Google, as shown in Figure 5.

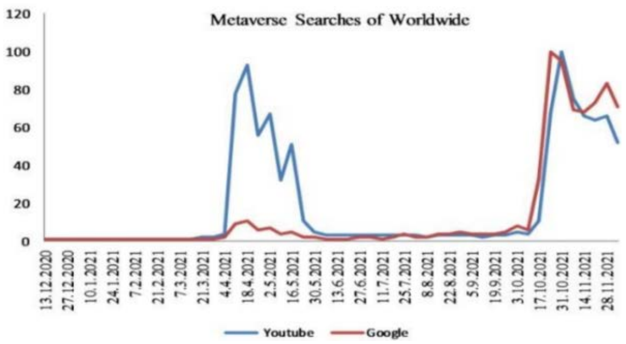


Figure 5. Popular Metaverse searches on YouTube and Google Source: (Narin, 2021)

The metaverse cyberspace platform creates a communication environment through computer networks by presenting interactive software control visual effects using modern software by connecting text, sound, graphics, photos, and videos in a digital representation (Díaz et al., 2020). Learning through the metaverse cyberspace platform contributes to more conscious assimilation and deeper understanding of the material, saving learning time, efficiency in learning, and visual information that can arouse students' motivation and interest in learning (Yazdani et al., 2020). Implementing the metaverse cyberspace platform is characterized as an exchange between humans and avatars in a three-dimensional virtual space that can engage in social activities like the real world in cyberspace (Hyun, 2021). It creates a visual state of the classroom in cyberspace to increase student learning motivation.

The metaverse cyberspace platform is an innovation in learning that can optimize distance (online) learning, which is currently implemented through the independent learning curriculum so that students can learn independently (Muslim, 2023). Using the cyberspace metaverse platform allows students to develop their abilities through interactive learning that is not limited by space and time (Indarta et al., 2022). The metaverse cyberspace platform has a high chance of implementing the independent curriculum because this platform supports the development of student potential and makes it easier for teachers and students to carry out learning (Mustofa & Mariati, 2022). A visualization of the metaverse cyberspace platform in creating classrooms in cyberspace is shown in Figure 6.

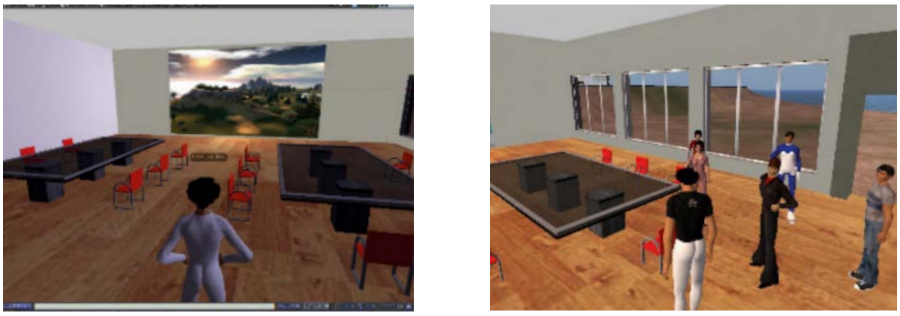
Figure 6. Visualization of student avatars present in class. Source: (Díaz et al., 2020). The virtual world as a resource for hybrid education. Avatar at platform cyberspace metaverse.

Metaverse cyberspace platform-based learning creates real-like learning in cyberspace (Yazdani et al., 2020). It, of course, can increase students' learning motivation. However, using the cyberspace metaverse platform still cannot directly control student activities. Therefore, it is necessary to use artificial intelligence (AI). Technology supported by artificial intelligence (AI) can provide sensors for metaverse cyberspace platform users (Rathore, 2023). Face and gesture detection sensors can recognize and ensure that students are in front of the camera (Kuklin et al., 2023).

Face and gesture detection sensors can control students using metaverse cyberspace platforms (Dimitriadou & Lanitis, 2023). The metaverse cyberspace platform connected to artificial intelligence (AI) as a facial detection sensor and gesture recognition can control students so they do not cheat and are disciplined (Salamah et al., 2022). The cyberspace metaverse platform connected to artificial intelligence (AI) has a high opportunity to implement the independent curriculum because it can minimize cheating and thus shape students' character to be disciplined and honest following the Pancasila student guidelines (Kemdikbud, 2020). The metaverse cyberspace platform connected to artificial intelligence (AI) can create innovative learning in line with current developments without eliminating the student guidelines of Pancasila as the nation's identity. The facial recognition sensor using artificial intelligence (AI) can be seen in Figure 7.

Figure 7. Visualization of facial recognition sensors. Source: (Kuklin et al., 2023)

The metaverse cyberspace platform can facilitate independent learning, one of which is science learning. Science material that studies living things and the elements of life in all their complexity can gain knowledge through experimental activities to find new findings (Priyani & Nawawi, 2020). As virtual learning technology develops, experimental activities will be more accessible using virtual technology (Martani, 2023). The metaverse cyberspace platform can create an online practicum atmosphere like in the real world (Suzuki et al., 2020). The cyberspace metaverse platform connected to artificial intelligence (AI) on science material in conducting natural virtual experiments allows students to collaborate in a virtual room, which can be seen in Figure 8.



(a) (b)

Figure 8. (a) Experiment room (b) Students collaborate to create a project. Source: (Suzuki et al., 2020). Virtual experiments in metaverse and their applications to collaborative project: The framework and its significance

Apart from making it easier to carry out virtual experiments, the metaverse cyberspace platform integrated with local wisdom can also make it easier to learn science based on local wisdom and everyday life. Science learning integrated with local wisdom makes it easier for students to understand concepts and create meaningful learning without abandoning socio-cultural concepts so that they are not eroded by developments over time (Fauzi et al., 2022). It is because the cyberspace metaverse platform integrated with local wisdom can integrate technology with daily life, thereby creating digital literacy that does not eliminate elements of local culture. Integrating technology with culture and the social environment in science learning will become more meaningful, supported by ease of use, such as when playing online games (Jovanović & Milosavljević, 2022). The integration of technology and daily life on the metaverse cyberspace platform can be seen in Figure 9.

Figure 9. Student interaction with the virtual environment. Source: (Huynh-The et al., 2023). Artificial Intelligence for the Metaverse: A Survey

Using a metaverse cyberspace platform connected to artificial intelligence (AI) has excellent opportunities for implementing the independent curriculum. The metaverse cyberspace platform connected to artificial intelligence (AI) can create technology-based interactive learning and foster honest, disciplined, and responsible student character.

Implementing a metaverse cyberspace platform connected to artificial intelligence (AI) in science learning based on local wisdom can make technology-based learning more accessible and meaningful. It aligns with the objectives of the independent curriculum, namely flexible, technology-based learning, developing student potential through creativity and innovation, and building student character and culture (Arnes et al., 2023).

CONCLUSION AND IMPLICATIONS

Implementing the metaverse cyberspace platform connected to artificial intelligence (AI) in the independent curriculum has a good impact on the quality of education. The metaverse cyberspace platform can provide a variety of media, so it does not take up student storage space. The metaverse cyberspace platform based on local wisdom can integrate technology with everyday life and enable students to carry out practicums in cyberspace so that this platform supports science learning. Apart from that, the metaverse cyberspace platform connected to artificial intelligence (AI) solves the independent curriculum problem, namely the character education crisis. The presence of facial and movement sensors on the metaverse cyberspace platform connected to artificial intelligence (AI) can shape the character of students who are honest and disciplined in digital-based independent learning. Using the cyberspace metaverse platform connected to artificial intelligence (AI) in science learning based on local wisdom makes it easier for students to understand science concepts and create meaningful learning without abandoning socio-cultural values and character education so that they are not eroded by developments over time.

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The Study of Indonesian High School Students' Collaboration Skills: Student Self-Assessment

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Abstract. Collaboration skills are one of the most important skills in the 21st century. The concepts of collaboration skills include motivation, contribution, problem-solving, interaction with others, team support, preparedness, time management, team dynamics, reflection, role flexibility, and work quality. The purpose of this study was to describe the level of collaboration skills of high school/equivalent students in Indonesia. The instrument used was a CSAT (Collaboration Self-Assessment Tools) questionnaire totaling 11 categories. The instrument contains four answer choices in the form of questions about the collaboration skills category and open-ended questions. The questionnaire was distributed online via Google Forms to 325 students. Characteristics of students include those aged 15–18 years from various majors such as Science, Social Sciences, Languages, and others. Descriptive data analysis and simple coding. The results showed that 49% of the collaboration skills of high school/equivalent students in Indonesia were in the developing category, 40% were good, and 11% were emerging. Students' good intrapersonal skills include task quality and time management, while their good interpersonal skills involve contribution and interaction with others. In conclusion, students' ability to work together in teams has begun to evolve. Future research can develop various learning strategies and methods that can improve students' collaboration skills.

Keywords: Collaboration skill, interpersonal skills, intrapersonal skills, CSAT

INTRODUCTION

One of the 21st-century talents that should be owned and developed by students is collaboration. Collaboration skills have a brief definition, namely the existence of two or more people working together to achieve certain goals (Cooper et al., 2022; Møgelvang & Nyléhn, 2022; Saldo & Walag, 2020). In learning, collaboration skills are crucial for students, especially in solving problems. Previous studies have developed various learning models that can help improve student collaboration, for example, problem-based learning, project-based learning, and so on. These models are also recommended by the Indonesian government in implementing the latest curriculum "Curriculum Merdeka" from elementary to high school.

In education, the term "collaboration" is utilized indiscriminately (Friend, 2000). Each school's purpose description seems to include collaboration in which every group that meets is labelled as a collaborative team, and every classroom with two educators in charge of instruction is dubbed collaborative (Palmer et al., 2016; Friend, 2000).

Collaboration has been suggested across audiences (parents, support staff, volunteers, student teachers), practices (conferencing, teaming, evaluating), and venues (school-university collaborations, school-business collaborations, school-agency partnerships) (Gladstone-Brown, 2008; Friend, 2000). However, simply speaking the term does not always imply carrying out the action. Collaboration necessitates each individual's dedication to a common objective, a particular focus on interaction skills, and participants maintaining parity throughout their conversations (Cook & Friend, 1995). Collaboration does not happen as a result of a requirement from the administration, pressure from peers, or political correctness (Friend, 2000) as well as by proclamation. Otherwise, it must emerge from a comprehension of its promise and hazards, and only be able to be perpetuated as a system-level norm via professionals' purposeful utilization of suitable skills and understanding (Friend, 2000). Therefore, the collaborative process is not always simply not present every time professionals meet, and this is not an unreasonable expectation.

Miyake demonstrated that in collaboration, some accidental division of labour can happen: the individual who has more to say about the current topic takes the task-doer's role, while the other becomes an observer, monitoring the situation." The spectator can participate by critiquing and making topic-divergent gestures, which are not the task-doer's major tasks." 174 (Miyake, 1986). Similar findings have been reported by O'Malley (1987) with couples attempting to comprehend the UNIX C-shell command interpreter. This role allocation is determined by the nature of the activity and may alter often (Dillenbourg et al., 1996). In computer-assisted tasks, for instance, the person who operates a computer mouse is known as the "executor," while the other is known as the "reflector." Collaboration and collaboration diverge not in whether or not the task is spread out, but in how it is divided: in collaboration, the task is divided (hierarchically) into independent subtasks; in collaboration, cognitive processes can be divided (heterarchical) into interconnected layers (Molina et al., 2009; Dillenbourg et al., 1996). Coordination is only necessary when constructing incomplete outcomes in collaboration, but collaboration is a coordinated, synchronous action that is the result 3 of a continuous endeavor to develop and sustain a common picture of an issue (Baker, 2015; Dillenbourg et al., 1996).

A difficult topic in educational research and practice is how to evaluate students' collaborative work in a way that supports constructive collaboration (Baker, 2015). Giving learners feedback on their achievements is an important part of teaching, but there is a catch-22 here: on the one hand, teachers must evaluate individual student skills, yet this cannot be done if assessment only concerns the product of collaboration; on the other hand, evaluating one's contribution to teamwork emphasizes individual contributions, potentially to the disadvantage of collaboration itself (Lenkauskaitė et al., 2020; Mandinach & Gummer, 2016; Baker, 2015). Collaboration involves more than just the joining or combining of distinct tasks; hence, judging each person's contribution from the total outcome will be difficult (Wilson & Daugherty, 2018; Baker, 2015). Personal and team evaluation (rating individual development based on individual examinations following collaboration, as well as the quality of the joint result) is typically used by teachers. Hinyard et al (2019) used the Self-Assessed Collaboration Skills (SACS) tool to measure student collaboration skills. SACS was piloted on students taking interpersonal education courses. The final SACS validation results obtained 11 item scales consisting of three dimensions of collaboration namely information sharing, learning, and team support.

On the other hand, Ofstedal and Dahlberg (2009) have developed a tool that so-called the Collaboration Self-Assessment Tool (CSAT) to measure collaboration skills in various fields. CSAT arose from a thorough examination of research in fields such as enterprise, medicine, information technology, and education, as well as the realization that there was not much knowledge accessible to help instructors understand, assess, and enhance their collaboration abilities. For the purpose of supporting effective interactions between teacher candidates and collaborating teachers, a group of teacher educators initiated the process of defining the fundamental elements of collaboration in educational settings. The

CSAT was created as a consequence of 18 months of development and refinement. The very first version of the collaboration tool was titled Collaborative Work Skills for Co-Planning and Co-Teaching, and it identified ten critical collaboration skills encompassing contributions, kaizen (continuous improvement), time management, representation, problem-solving, group process, interactions with others, role flexibility, reflection. The latest version of CSAT consists of 11 categories of collaboration skills, namely contribution, time management, problem-solving, team support, preparedness, team dynamics, role flexibility, quality of work, motivation, interactions with others, and reflection. The CSAT instrument is equipped with a rubric consisting of a scale of 1 – 4 (1 = not at all, 4 = to a great extent) and examples of collaboration in each of these categories.

In the CSAT developed, collaboration skills are classified into two categories: interpersonal skills and intrapersonal skills (Ofstedal & Dahlberg, 2009). Interpersonal skills are skills connected to interpersonal relationships, such as two-way communication and offering objective feedback (Stiehl et al., 2023; Ofstedal & Dahlberg, 2009). In contrast to intrapersonal skills, which are associated with an individual's internal qualities, such as self-confidence (Torsney et al., 2023; Carroll et al., 2022; Ofstedal & Dahlberg, 2009). Contribution, team support, problem-solving, team dynamics, and relationships with others are the interpersonal skills categories. Meanwhile, intrapersonal skills include motivation/participation, work quality, time management, preparedness, role adaptability, and reflection.

The CSAT instrument was chosen for this study because it has been well established and appropriate for measuring students' collaboration abilities. This instrument was written in English before being translated into Indonesian. However, little study has been conducted to date on the level of collaborative abilities among Indonesian high school/equivalent pupils. The context of this study is to determine the level of collaboration abilities among high school/equivalent students from diverse Indonesian sample schools. This questionnaire was successfully completed by 325 pupils from more than 20 schools with the help of teachers and colleague.

RESEARCH OBJECTIVES

Collaboration skills are very important for students' futures. Students who are skilled at collaborating tend to share ideas in solving problems. This is the background for raising this topic. This research aims to determine the collaboration skills of high school/equivalent school students in Indonesia.

METHODOLOGY

This research is descriptive qualitative research. Descriptive research is a research method that focuses research on observations and phenomena of certain populations or situations. This research aims to provide a comprehensive picture of the collaboration skills of high school students from various schools in Indonesia.

Participants

This questionnaire was distributed to several samples of students from high school or equivalent. The distribution of students who filled out the questionnaire can be seen in Figure 1. The sample consisted of 325 students, accounted for 66% female and 34% male. Their age range is 15 years to 18 years. The largest sample came from the province of West Sumatra, namely 171 students, while the areas of Jakarta and East Java were only filled by 1 student each. They are from the first year (60%), the second year (30%), and the third year (10%). The backgrounds of the students' majors varied such as Science (49%), Social Sciences (13%), Languages (5%), undetermined (24%), and other majors (9%). It is noteworthy that students who do not have a major are in the first year. Since the Indonesian curriculum is currently changing the education system, students can therefore choose majors in their second year.

Figure 1: Distribution of students who filled out the questionnaire (Map source: https://www.worldatlas.com/maps/indonesia)

Research Tools

The instruments used were taken from the development of a collaborative self-assessment tool (CSAT) by Ofstedal and Dahlberg (2009). This instrument is very detailed and suitable for independently assessing students' collaboration skills. Initially, original instruments in English were translated into Indonesian before being distributed to students. In addition, the instrument includes open-ended responses about the reasons students chose these answers. CSAT is grouped into two major groups: interpersonal skills and intrapersonal skills. Intrapersonal skills are divided into 6 categories, namely motivation, quality of work, time management, preparedness, role flexibility, and reflection, while interpersonal skills are divided into 5 categories, namely contribution, team support, problem-solving, team dynamics, and interaction with others. CSAT scoring rubric on a scale of 1 to 4 (1 = not at all, 4 = to a great extent). These three categories are concluded based on each student's score (10-25: Collaboration skills are emerging, 26-34: Collaboration skills are developing, 35-44: Collaboration skills are established) with a maximum score of 44.

Data Collection

Data collection was carried out for nine consecutive days using Google Forms. The number of students who filled out the questionnaire from the first day to the last day accounted for 42 students, 68 students, 50 students, 21 students, 58 students, 4 students, 12 students, 56 students, and 14 students. Students are free to fill out a questionnaire during school hours or outside school hours. This is because there are several schools that do not allow their students to bring smartphones to school. There are several CSAT categories whose definitions are given in the Google form so that students are not confused when filling out the questionnaire.

Data Analysis

The data analysis was carried out in stages. The first stage is the analysis of data originating from the Google form, while the second stage is the analysis of the student's open-ended question transcript. Data is analysed automatically with Ms. Excel to produce relevant information in the form of tables and graphs. To make it easier to calculate the data, we carried out simple coding, especially on the answer scale, gender, major, and school origin. In the second stage, the researcher collected all student responses with Ms. Word and grouped them by category. In other words, each CSAT category has 325 student answers. The transcript is very helpful in making network items, as shown in Figure 3. This analysis is done manually with simple coding.

RESULTS AND DISCUSSION

Results

Table 1 illustrates the results of a study on collaboration abilities among high school/equivalent students from diverse samples in Indonesia. The CSAT yields unambiguous results on students' capacity to collaborate. Each category includes four scales ranging from 1 to 4. The number of scales received by each student is used to interpret the data. If the overall student scale is 10–25, it will indicate that their collaboration abilities are improving; 26–24 shows that their collaboration skills are developing; and 35–44 exhibits that their collaboration skills are already strong. The following table shows the proportion of outcomes for each category.

Table 1: Presentation on the development of collaboration skills of high school students (N=325)

No	*Category*	*1 (%)*	*2 (%)*	*3 (%)*	*4 (%)*	*Mean*	*SD*
	Intrapersonal						
1	Motivation	10.2	28.6	41.2	20.0	2.71	0.901
2	Quality of Work	5.3	21.5	32.3	40.9	3.09	0.910
3	Time Management	5.2	11.1	40.6	43.1	3.22	0.841
4	Preparedness	7.7	22.5	41.5	28.3	2.90	0.899
5	Role Flexibility	20.3	17.2	28.3	34.2	2.76	1.129
6	Reflection	11.7	11.7	44.0	32.6	2.98	0.955
	Interpersonal						
7	Contribution	8.0	20.6	25.8	45.6	3.09	0.988
8	Team Support	5.2	30.8	37.5	26.5	2.85	0.873
9	Problem Solving	5.2	22.8	43.4	28.6	2.95	0.850
10	Team Dynamics	18.2	30.8	33.8	17.2	2.50	0.980
11	Interaction with others	2.5	12.0	23.1	62.4	3.46	0.799

According to Table 1, The scale percentage (1-4) with the highest percentage is derived from many criteria. The area of role flexibility received the highest proportion (20.3 %), while interaction with others received the lowest percentage (2.5%). The areas with the highest percentages in scale 2 (30.8%) are both team support and team dynamics, while time management has the lowest number (11.1%). The category with the highest percentage in scale 3 (44%) is reflection, whereas the one with the lowest number (23.1%) is interactions with others. Most students (62.4%) picked scale 4 (interactions with others), while the least people (17.4%) chose team dynamics. The engagement with others category has the highest average, at 3.46. As a result, the most popular student collaboration abilities are those that involve connecting with others.

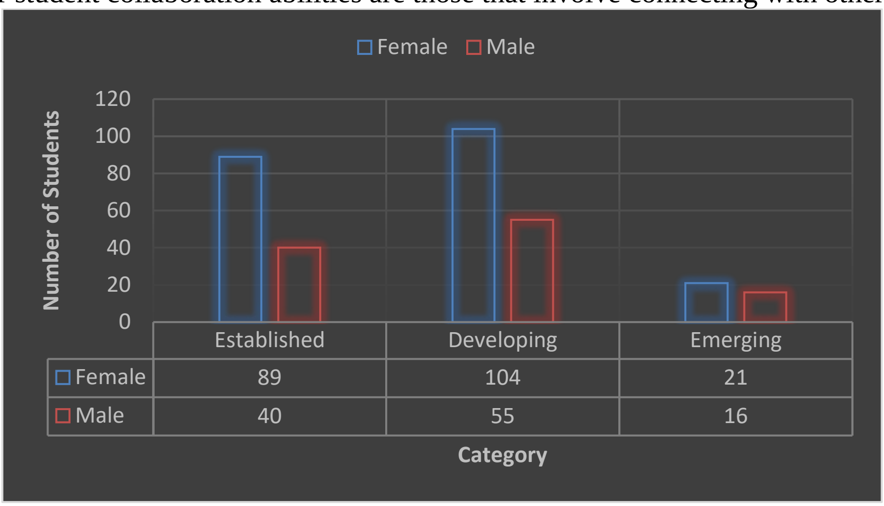

Figure 1: The development of high school student collaboration based on gender

Figure 2 depicts the findings of a gender poll on student collaboration skills. The level of student collaboration abilities is classified into three categories: established, developing, and emerging. Student collaboration skills are mostly in the developing stage (49%). While pupils in the established group are 9% smaller than those in the developing category. Only 11% of pupils still perform at the lowest level of teamwork. That is, the instructor must provide additional instruction to these kids in order to increase their teamwork abilities. In the developing category, male and female students have nearly identical collaboration skills. Overall, high school students' teamwork abilities are still growing and may be enhanced.

Discussion

An analysis of student collaboration skills was performed by distributing self-assessments, namely the CSAT. This questionnaire contains eleven categories of collaboration skills, i.e., motivation, contribution, role flexibility, time management, team support, reflection, team dynamics, problem-solving, preparedness, interaction with others, and quality of work. Each category is given four forms of statements containing possible student answers. Students are asked to fill in the reasons after choosing one of these options. This strengthens the results of the student collaboration skills survey. There are three groups of student skill levels: emerging, developing, and established. In general, students' intrapersonal skills that were found to be good were task quality and time management, while students' interpersonal skills that were found to be good were contribution and interaction with other people.

The ability mastered by students is interaction with other people. Many realise that the ability to interact with friends is needed, especially when completing projects. In accordance with this meaning, humans are social creatures (Lima de Miranda & Snower, 2020; Moghtader & Shamloo, 2019). Each member needs suggestions, ideas, criticism, information, experiences, and solutions from other members. Complex problems will become easier when solved together. This is in agreement with the opinion of Heller and Heller (1996), who believe that the purpose of group problem-solving is that each individual contributes a strategy to find solutions to problems. Interaction and communication skills also play an important role so that misunderstandings do not occur (Hinner, 2017).

Interactions between members can result in the sharing of ideas or opinions. Collaboration skills are closely related to contribution skills because contribution itself is part of that skill. The learning process is meaningful when students are able to apply concepts to solve problems. For example, in a STEM project, at least four students are experts in the respective fields of science, technology, engineering, and mathematics. That is, each student has a clear role so that they remain active in learning. Students who become leaders can be replaced as members, and vice versa. Perhaps this ability has not emerged among many students. This is evidenced by the survey results in Figure 2, which show that the role flexibility category is still developing.

Based on the results of preliminary observations by Santoso et al. (2021), the collaboration skills of high school students from three schools in East Java are still relatively low. Zhuang et al. (2008) summarised five concepts of collaboration/teamwork skills, including 1) process skills such as solving problems, making plans, and making decisions together; 2) skills in working together between teams and being able to adapt; 3) providing support; 4) resolving disagreements; and 5) role flexibility. Student collaboration skills are good if this concept has become a habit for students. But in fact, there are still high school students who are not confident in expressing opinions, are not active in learning, do not contribute anything to their groups, and so on. This can be seen from the results of open-ended questions where some students convey their weaknesses in learning in groups. The Indonesian government has realised the importance of collaboration skills for students. The proof is that learning from elementary to secondary levels must be project-based (Wasimin, 2022).

Students are given the option to submit further feedback on their collaborative abilities using the Google form. This can aid in reading pupils' minds, particularly when it comes to collaborative projects. The categories on the right side are related to interpersonal abilities, and vice versa. The categories on the left side are related to intrapersonal abilities. CSAT open-ended questions provide a network of connected concepts (see Figure 3). Collaboration skills are grouped into two main parts, namely interpersonal and intrapersonal skills. In general, students already understand the meaning of these categories. Each category contains several terms, ranging from 7 to 16 terms.

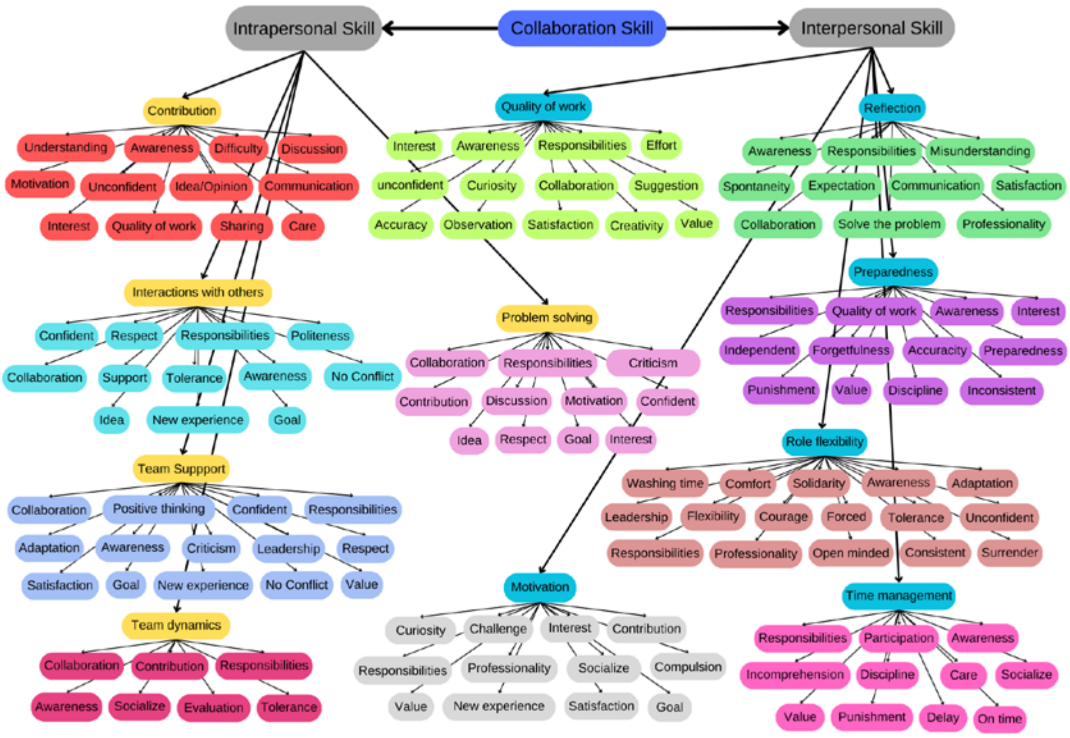

Figure 2: Themed results of the open-ended responses

Reflection

Reflection is giving an opinion, both input and criticism, about the actions that have been taken. In learning, students can do self-reflection to see the development of their collaboration skills in a group (Weinberg et al., 2021). Self-reflection aims to align actions, character, and abilities (Rashidova et al., 2023; Travers et al., 2015). Students generally say that reflection is related to awareness, responsibility, misunderstanding, spontaneity, hope, communication, satisfaction, collaboration, problem-solving, and professionalism. Self-reflection provides an opportunity for students to introspect themselves so that they become better (Rashidova et al., 2023).

"*I tend to be more conscious of self-reflection when things are not going well*"

Quality of Work

According to Gallie (2023) the quality of work can be emphasized in terms of employees, objectives, and implications. First, quality of work emphasizes what employees need at work. Second, quality of work emphasizes reasons for improving employee skills. Third, the quality of work focuses on psychological well-being and health. In learning, students need to be aware of their responsibilities in carrying out tasks that have been arranged by the group leader (Bubb & Jones, 2020). There are students who realize that it is important to discuss subjects with friends, especially those that are less interesting. This aims to improve the quality of the task.

“It is a task that maybe I am not interested in, so it needs more effort to improve its quality. So, every time I finish this assignment, I will do more research on what I have done.”

Role Flexibility

Role flexibility is the ability to change roles from leader to member (Borko et al., 2017; Ofstedal & Dahlberg, 2009). This ability can be taught to students during group discussions; they get the role of chairman, and on other occasions, they may just become members. According to Cooper (2005), leaders should master social communication to entertain their subordinates. In line with the opinion of students, good leaders are those who are able to direct their members.

"A leader does not mean a chairman; a good leader is one who can communicate and direct his group. Sometimes that is how I feel”

Motivation

Motivation usually appears when the field is in demand (Zou et al., 2021). However, always being involved in group activities, even if they are not very interested, is good motivation (Ofstedal & Dahlberg, 2009). At school, it is rare for students to like all subjects. Student opinion polls show that they are still trying to understand the task they are responsible for, even though the task is not of interest. Another opinion states that being involved in a project that is less desirable can add new experiences.

“I am not only not interested, but I do not understand the task in a particular field. I still try to get involved and understand the task”.

Time Management

The keyword for time management is to ensure that the tasks for which you are responsible have been completed and do not need the help of others (Ofstedal & Dahlberg, 2009). This shows that they have good time management. In fact, time management is one of the problems students face in tertiary institutions (Pedroso et al., 2022). Student opinion polls state that time management is related to discipline in submitting assignments because it greatly affects their grades.

"Because assignments are important for increasing grades, and I do not want my grades to be low just because of assignments that I did not do because I was not disciplined in time. So, I always try to complete my assignments on time."

Preparedness

Readiness of students to work on a given project. Good preparation will reduce the risks that will occur, for example, the needs of groups left behind at home. A high level of preparedness can increase student motivation (Prijambodo & Lie, 2021). Many students say that they have to bring the things needed for a project because it is their own responsibility.

“I bring the materials needed and am always ready to make assignments because I have to be responsible, so I do not look for those materials again.”

Contribution

Students are expected to be able to share ideas and information on certain tasks (Ofstedal & Dahlberg, 2009). This is in line with the opinion of some students in which contributions can improve project quality because students share knowledge and opinions. In fact, the contribution of students to learning is a positive activity apart from being present and doing assignments (Bowden et al., 2021). So, they are aware that contribution is important in learning activities, especially in groups.

“Giving each other ideas or information while working on a project may, in my opinion, produce good results for these projects.”

Problem-solving

Students are expected to be active in finding solutions to problems given by the teacher. According to Heller and Heller (2001), the benefits of solving problems in groups are that problems that look complex can be solved together, and students are free to convey appropriate strategies to solve these problems. Many students state that problem-solving is important to find a solution to a problem and is a good form of communication with various ideas. Problem-solving is one of the 21st-century skills (Szabo et al., 2020).

“I am happy to provide ideas and opinions to discuss in order to get solutions to problems and accept other people's opinions without reproach.”

Team Support

Each member is responsible for the group's needs (Ofstedal & Dahlberg, 2009). Students state that team support is done to avoid conflict and achieve common goals. Another opinion says that conducting group discussions requires responsibility and leadership. There are students who are aware of giving criticism to group projects for the sake of group success, even though at first, they are not used to it.

“Because when I am in a new environment, it is difficult for me to adapt, let alone criticize. But if it really is to be criticized, I will venture to question the success of a group.”

Interaction with others

In interacting with other people, we should speak clearly, carefully, and professionally (Binkley et al., 2012). Many students think that when interacting with friends, it is better to have a good attitude, such as respecting their opinions. In other words, respect for others can take the form of listening, saying thank you, and providing support for their efforts (Ofstedal & Dahlberg, 2009).

“I respect my friends, and I always pay attention to the efforts they make. Because it is important for people to respect us too.”

Team Dynamics

Group dynamics is believed to be an important part of sports psychology because it can represent changes, actions, and processes that occur within and between groups (Reyes-Hernández et al., 2021). Overall, team dynamics relate to the contributions made to achieve common goals. This is in line with the student's opinion poll about their awareness of inviting friends who are not yet active in discussions.

“I often pay attention to team dynamics and encourage team members who were not active before. But there were also times when I was too focused on the end result of the project or task and ignored the less positive team dynamics”.

CONCLUSION AND IMPLICATIONS

This research completely examines the collaboration skills of high school students in Indonesia. In collecting data, students assess themselves according to the indicators mentioned. This assessment is a self-assessment of collaboration skills as a formative assessment. The research results showed that 49% of the collaboration skills of high school/equivalent students in Indonesia were in the developing category, 40% were good, and 11% were emerging. These three categories are concluded based on each student's score (10-25: Collaboration skills are emerging, 26-34: Collaboration skills are developing, 35-44: Collaboration skills are established) with a maximum score of 44. Overall, students have achieved collaboration skills on the indicators of interacting with other people, while the team dynamics indicators have not been mastered by students. Based on the results of open responses, students realized that it is important to carry out good collaboration such as sharing ideas, solving problems, taking roles, and so on.

Collaboration skills are not only needed by students in learning. However, students who are used to collaborating will use their abilities in the workplace later. One of the requirements needed in the world of work is being able to collaborate in a team. Therefore, students are expected to master collaboration skills since school. The results of this research provide a general picture of the profile of Indonesian students' collaboration skills at high school/equivalent level. The findings of this research can contribute to further research and teachers to develop learning models/approaches that can train students' collaboration skills.

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