Navigating Learning Differences: the Role of Mind Mapping in Fostering Inclusivity in Science Education

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ABSTRACT:

This study thoroughly scrutinizes the utilization and influence of mind mapping (MM), as a teaching tool in science education, particularly focusing on its application for students with special educational needs (SEN). We investigated how employing MM techniques impacted students' learning abilities through mixed methods, using quasi-experimental design and semi-structured interviews. The findings revealed that the comparison scores before (pretest) and after (posttest) the intervention using Popplet as a MM tool showed improvements for both control and experimental student groups. Additionally, by utilizing thematic analysis to explore students' experiences using MM, two main themes emerged: (1) adaptive learning strategies and (2) between individual and collaborative learning Feedback from students highlighted how MM can enhance memory and presentation skills, although issues related to design features and accessibility may challenges students with SEN. This paper is the first research exploring how mind mapping is accessible for Indonesian inclusive higher education, particularly for students with visual impairments. Physical guidance and verbal instruction were effectively used to explain the mind mapping concept and the spatial representation and relationship for students with visual impairments. This study emphasizes the significance of utilizing tools that cater to diverse learning styles and requirements to promote inclusivity in educational practices.

Keywords: Mind Mapping, Inclusive Education, Visual Aids, Science Classroom

INTRODUCTION

The use of mind mapping (MM) tools in education has received praise for its ability to improve learning outcomes. Mind mapping is a technique that helps organize ideas and concepts in a way that mirrors how our brains process information (Buzan & Buzan, 2010; Erdem, 2017). This study focuses on the application of mind mapping in science classrooms, especially looking at its benefits and accessibility for students with special educational need (SEN). Previous studies (Beal & Hontvedt, 2023; Stokhof et al., 2020; Wu & Wu, 2020; Zheng et al., 2020) shown the positive learning outcomes from the integration of MM during lessons. While previous research (Al-Jarf, 2011; Moytzouri, 2019; Polat & Aydin, 2020) has highlighted the aspects of MM for memory enhancement, creativity, and understanding there is limited exploration into how students with diverse learning needs can use and benefit from such tools. As education moves towards inclusivity and ensuring access to resources, it is important to evaluate tools not only based on their educational value but also on how well they can be adapted to different learning preferences and needs. Research often focuses on the cognitive benefits for the general student population (Adodo, 2013; Al-Jarf, 2009, 2011; El Shaban, 2022; Feng et al., 2023; Fiktorius, 2013; Jones et al., 2012; Koznov & Pliskin, 2008; Shih et al., 2009; Zheng et al., 2020), often overlooking the specific challenges faced by SEN students. This oversight signals a critical gap in pedagogical research that fails to consider students with SEN and the equitable effectiveness of MM across different learning abilities.

The current study stems from the imperative to bridge these gaps by exploring MM's impact on diverse students using Popplet. It is crucial to understand how such educational tools can be optimized not only to support conventional learning paradigms but also to cater to the diverse requirements of SEN students. This inclusive approach is particularly relevant in science courses at the university level, in which the complexity of content and the need for detailed comprehension are important. The research questions in this study are follows:

(1) Is there a difference in science class scores between students who participate in MM and those who do not when controlling for pretest and posttest scores?

(2) What are SEN and typical students' experiences of using visual MM in enhancing understanding of the course?

LITERATURE REVIEW

The diversity of students' learning styles, needs, and characteristics in the field of science education calls for teaching methods that cater to all students, including those with learning needs. MM, a tool for organizing information has been recognized for its ability to enhance comprehension and memory of scientific ideas. This review delves into the impact of MM on promoting inclusivity in science education, specifically highlighting its advantages for students with learning needs.

Exploring Mind Mapping and Learning Variances

MM is a method that visually arranges information, making it simpler for students to grasp and remember concepts. According to Buzan and Buzan (2010), mind maps engage both hemispheres of the brain, boosting abilities and creativity. This holistic approach can be especially advantageous for students with learning differences like dyslexia, attention deficit and hyperactivity disorder (ADHD) and other cognitive challenges. Research by D'Antoni et al. (2010) has indicated that utilizing mind maps can elevate the performance of students with learning differences by offering a framework that aids in processing information. By connecting ideas, mind maps assist these students in structuring their thoughts and enhancing their comprehension of scientific content.

Many MM softwares or website-based tools can be easily found and used for teaching and learning purposes, for instance, NovaMind Software, Mindmapper software (Gómez Betancur & King, 2014), Mind Mapper Arena 14 (Sabbah, 2015), and Popplet https://www.popplet.com/ (El Shaban, 2022; Frazier, 2015). Popplet enhances pupils' abilities to categorize and arrange information using visual aids, hence developing their analytical thinking abilities. In the current research, Popplet was chosen for the experiment since, as a website-based tool, it is easier to access and use for students, especially those with SEN (Frazier, 2015).

Promoting Inclusivity in Science Education

Inclusive education aims to address the needs of all learners, fostering opportunities and active involvement in classroom settings. In science education, incorporating teaching techniques that cater to diverse learning preferences and capabilities is essential. MM promotes inclusivity by providing an alternative to linear note-taking methods, which may pose difficulties for students (Nesbit & Adesope, 2006). Mind maps benefit science education, in which grasping systems and connections holds significant importance. For example, Vanides et al. (2005) discovered that students utilizing mind maps in science courses enhanced their comprehension and ability to express their understanding.

While many previous studies (Al-Jarf, 2009; D'Antoni et al., 2010; Gómez Betancur & King, 2014; Lin & Faste, 2011; Shih et al., 2009) have emphasized the effects of utilizing mind maps to enhance the learning experience of SEN students, this is the first study involving MM in an inclusive classroom at an Indonesian university. A study by Nesbit and Adesope (2006) noted a significant improvement in reading comprehension and information retention through MM. Similarly, D'Antoni et al. (2010) explored how medical students benefited from MM as it aided them in comprehending and memorizing information. Furthermore, research by Mento et al. (1999) illustrated that MM could boost students' motivation and involvement in the learning process. By offering a visually engaging method to structure knowledge, mind maps can contribute to making learning more enjoyable and accessible for learners with diverse educational requirements.

Integrating MM into science education necessitates educators to receive training on its application and incorporate it proficiently into their teaching methodologies. Teachers are encouraged to empower students to craft their mind maps, fostering a feeling of ownership and active participation in the learning journey (Buzan & Buzan, 2010). Additionally, integrating tools for MM can cater varying learning styles while providing flexibility in creating and sharing these visual representations (Eppler, 2006).

METHOD

This research used a mixed-method approach by employing a quasi-experimental design coupled with semi-structured interviews to examine the effectiveness of MM in a science classroom setting (see Figure 1). We included both SEN and non-SEN university students in our study to compare and contrast the effectiveness of mind maps as a learning aid. This comparative approach aimed to reveal nuanced insights into the pedagogical value of mind maps, considering the varied cognitive and sensory needs of our diverse participant group.

After preparing the transcripts, all writers conducted a collaborative theme analysis, using the method outlined by Braun and Clarke (2006). This strategy is especially suitable when a scientific study tries to detect underlying patterns within data while considering the researcher's reflective relationship with it. The data analysis procedure included six phases according to our methodology (Figure 2).

Research Instruments

The instruments in the first phase of the quasi-experimental design including pre-test and post-test, consisted of 15 questions with four multiple-choice answers about

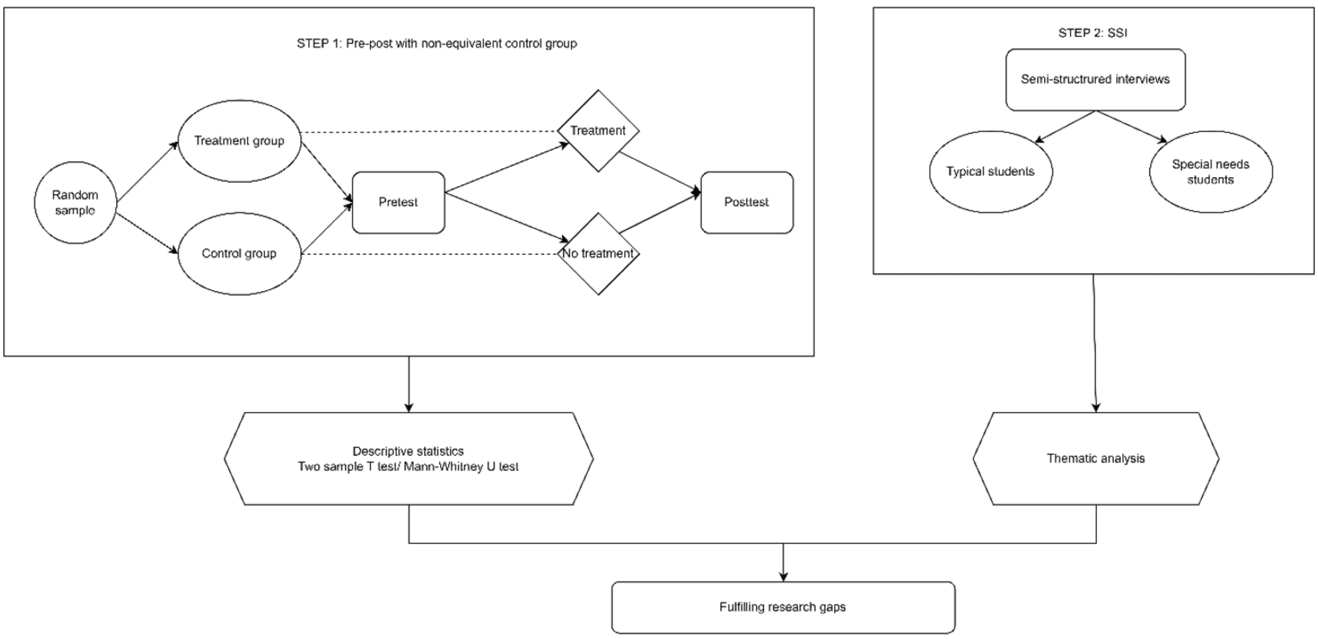

Figure 1: Research Design Used in this Study

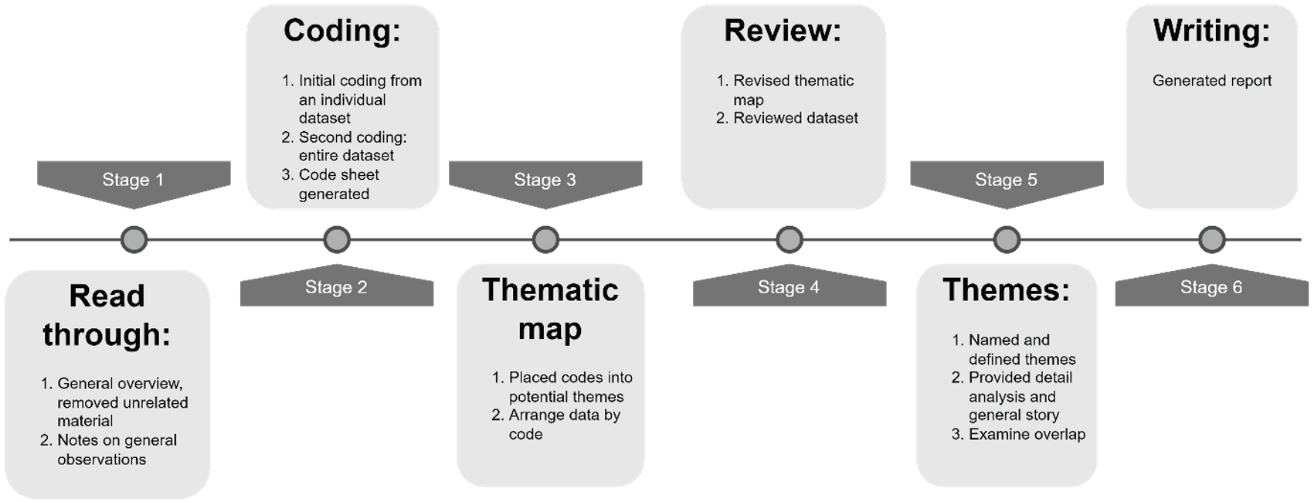

Figure 2. Thematic analysis steps
Source: own elaboration based on Braun & Clarke (2006, p. 87)

the technical procedure of using Popplet and the individual project-based task on the topic of the digestive system in a science course using Popplet MM. To gather insights about students' experiences using MM as visual aids to understand specific topics in their science course, and possibly to complement the research findings from the first phase of the quasi-experimental design, the second phase conducted semi-structured interviews. These interviews were conducted individually, guided by two different question sets divided into two groups: students with SEN and typical students (without SEN) to understand the effectiveness of MM and students' experiences regarding this strategy is consisted of eight questions for typical students about personal experiences, motivation before and after using visual aids, effectiveness of mind mapping, peer interaction, challenges and preferences. Furthermore, students with SEN were asked eight questions about adaptation and accessibility, motivation in the learning process, individualised learning, collaboration and support, challenges, and impact on memory and understanding.

Procedures

Several measures were taken to ensure the objectivity and reliability of the results. First, we explained the research goals to all participants before the experiment to ensure they understand and could apply them, including ethical considerations that allow them to decide their contribution to this research. All participants agreed to join in the research project by signing consent letter. In the experimental group, teachers used the MM strategy to support students' understanding using Popplet website on the specific topic "matter and change" as part of the science course during one semester from August 2023 to January 2024. In the control group, teachers used traditional teaching methods, which is the teacher-centred approach. The topic covered the digestive system, including matter and change, physical and chemical changes, digestion, and organ function as part of the science course plan.

The qualitative component of the research consisted of individual semi-structured interviews, with each session lasting roughly 20 minutes. Participants had the option to choose the method of interview, either in-person or online, using the Zoom platform. Participation in this study was entirely voluntary, and all responses were kept confidential which no personal identities disclosed. Interviewees had the right to withdraw from the interview at any time. The initial discussion with the respondents included a concise introduction that provided background information and stated the study goals. This supplied participants with comprehensive information, including the study's objectives, the interview process, and the utilisation of the transcripts. Subsequently, students who participated in the interviews sign a document indicating their willingness.

Participants

The participants were selected from 60 students aged 18 to 20 enrolled in the third semester of the special education major at the Faculty of Education, Universitas Negeri Surabaya, Indonesia. Random sampling using the lottery method was employed to assign students to the experimental and control groups by writing their names on rolled-up paper and choosing them randomly.

Thirty students were assigned to the experimental group and thirty to the control group. The intervention used in this study was utilising Popplet MM. After the first phase of quantitative research, 15 students voluntarily participated in semi-structured interviews, which is the second phase of research. This group consisted of five students with special needs (two with visual impairments, two slow learners and one with hearing impairment) and ten typical students (eight female and two male students) who participated in the first phase experimental group.

RESULTS

Statistical Analysis

Statistical analysis conducted using IBM SPSS v.27 on the pretest and posttest data of the control group and treatment group showed that the data was normally distributed, as tested by the Shapiro-Wilk test. The results show that the pretest value was normally distributed ($W=0.963$, $p>0.05$) as well as the posttest value ($W= 0.963$, $p>0.05$). Based on the normality test, the further statistical test used in this study is the parametric test. A T-test was used to compare data from two groups and test its significance, based on the treatment. The following are the results of the one-sample statistical test in Table 1.

Table 1 comparatively describes the control and experimental group in this study using one-sample statistics. The results show that the posttest results from the control group ($M=8.07$, $SD= 2.545$) are higher than the pretest results ($M=6.03$, $SD=1.921$) while the experimental group shows a similar trend with the posttest results ($M=9.80$, $SD=2.295$) being higher than the pretest results ($M=6.70$, $SD=2.136$). This indicates differences between the pretest and the posttest, but to test the significance of these results, a paired sample T-test is necessary to determine the effect of the treatment given to the two groups, which answer the hypothesis. The test results are presented in Table 2.

Table 2 reveals significant improvements in scores from pretest to posttest for both control and experimental groups. The experimental group shows a significant difference between pretest and posttest ($t= 7.040$, $p<0.01$) than the control group, which also shows a significant difference ($t=4.363$, $p<0.01$). This suggests that both groups improved , with the experimental group experiencing a more substantial increase in posttest scores, specifically those in the experimental group using Popplet MM in the science classroom. To comprehensively understand students' experiences using MM in the science classroom, a thematic analysis of semi-structured interviews with students with and without SEN was chosen.

Thematic Analysis

Complementing our quantitative findings, the semi-structured interviews explored the students' experiences with MM. Two themes emerged: (1) Adaptive learning strategies and (2) Between individual and collaborative learning (Figure 3). The interviews highlighted both the potential and the limitations of mind maps, revealing a consensus on their benefits for understanding and retention, yet underscoring the imperative for pedagogical flexibility to accommodate individual learning styles and needs.

Theme 1:
Adaptive Learning Strategies

This theme combines discussion on the educational advantages of MM, particularly its role in summarizing les-

Table 1. **Comparative Description of the Two Groups Using One-Sample Statistic**

Group		N	Mean	Std. Deviation	Std. Error Mean
Control	Pretest	30	6.03	1.921	0.351
	Posttest	30	8.07	2.545	0.465
Experiment	Pretest	30	6.70	2.136	0.390
	Posttest	30	9.80	2.295	0.419

Table 2. **Paired Sample Test Results between Control and Experiment Groups**

Comparison	Mean Difference	Standard Deviation	Standard Error	95% CI Lower	95% CI Upper	t-Value	Degrees of Freedom (df)	Sig (p-value)
Control Group	2.033	2.553	0.466	1.08	2.987	4.363	29	0.000
Experiment Group	3.1	2.412	0.44	2.199	4.001	7.04	29	0.000

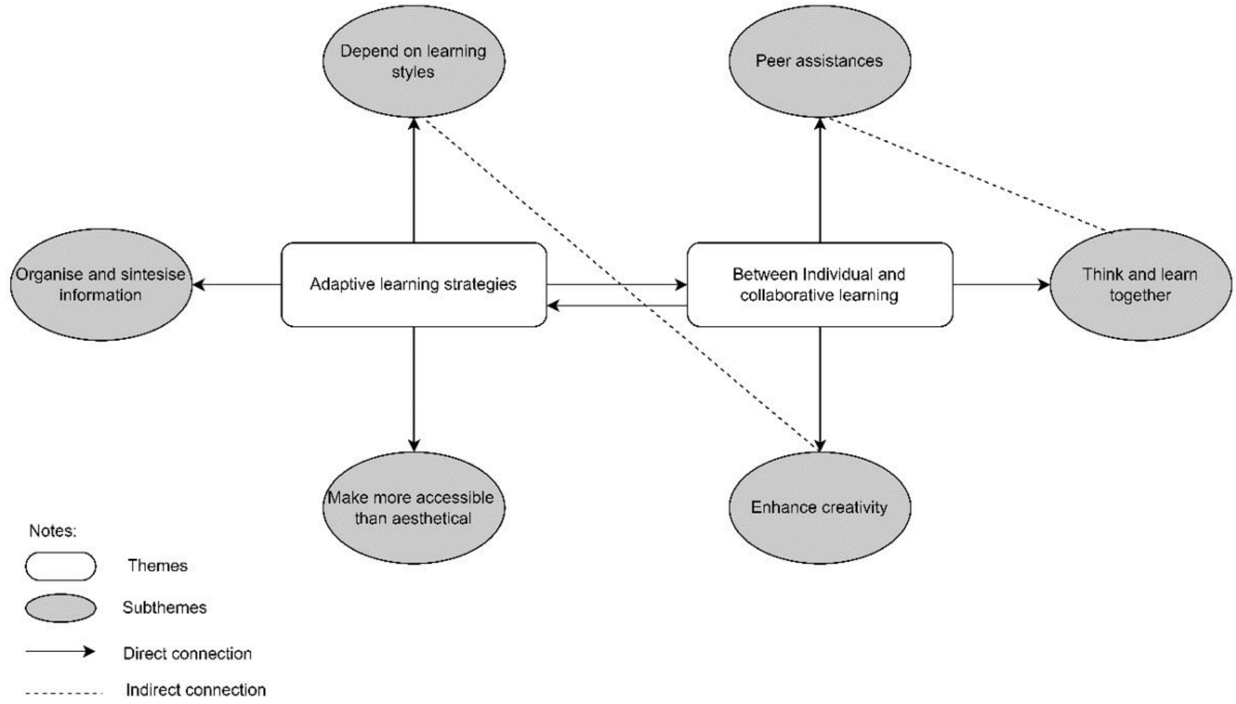

Figure 3. Thematic Map of Students Experiences Using Mind Map Tools for Learning

sons and meeting the demands of various learning styles, with a forward-thinking approach to its implementation and adjustment. The statement recognizes the distinct benefits of MM for different types of learners, while also considering the challenges encountered by students with SEN. The subject implies the need for an using a adaptable and responsive teaching method using MM. Three sub themes emerged: (1) Depend on learning styles, (2) Organize and synthesis information, and (3) Make more accessible than aesthetical.

Depend on Learning Styles

In education, understanding different learning styles is key to optimizing the teaching and learning process. Each individual has their own way of absorbing and processing information, which affects the effectiveness of various learning methods. For example, some individuals may find visual techniques such as MM helpful, while others prefer traditional approaches such as writing notes to deepen their understanding. A combination of classic methods and modern techniques is often considered an effective strategy, allowing each learner to customize the learning process according to their personal needs. This shows the importance of flexibility and adaptation in education to reach and activate the maximum potential of each learner.

'To be honest, from mind mapping or other traditional learning styles, my learning style is more about writing. But if I want to remember more deeply, from mind mapping I write again. So I think mind mapping is also useful. But the traditional learning method also fulfils my learning style better'. (P9).

'I don't think it fully increases my motivation, because it doesn't 100% fulfil my learning style. I personally prefer other traditional learning methods, because I myself prefer to write and then read it rather than just points. Because I think writing and reading fulfils my learning style more than mind mapping itself'. (P10).

'*I don't prefer mind mapping, but I can combine it, for example, with the Pomodoro technique (learning technic by time management) or other learning techniques. So it's more efficient, if Pomodoro is related to the division of learning time. If mind mapping is how we learn a material, learning techniques to learn a material. Now that can be combined, so you don't just choose one or the other'.* (P8).

Organize and Synthesis Information

The interviews revealed the importance of organizing and synthesizing information to aid in understanding and managing lesson. Respondents stated that MM is very effective in summarizing and organizing important information, especially for complex material or when time is limited. This technique not only makes it easier to understand the courses, but also increases interest in learning due to a neater, more concise, and structured presentation. Participants agreed that this approach was very helpful in clarifying and deepening their understanding of the topic being learnt.

'I think it is very useful for organizing material so that it is more structured and also easy to understand. To imagine, maybe I will use this mind mapping for complex material, so I just summaries the points, especially if the material is in a short time situation. So mind mapping is very useful for summarizing the points, to make it easier for me to read it and then I can review it later when I have time'. (P10).

'It is useful because I will be more interested if it is packaged more neatly, more concisely, more organized, structured when we are learning'. (P9).

Make More Accessible than Aesthetical

This sub-theme combines the aspects of design and usability with the challenges and requirements of accessibility and inclusion. The interviews revealed the importance of accessibility in using mind maps as learning aids. Some respondents with SEN, such as visual impairment and deafness, highlighted the need for modifications in mind maps to make them more accessible. They suggested adding audio features and adjustments in visual presentation, favoring clarity over mere aesthetics. Comments from students indicated that, with proper adaptation, mind maps can greatly help in understanding lecture material and making assignments easier, especially for those who have difficulty following conventional teaching that relies more on spoken language or formats that do not favor accessibility. P11 and P13, who are students with visual impairments highlighted the importance of accessible mind maps and suggested adding audio features to help visually impaired users understand the content without the help of others.

'Well. I just can't access it, how do I want to understand it?. Unless a friend reads the mind mapping to me, like oh, this is the title down here. Well, that's quite interesting in my opinion but that requires the help of others. Just to make it more accessible, in my opinion, add the audio features. Mind mapping can basically be used for accessibility but for the aesthetics, it can be arranged by its own person. So it can be considered'. (P11: Visual impairment)

'What was asked was how to modify, yes the order of the placement of the text because if it's an example of mapping, it's like branching out so we have to go through the slides. So how can this be read by the visually impaired, if making it is more concerned with accessibility than aesthetics?'. (P13: Visual impairment).

Indeed, the necessity to modify the MM teaching method for students with visual impairments becomes important to consider, as expressed by P11 and P13 as "accessibility". In this study, teachers used detailed narrative techniques and physical prompts to explain the mind maps, including the concepts of spatial representations. In MM, students are supposed to understand the spatial concepts and linking words, including located concepts such as inside, occurs near, packed in, surrounded by, wound around, between, within, which for students with special impairments reported difficulties (Warren, 1994). In this study, teachers used physical prompts and verbal instruction to help students with visual impairments understand spatial representation and relationships.

Additionally, the assignment was adapted for those with visual impairments, allowing them to used text-based narratives and verbal explanation related to their assignment projects instead of drawing MM using Popplet. Collaborative learning between students with visual impartments and typical students in small groups were reported as a helpful model. In practice, students with visual impairments contributed MM ideas, and their peers without SEN would help to draw the mind map as a collaborative group.

In contrast to P11 and P13, P12 and P14 who are deaf students, emphasized the effectiveness of mind maps in visual form as a better comprehension aid for deaf students than oral instructions were. They considered using mind maps in lectures to make it easier to do assignments and understand lecture projects.

'Now as a deaf student, the experience I get from this mind mapping, the first is to be able to understand something that is actually very difficult for me to understand, because yes, while sitting in class, the lecturer explains more through spoken language, while I better understand the material conveyed in written media or maybe visual, through pictures and this mind mapping is in the form of graphics or that I can access and see, therefore instead of sound media I understand image media better. Therefore, mind mapping is very good for improving the understanding of deaf friends during lectures'. (P12: Deaf).

'I feel when lectures using mind mapping is very simple and help those of us with disabilities. This makes it easier to work on course because if our lectures are [not using] mind mapping, then we will have difficulty finishing the project'. (P14: Deaf)

P15, who has a learning impairment, expressed that mind maps helped him understand the lecture material faster. "*During the lecture, the benefits can be more quickly understanding the material*". (P15: Slow learner)

Theme 2:
Between Individual and Collaborative Learning

This theme examines the dual functionality of MM, including its use in both individual learning situations and collaborative settings. The application highlights its ability to facilitate individual learning and memory retention, as well as promote group brainstorming, idea sharing, and project management. Moreover, it explores the dynamics of engagement levels and emphasizes the significance of peer support, demonstrating how MM can connect individual and group learning experiences.

Peer Supports

In the sub-theme of "Peer Support," some respondents shared their experiences of how interactions with classmates affected their understanding and motivation towards the subject matter. P11 emphasized the importance of explaining concepts that did not understand through discussions with friends, which in turn helped them to understand the material better.

> *'I admit that there is material that I don't understand. So I ask my friends what I don't understand from the mind mapping. But thank God, thanks to their explanations, I finally understood what I didn't understand from the mind mapping'.* (P11: Visual impairment).

Meanwhile, P13 expressed frustration when peer support was unavailable, resulting in a loss of motivation and frustration.

> *'Yes ... this is if you say forced. Well it was given by the material lecturer. Yes, I have to accept it. Yes, if you say, it motivates or makes me happier with friends. Yes, if there is someone to help, but if there isn't? So if the lecturer gives the material, there is no one to explain it, I am not motivated. Instead, I get annoyed because I don't know the content'.* (P13: Visual impairment)

P15 also described their approach of utilizing explanations from friends to better understand the assigned tasks. Through their stories, it is clear that peer interaction plays a crucial role in the learning process and achieving a deeper understanding.

> *'If you ask me whether or not I understand the assignment, I don't understand it, but I also try to find information from my friends regarding the explanation of the assignment. As I explained earlier, I saw an example of my friend's assignment, and after that I made it myself'.* (P15: Slow learner).

Think and Learn Together

This sub-theme summarizes the interviews that highlight the importance of cooperation in the learning process, especially their experiences using collaborative mind maps in science courses. These perspectives show how collaboration and the exchange of ideas can positively impact motivation and learning outcomes. P6 revealed that he and his friends made key points of the lecture material, which were then processed into mind maps. This process not only deepens their understanding of the material, but also strengthens the interaction between classmates, which in turn motivate learning.

> *'My classmates and I processed the material or explanation given by the lecturer, by making points which were then written in mind mapping, which then in this case can build my interaction with classmates. Then with the interaction and the results of the mind mapping will be able to motivate me in understanding the material that has been given"* (P6).

Meanwhile, P9 added that collaboration in creating the mind map brought different ideas, which increased the group's motivation to make the mind map more interesting and informative. "*It can affect motivation because together we have different ideas, so it motivates us to make this mind mapping more interesting*" (P9).

Enhance Creativity

The sub-theme "enhance creativity" summarizes students' views on the use of mind maps as an effective tool. These perspectives show how creative techniques such as MM can be instrumental in developing more efficient and innovative methods of learning and working. P1 emphasized how mind maps enhance the visual and creative aspects of her work, speed up the work process, and construct interesting ideas.

> *"..the first is the visual aspect and then the creativity aspect of using mind mapping, this motivates me in helping to make my work faster, easier and build more interesting ideas"* (P1).

Meanwhile, P3 regarded mind maps as a versatile tool that not only facilitates creative learning but can also be applied across a wide range of other subjects, demonstrating its broad usefulness in education.

> *"In my opinion, mind mapping is a multipurpose tool that can still be used in various other subjects. This is the best, because it is a tool for learning that makes creativity used for learning but can be used. As for learning subjects, it can be used"* (P3).

DISCUSSION

The study emphasizes the innovation in utilizing MM in higher education, specifically in the context of inclusive education that considers students with impairments. Based on the findings, students expressed that MM has many benefits, including its role as a learning tool, its ability to foster collaboration, its adaptability to different learning styles, and its contribution to a more engaging learning environment. The findings of this research originally contribute to the literature concerning the effectiveness of MM as a visual aid in inclusive higher education classrooms.

The study shows that using MM can significantly improve understanding and retention of material. Students with SEN found the organized and visual nature of mind maps beneficial, aligning well with inclusive teaching approaches. This is line in with studies (Cheng & Lai, 2020; María Fernández-Batanero et al., 2022) which mentioned that SEN students require supportive technology or learning methods. For students with visual impairments, the importance of tools in various learning environments, including auditory aids for reading, was emphasised. Similar to Mulloy et al. (2014), the range of technologies required by visually impaired students recognition

The findings in this study suggest that students with visual impairments face some difficulties using MM which have nothing to do with their cognitive abilities. Students with visual impairments possess a broad range of cognitive abilities similar to other students (Kachhap & Mane, 2019), however, they generally have fewer chances to gain knowledge through visual capacities. They often face learning challenges because they cannot easily rely on vision to process information. Therefore, it is necessary to modify MM, for instance, by changing visual text into braille (Hatwell, 2003), or converting visual text into verbal-based instruction. Previous research (Sánchez, 2008) has shown that audio is effective method for engaging users with visual impairments.

The MM strategy typically involves visual observation. For students with visual impairments, teachers need to provide physical guidance or tactile modelling to convey the correct knowledge and skills (Alberto & Fredrick, 2000). These physical demonstration techniques need to be paired with verbal prompts, descriptions, and feedback that align with the student's level of receptive language. These were effective strategies in the present research for teaching students with visual impairments (O'Connell et al., 2006). Demonstrating the correct technique, accompanied by verbal instruction suited to the student, is vital when teaching a new skill (Sherrill, 1998).

MM supports learning by catering to diverse preferences and individual learning styles, aligning with the principles of inclusive education, which seek equal opportunities for all students, including those with disabilities, as mentioned in the Convention on the Rights of Persons with Disabilities (UN, 2006). The research underscores the importance of incorporating accessibility features into mind maps to ensure that all students benefit from this tool regardless of their cognitive abilities. According to studies, students noted that their choice of learning techniques, like MM is influenced by their learning styles. Based on this research' findings, the use of MM facilitate learning diversity in various settings while ensuring individual-based learning, which is certainly crucial of students with SEN.

Some students appreciate the effectiveness of learning tools, while others prefer alternative learning methods that better align with their individual learning preferences. A previous study by Feng et al. (2023) highlighted that MM is most suitable for visual learners who can learn better through their eyes. Moreover, earlier studies (Li et al., 2021; Suriya et al., 2022) reported that MM could improve students' learning outcomes and behaviors. It was also effective in supporting online learning (Alsuraihi, 2022). On the other hand, study by Rofiah et al. (2023) examined the difficulties encountered by SEN students in obtaining higher education in Indonesia. The results revealed the importance of providing adaptive learning for students with SEN at the higher education level, as students continue to encounter substantial challenges in terms of lodging, social integration, and accessing university resources, despite some improvements as university efforts to support inclusive education in Indonesia.

Surprisingly, this study also discovered that MM promotes collaborative learning and peer support. Collaborative efforts among students can be used to generate and distribute mind maps, thereby augmenting their engagement and comprehension of the topics. This cooperative approach not only facilitates learning achievement but also fosters a cohesive community inside the classroom, which is essential for inclusive education. Previous research by Zheng et al. (2020) examined the comparative effectiveness of collaborative and individual MM strategies combined with flipped classroom and conventional methods. The results revealed that the most effective strategy to improve students' learning achievement and self-efficacy is collaborative MM in the flipped classroom. Moreover, previous studies have shown that utilizing MM can impact on group dynamics, concept organization, learning outcomes, and effectiveness (Lin & Faste, 2011; Shih et al., 2009; Zheng et al., 2020).

Incorporating mind maps into approaches offers an enjoyable way of learning, thereby boosting student motivation and contentment. This finding is consistent with a study conducted at an university, by Sujarwanto et al. (2021) which explored student motivation and satisfaction in online learning, focusing on interactive teaching methods that create a stimulating and enjoyable learning atmosphere. Moreover, an experimental study by Shah and Haqeeb (2020) showed that MM could also improve students' motivation during learning. The significance of connecting teaching methods with students' epistemological beliefs, which are their conceptions of knowledge and learning, lies in the correlation between social constructivist methodologies, which view learning as a collaborative and participatory process, and elevated degrees of student contentment and drive. These approaches not only increase the enjoyment of learning but also promote students' capacity to engage thoroughly with the information throughout their educational experience. These methods emphasizes the crucial significance of 'fun' as a motivating component in the learning process. According to the findings, it is important to include engaging and fun teaching methods, such as MM techniques, especially in diverse classrooms.

CONCLUSION

The results corroborate the idea that collaborative learning using MM outperforms conventional lecture-based methods, particularly in inclusive settings with diverse students. This approach was successfully implemented in a science classroom in an Indonesian university. Utilizing MM as a form of cooperative learning not only boosts academic performance but also fosters the development of social skills and cultivates a community of learners who provide mutual support in their academic endeavors. The findings suggested significant difference on pre- and post-test scores in both groups (experimental and control) with higher scores in the experimentally group ($t= 7.040$, $p<0.01$). The thematic analysis revealed two main themes to understand this context comprehensively (1) adaptive learning strategies and (2) between individual and collaborative learning. Students with and without SEN reported positive experiences, noting that MM helped them understand the science course more easily and encouraged the development of social skills, teamwork, and collaboration skills needed in the future. Additionally, adapted MM for students with visual impairments, such as braille-based MM, tactile-based MM, physical guidance, and verbal instruction, effectively helped them to grasp the MM concept and the spatial representation and relationship of MM.

Limitation

Several limitations were identified in this study regarding including MM in the inclusive science classroom at the Indonesian university. Based on students' responses and their experiences expressed in the semi-structured interviews, this teaching strategy cannot be used for students with visual impairments without modifications. Although this study utilized mixed-method design, the number of participants was too small to generalize the findings. Further research should consider the collaborative MM strategy and could utilize online and more user-friendly MM apps.

DECLARATION OF ETHICS

This project was carefully reviewed and received positive feedback from the Research Ethics Committee Centre, Universitas Negeri Surabaya, No.004/UN38.III.1/DL.01.02/2024.

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None.

DECLARATION OF INTEREST

The authors reported no potential conflict of interest.

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