ISSN 2085-4579

# From Tradition to Innovation: Mind Map Generation in Higher Education

Aditya Rama Mitra[1], Feliks Victor Parningotan Samosir[2], Robertus Hudi[3], Riswan Effendi Tarigan[4]
*Faculty of Computer Science*
*Universitas Pelita Harapan*
Tangerang, Indonesia
{aditya.mitra[1], feliks.parningotan [2], robertus.hudi [3], riswan.tarigan [4]}@uph.edu

Accepted on December 6th, 2023
Approved on December 19th, 2023

***Abstract*— This study conducts an in-depth survey of mind map utilization in higher education from 2003 to 2022, addressing the challenge of conveying complex topics to diverse learners. It examines the implementation of mind maps, focusing on development techniques, target audiences, objectives, and outcomes. Mind maps, recognized for enhancing memory retention, comprehension, and engagement, are used in two main scenarios: Learner-Driven for revision and understanding, and Lecturer-Driven as visual aids for content organization. The research underscores the importance of inclusivity and diverse learning preferences, advocating for mind maps as part of a comprehensive educational toolkit. It also identifies a gap in current mind map creation tools, particularly the lack of advanced technology integration like AI and deep learning. The study proposes developing an AI-based tool to facilitate lecturer involvement in mind map creation, enhancing teaching methods. Ultimately, it emphasizes the vast possibilities of integrating mind maps in academic settings, enhanced by technological progress, indicating transformative opportunities for future applications involving educational technology.**

***Keywords—mind maps, educational technology, higher education, learning preferences, memory retention.***

## I. INTRODUCTION

Higher education, as a pivotal milestone in shaping one's intellectual and professional development, plays a crucial role in fostering a profound understanding of various academic disciplines. Students in the higher education environment exhibit increasing diversity in their learning styles, backgrounds, and academic abilities, compelling lecturers to adapt their instructional methods. Presently, the challenge lies in effectively delivering knowledge to students with varying learning preferences. In addressing this challenge, lecturers, acting as learning facilitators, continue to innovate in their approaches to delivering course materials. One increasingly popular approach is the adoption of active learning, wherein students actively engage in the learning process through discussions, collaboration, and direct interaction with course content [1]. Active learning holds the potential to enhance students' understanding of concepts and their overall engagement in the learning process.

Another long-standing tool employed to bolster the effectiveness of teaching is the visualization of course materials. Visualization aids in illustrating the relationships among complex concepts, assists students in grasping key ideas, and synthesizes crucial information. This technique is commonly referred to as mind mapping. The other technique is concept mapping [2] which represents knowledge and shows the relationships between different concepts in more structured and formal style than a mind map.

Mind mapping, introduced by Tony Buzan in the 1970s [3], is a centralized and radial visual technique that begins with a core concept from which related ideas branch out. It's predominantly utilized for brainstorming, organizing thoughts, and as a memory aid, often adopting a more personal and less structured approach [4]. Unlike other visual tools, mind maps do not typically label relationships explicitly. They are distinctively characterized by vibrant colors, imagery, and curved lines to depict and connect ideas.

Mind maps, as an educational medium, offer a visual platform for both students and lecturers to represent and communicate knowledge. They serve as a creative tool that bolsters memory and understanding [5]. With technological progress, mind maps have evolved into pivotal learning mediums across various educational stages. In higher education, they not only promote active learning, motivating students to visualize and structure their thoughts, but also aid lecturers in transmitting complex topics, curriculum design, and providing feedback. When crafted by learners, mind maps facilitate a deeper grasp of intricate subjects, emphasizing concept interconnectedness and kindling creativity in learning. Concurrently, lecturers harness this medium to enhance the teaching-learning experience, making abstract ideas more tangible and accessible [6], [7].

The highlight of this research centers on the development and assessment of the effectiveness of

mind map generation methods in aiding learners in planning, organizing, and recalling information, as previously explored in other studies [8]. This research, however, identifies an opportunity for educators to utilize mind maps to provide a comprehensive overview of topics or subjects taught, thereby encouraging students to create their own mind maps after learning sessions.

This study's primary objective is to present an exhaustive overview of research related to the creation of mind maps in higher education. It aims to uncover gaps in existing research and proposes subsequent steps for future studies to address these gaps. The method involves reviewing empirical evidence and findings that underscore the efficacy of mind maps as a learning tool in higher educational settings. This approach intends to contribute significantly to the understanding and application of mind maps in educational methodologies.

## II. Research Method

The study adopted a multi-step survey methodology to examine the application of mind maps in higher education comprehensively. This approach comprised several distinct phases, each designed to ensure a systematic exploration of relevant literature.

a) Keyword Definition and Initial Search: The research began by defining the primary keyword: "*mind map in higher education*". This keyword was strategically chosen to focus the search on the most relevant studies.

b) Utilizing Elicit Platform (elicit.com): Leveraging the Elicit platform [9], which uses advanced language models like GPT-3, an initial search was conducted. Elicit's algorithms enabled efficient sifting through extensive databases, identifying studies that specifically mentioned the keyword. Elicit conducts its searches through a vast database of 200 million scholarly articles provided by the Semantic Scholar corpus, encompassing a wide range of academic fields. When pulling data from these papers, Elicit utilizes the complete text wherever accessible, or defaults to the abstract in cases where the full text is not available.

c) Inclusion and Exclusion Criteria: To refine the search results, clear inclusion and exclusion criteria were established. Studies were included if they focused on the application of mind maps within tertiary educational contexts. Works not explicitly addressing mind maps in higher education, such as those discussing mind maps in general terms or their use in primary and secondary education, were excluded.

d) Data Extraction and Categorization: Upon identifying relevant studies, key data points were extracted. This included the year of publication, the development techniques used in the studies, their primary objectives, and main findings. Each study was then categorized based on these parameters to facilitate an organized analysis.

e) Analysis and Synthesis: With the data collated, a thorough analysis was conducted, synthesizing the findings to draw out trends, common techniques, and notable outcomes in the use of mind maps in higher education.

f) Cross-Verification with Elicit: To ensure the accuracy and comprehensiveness of the findings, data was cross-verified with the results generated by the Elicit platform. This step was crucial in confirming the relevance and reliability of the studies included in the analysis.

g) Final Compilation: The final step involved compiling the findings into a coherent narrative, highlighting the application of mind maps in higher education, their evolutionary use over time, and the main outcomes reported in the literature.

## III. Results

Table I presents a summary of all the papers collected for this survey. The emphasis of the survey is on the mind map generation technique, target audience, the purpose of each study, and its results, in addition to the year of research publication.

TABLE I. Summary of Collated Papers

| No | Year | Techniques | Audiences | Goals | Results |
|---|---|---|---|---|---|
| 1 | 2003 [10] | using Paper-based MM and existing Digital MM | Undergraduate students in School of Art and Design (SAD) and students in School of Computing and Information Technology (SCIT) | To investigate the idea of mind mapping and the application of MindManager software to help and enhance students' academic achievement | Because of their visual culture, SAD students were more confident in their ability to comprehend mind mapping than SCIT students were, but most students from both institutions thought it was useful, particularly for project management in group projects. |
| 2 | 2007 [11] | using Paper-Based MM | Undergraduate students in Medical | To help university students learn on their own. | Most participants thought it was a useful summarizing method and that it would be interesting to investigate mind maps in more detail in future research. They also thought it helped with information memorization. |

| No | Year | Techniques | Audiences | Goals | Results |
|---|---|---|---|---|---|
| 3 | 2009 [12] | using Paper-Based MM | Undergraduate students in Industrial Engineering Program | To maximize the amount of time allotted to industrial engineering departments' innovation development initiatives. | It is preferred to use integrative maps that include written and visual elements. The mind map applications that lecturers suggested were the most beneficial, and using the approach in industrial engineering education produced encouraging results, encouraging more students to attempt the method. |
| 4 | 2012 [13] | using existing Digital MM tools | Undergraduate students of educational psychology | To investigate potential differences in the effects of several socially mediated mind mapping activities on variables associated with students' motivation and effort. | Students' rankings of the three mind mapping exercises revealed a range of preferences, enjoyment, and learning even though there were no average variations in perceptions based on the MUSIC model or effort. The effectiveness of all three activities in terms of student motivation was further validated by quantitative analysis. |
| 5 | 2013 [14] | using existing Digital MM tools | The domain of this research article is applied in various educational contexts, such as schools, universities, and training programs. | To investigate the application of mind maps as a tool to raise educational standards and to offer information on how well mind maps work to improve student learning. | When it comes to observing constructivist learning, mind maps can be a useful substitute for concept maps, particularly in technical fields. Expert map templates outperform full expert maps as learning scaffolds, and their collective creation improves learning quality by helping students move from associative to relational thought, predicting expert ratings, and encouraging cooperative group work. These benefits are particularly evident in undergraduate engineering programs. |
| 6 | 2014 [15] | using Paper-Based MM | Undergraduate students in Geography | To help undergraduates studying geography learn more creatively, collaboratively, and innovatively. | Undergraduate geography students found that mind mapping was a useful tool for encouraging creative and collaborative learning; active engagement produced a wide range of creative and inventive mind maps. Small group work facilitated more in-depth topic study, increased student self-assurance, and demonstrated a diversity of thought processes, with some groups exhibiting enhanced knowledge of particular subjects, such as cartography. |
| 7 | 2015 [16] | using Paper-based MM and existing Digital MM | Undergraduate students in IT and Computing | To ascertain the results of employing DMM and the improvement in students' answers | The study indicated the use of Java 2 Micro Edition (J2ME) for mobile phone operating systems and highlighted the advantages of software-based mind maps, which demonstrated higher accuracy than student-created ones. It also detailed the technical requirements for Electronic Mind Mapping (EMM) tools, with students favoring EMM due to its speed and availability. |
| 8 | 2015 [17] | using existing Digital MM tools | Master students in Education Program | To investigate the effects of electronic mind maps on instruction and learning in a course on educational research methods | Quantitative evidence indicated that students' attitudes toward research increased after using the Free Mind program, making it the program of choice. The value of teachers' approaches and knowledge transfer in boosting students' knowledge and good research attitudes was further highlighted by the qualitative findings, which also highlighted students' enjoyment of mind maps in research learning. |
| 9 | 2015 [18] | using Paper-based MM and existing Digital MM | Undergraduate students in learning English as a second laguage (ESL) | To determine the subjects' views regarding creating computerized mind maps for reading comprehension as well as the possible impact of the self-generated mind maps created by college students on their reading comprehension | According to the study, students who were taught to read using computerized mind maps that they had created themselves demonstrated greater reading achievement and more positive attitudes about the teaching approach. The benefits of the method were ranked as follows: educational, mental, useful, and enjoyable. These results, which are in line with earlier studies, highlight the potential of electronic mind mapping to improve collaborative learning and reading comprehension. This makes a substantial contribution to cutting-edge teaching practices, particularly in the Gulf region. |

| No | Year | Techniques | Audiences | Goals | Results |
|---|---|---|---|---|---|
| 10 | 2016 [19] | using existing Digital MM tools | Undergraduate students in Accounting Program | Present MM as a substitute for attaining the desired learning objective in accounting education. emphasizes the value of utilizing cutting-edge and interactive teaching and learning resources, particularly for students who are accustomed to using digital devices. | Most students thought iMindMap was more interesting than conventional teaching techniques, praising its ability to clearly illustrate relationships between ideas. While 49% strongly agreed that iMindMap effectively imparted knowledge in lectures, more than half thought it was interactive and engaging, and its flexibility was seen to foster critical thinking, creativity, and engagement. Multimedia components catered to a variety of learning styles and improved the quality of the educational experience. |
| 11 | 2016 [20] | using Paper-Based MM | Undergraduate students in Biology | To evaluate students' capacity for original thought in a biotechnology course through mind mapping | Biology Education students were split into two teams for a study that employed mind mapping to assess students' creative thinking abilities in a biotechnology course. The majority of pupils on Team A demonstrated a notable enhancement in their creative thinking abilities, resulting in high marks. Team B, on the other hand, showed a minor improvement, with the majority of kids receiving low scores. |
| 12 | 2018 [21] | using Paper-based MM and existing Digital MM | Undergraduate students in IT and Computing | To improve students' comprehension, encourage the growth of their life-wide learning mindset, and fortify their capacity for both creative and logical thought. | When used in programming language training, mind mapping strengthens students' ability to think creatively and logically, which supports their holistic knowledge and attitude to lifelong learning. It helps with practical computer language learning by strengthening software engineering ideas and stimulating creative thought. Furthermore, mind mapping facilitates ongoing learning and encourages diverse thinking, creative reasoning, and problem-solving abilities by providing a visual clarification of course content, instructional objectives, and abstract concepts. |
| 13 | 2019 [22] | develop Digital MM tools (AI-based) | Undergraduate students in Environmental Engineering Program and Management and Production Program | To showcasing how digital mind maps may be used to make classrooms more visually appealing and inspire students to make their own connections and learn more. | The study demonstrates the range of respondents' attitudes four years later and the number of affirmative answers to questions. |
| 14 | 2019 [23] | using Paper-Based MM | Master students in Accountancy Program | To learn how the mind map, as a process, can support professional development and identity within any field of study; and how, as a product, it provides a concrete, fundamental function upon which to construct and build additional communicative goods. | Mind maps support professional development, identity creation, and improved comprehension through peer evaluation. They are emphasized in professional communication courses in higher education, as well as the end result and the mapping process itself. Examining these maps demonstrates how students have developed their thinking, fostering work-readiness and a sense of self as future professionals. Their design can improve text comprehension, clear up misunderstandings, and provide a multi-layered, cycle of analysis that can be used to build additional communicative products in a variety of fields. |
| 15 | 2019 [24] | using existing Digital MM tools | Undergraduate students in Education | Create a new teaching strategy focused on mind mapping and thinking development. This is crucial to assisting students in integrating their information and rationalizing their reasoning. | The learning outcomes of students in health fitness education were greatly improved by using a mind mapping-based teaching style. In comparison to the control group, the experimental group, who received instruction in mind mapping-based thinking development, significantly outperformed them on the post-test. |
| 16 | 2020 [25] | using existing Digital MM tools | Master students in Education Program | To investigate the impact of argument mapping and software-assisted mind mapping on academic performance in higher education. | Students' academic progress and skill set were greatly improved using software-assisted mind and argument mapping tools. The results of the study were obtained through a combination of qualitative and quantitative measures, including interviews, achievement tests, self-evaluations, and reflective diaries. |

| No | Year | Techniques | Audiences | Goals | Results |
|---|---|---|---|---|---|
| 17 | 2021 [26] | using existing Digital MM tools | Undergraduate students in Pharmacy | To assess the students' performance and their sense of having learned something significant in a pharmaceutical course on drug formulation design using the mind mapping approach | Students created well-structured and lucid mind maps; many preferred the two-layered "tree" style. Color-coding groups demonstrated greater interest and improved grades. Test scores were typically lower than those from mind map assignments. In terms of final course marks, the intervention group performed marginally better than the control group. The second term's scores for students in a later Large-Scale Drug Formulation course were worse than the first. In general, a sizable majority thought that concept retention might be achieved with the help of mind mapping. |
| 18 | 2021 [27] | using existing Digital MM tools | Undergraduate students in Islamic Higher Education | To comprehend the advantages of mind mapping approaches in organizing ideas, comprehending subjects, and coming up with writing ideas, it is important to investigate the impact of flow mind maps on writing accuracy and learning motivation at Islamic Higher Education. | The study looked at how students at an Islamic higher education institution in Kalimantan were affected by flow mind maps in terms of writing correctness and learning motivation. |
| 19 | 2021 [28] | using Paper-based MM and existing Digital MM | Undergraduate students in Science Teaching Program | Aids in the development of target audiences' thoughts about various mind mapping approaches as well as their experience in producing both paper-based and digital MM. | Participants had positive opinions on mind maps, praising their usefulness in enhancing and visualizing learning, bringing teachings to life, and being simple to use. Mind maps could be used for a wide range of subjects and contexts. Although they had technological issues, digital mind maps had advantages including simple revisions and multimedia integration. On the other hand, mind maps created on paper promoted the development of psychomotor skills and experiential learning; nevertheless, their ability to integrate multimedia and modify data was restricted. Notably, digital mind maps improved students' creativity, imagination, and engagement with both spoken and visual symbols. |
| 20 | 2022 [29] | using Paper-Based MM | Undergraduate nursing students. | The significance of implementing innovative teaching strategies that promote critical thinking and learning | The pass rates of the control and intervention groups were similar prior to the intervention. The experimental group's pass rate increased to 92% after the intervention, whereas the control group's pass rate remained at 52%. In spite of this, in another measure the control group fared better than the experimental group. The mind-mapping method was well received by the experimental group, who also saw a significant relationship between it and their results. Both groups were made up of undergraduate nursing students, the majority of whom were female, and whose median age was eighteen. |

### *A. Overview of Publication Years*

This rigorous survey culminated in the collation of 20 papers spanning the years 2003 to 2022. The number of publications related to the development and implementation of mind maps in higher education has seen an increase over the years, with more recent years having a higher number of publications.

### *B. Techniques Used*

Digital mind maps offer benefits like multimedia integration, which can enhance students' imagination, creativity, and engage them both visually and verbally. On the other hand, paper-based mind maps promote hands-on learning and psychomotor development, even though they might be limited in editing capabilities.

"*Using existing Digital MM tools*" appears to be the most common technique adopted in the surveyed papers. There's also a significant number of studies that utilize both "*Paper-based MM*". For example, students found tools like iMindMap to be more engaging than conventional teaching methods. The clarity with which mind maps show connections between points was highlighted. Over half of the students found it interactive and appealing. Its flexibility was observed to enhance creativity, engagement, and critical thinking.

### C. Target Audiences

From the collected papers, the majority of target audiences hail from the fields of education and engineering. However, there is also a diverse array of additional target audiences, encompassing fields such as medicine, psychology, biology, and accounting. This indicates that mind mapping techniques have been extensively investigated across a multitude of disciplines within higher education.

Participants perceived mind maps as multifaceted and beneficial across a range of topics and contexts. They underscored the efficacy of mind maps in fortifying and illustrating learning, invigorating instructional sessions, and their inherent user-friendliness.

### D. Research Goals

Based on the analysis of the results of the research papers, here are the most common keywords/themes:

- Students: This suggests that a significant portion of the research outcomes relates to the impact or benefits of mind mapping on students.
- Mapping and Maps: Both terms reinforce the central theme of the surveyed papers.
- Group: This might indicate discussions related to group activities or comparisons between groups in the studies.

From this preliminary analysis, we can deduce that a significant portion of the surveyed papers focuses on the benefits or impacts of mind mapping on students' learning processes and outcomes.

## IV. Discussion

There are two common scenarios in the higher educational context when it comes to mind mapping:

- Learner-Driven Development: Here, learners (students) create mind maps after class sessions, often as a part of their revision or study routine. This helps them consolidate their understanding, identify knowledge gaps, and prepare for assessments. The process of creating the mind map can also enhance memory retention and improve comprehension.
- Lecturer-Driven Development: In this scenario, lecturers (teachers or lecturers) create mind maps to support their teaching process. These mind maps are often used as visual aids during lectures or presentations to help students understand complex topics. The lecturer uses the mind map to structure the subject matter, delineate relationships between concepts, and provide a bird's-eye view of the topic.

The majority of papers focus on the learners (students) when discussing the goals and results of their research related to mind maps. This suggests that many papers might be looking at the benefits, challenges, or practices of students creating or utilizing mind maps. Only a negligible number of papers seem to mention lecturers in the context of the results, indicating that the focus on lecturer-driven development of mind maps in the surveyed papers is limited.

This data seems to support the notion that the primary participants in the development and utilization of mind maps, as discussed in the surveyed papers, are the learners themselves. From an educational perspective:

- Lecturers might prefer concept maps due to their structured nature [2], which can aid in explaining complex topics and showing relationships between concepts. Concept maps are especially useful for curriculum planning or presenting hierarchical or interconnected information.
- Learners (students) might gravitate towards mind maps because of their flexibility and the creative freedom they offer, making them great tools for brainstorming, note-taking, and revision.

The employment of mind maps by lecturer in delivering educational material represents a beneficial approach, assisting them in planning, organizing, and visualizing concepts more effectively [30]. This not only facilitates a more structured material delivery but also enables lecturers to comprehend student perspectives and can inspire students to adopt similar techniques, enhancing material understanding and retention.

Nevertheless, the use of mind maps by lecturers should be inclusive, accommodating diverse student learning styles, and be a component of a broader teaching toolkit. In conjunction with other teaching methods, the utilization of mind maps can amplify instructional creativity and render learning more engaging and efficacious.

## V. Future Research

Current research indicates that the majority of mind map design and utilization is student-driven, highlighting their role in expressing creativity and evaluating learning. However, the potential benefits of lecturers employing mind maps in teaching, particularly in material enrichment, are substantial. Mind maps are currently underutilized by lecturers in preparing lesson materials, signifying a need for a tool that can facilitate mind map generation using additional information for enrichment purposes.

Present tools for creating mind maps do not extensively utilize advanced technologies like artificial intelligence and deep learning. There is an opportunity to develop a deep learning model that can generate mind maps from various textual sources, assisting lecturers in material enrichment and effective content delivery.

The integration of advanced technology in mind map creation holds promise for automation and

personalization in the generation process. An AI-based tool could suggest conceptual connections based on academic literature or historical data, or adapt the map to suit the learning needs and preferences of students. This technological advancement can significantly augment the utility and effectiveness of mind maps in educational settings.

## VI. Conclusion

The existing literature primarily highlights the benefits of mind maps in higher education. The integration of mind maps into active learning processes by lecturers, providing overarching views of subjects, can unlock further potential. Coupling this approach with encouraging students to generate mind maps after classes can significantly enhance understanding. The future of mind mapping in education, especially with the integration of advanced technologies, is highly promising. Leveraging these technological advancements can lead to transformative changes in teaching and learning methodologies, greatly benefiting the educational landscape.

## Acknowledgment

The authors wish to express their sincere gratitude to Lembaga Penelitian dan Pengabdian kepada Masyarakat (LPPM) at Universitas Pelita Harapan for their generous support in funding this research. The grant provided, under the reference number P-90-SISTech/VII/2023 issued on July 13, 2023, has been instrumental in facilitating the comprehensive survey and subsequent analysis presented in this paper.

## References

[1] S. Freeman *et al.*, "Active learning increases student performance in science, engineering, and mathematics," *Proceedings of the National Academy of Sciences*, vol. 111, no. 23, pp. 8410–8415, 2014.

[2] J. D. Novak and A. J. Cañas, "The theory underlying concept maps and how to construct and use them," 2008.

[3] T. Buzan, *Use your head*. BBC Books, 1974.

[4] T. Buzan and B. Buzan, *The mind map book: Unlock your creativity, boost your memory, change your life*. BBC Books, 1996.

[5] A. V D'Antoni, G. P. Zipp, V. G. Olson, and T. F. Cahill, "Does the mind map learning strategy facilitate information retrieval and critical thinking in medical students?," *BMC Med Educ*, vol. 10, no. 1, pp. 1–8, 2010.

[6] P. Farrand, F. Hussain, and E. Hennessy, "The efficacy of the mind map study technique," *Med Educ*, vol. 36, no. 5, pp. 426–431, 2002.

[7] J. C. Nesbit and O. O. Adesope, "Learning with concept and knowledge maps: A meta-analysis," *Rev Educ Res*, vol. 76, no. 3, pp. 413–448, 2006.

[8] B. M. Holland, L. Holland, and J. Davies, "An investigation into the use of a mind map teaching technique to support student learning in a nursing module," *Nurse Educ Today*, vol. 23, no. 4, pp. 302–308, 2003.

[9] Ought, "Elicit: The AI Research Assistant." Feb. 22, 2023. Accessed: Jul. 08, 2023. [Online]. Available: https://elicit.org

[10] B. Holland, L. Holland, and J. Davies, "An investigation into the concept of Mind Mapping and the use of Mind Mapping software to support and improve student academic performance," *Learning and Teaching Projects / p*, 2003.

[11] A. Wickramasinghe, N. Widanapathirana, O. Kuruppu, I. Liyanage, and I. Karunathilake, "Effectiveness of mind maps as a learning tool for medical students," *South-East Asian Journal of Medical Education*, vol. 1, no. 1, 2007, doi: 10.4038/seajme.v1i1.506.

[12] C.-C. Lin and D.-H. Shih, "Mind Mapping : A Creative Development in Industrial Engineering Education," in *2009 5th International Conference on Wireless Communications, Networking and Mobile Computing*, 2009. doi: 10.1109/WICOM.2009.5303453.

[13] B. D. Jones, C. Ruff, J. Snyder, B. Petrich, and C. Koonce, "The Effects of Mind Mapping Activities on Students' Motivation," *International Journal for the Scholarship of Teaching and Learning*, vol. 6, no. 1, 2012, doi: 10.20429/IJSOTL.2012.060105.

[14] C. Radix and A. Abdool, "Using mind maps for the measurement and improvement of learning quality," 2013.

[15] A. Karunarathne and W. Weerasinghe, "The application of mind mapping as a technique to enhance collaborative, creative, and innovative learning among Geography undergraduates," 2014.

[16] A. S. Al-Badwoi, "Using E-Mind Mapping in learning at Ibri College of Applied Sciences," 2015.

[17] T. Tungprapa, "Effect of Using the Electronic Mind Map in the Educational Research Methodology Course for Master-Degree Students in the Faculty of Education," *International Journal of Information and Education Technology*, vol. 5, no. 9, 2015, doi: 10.7763/IJIET.2015.V5.615.

[18] S. Salman Sabbah, "The effect of college students' self-generated computerized mind mapping on their reading achievement," 2015.

[19] W. N. H. W. Jusoh and S. Ahmad, "iMindMap as an innovative tool in teaching and learning accounting: an exploratory study," 2016, [Online]. Available: https://doi.org/10.1108/JARHE-10-2014-0079

[20] S. A. Sulistyorini, "The Analysis of Student's Creative Thinking Ability Using Mind Map in Biotechnology Course," 2016, [Online]. Available: https://doi.org/10.2991/icstar-16.2017.9

[21] Y. Liu, Y. Tong, and Y. Yang, "The Application of Mind Mapping into College Computer Programming Teaching," 2018, [Online]. Available: https://doi.org/10.2991/mec-16.2016.132

[22] M. Krzywicka and J. Grudzinski, "Digital mind maps in teaching materials science at the university level," *XXII International Scientific Conference POLSITA 2019*, 2019, [Online]. Available: https://doi.org/10.1063/1.5005433

[23] T. Grant and A. Archer, "Multimodal mapping: Using mind maps to negotiate emerging professional communication practices and identity in higher education," 2019, [Online]. Available: https://doi.org/10.1177/1750481317695739

[24] J. Luo, "Teaching Mode of Thinking Development Learning Based on Mind Mapping in the Course of Health Fitness Education," *International Journal of Emerging Technologies in Learning (iJET)*, 2019, [Online]. Available: https://doi.org/10.2991/iceem-17.2017.70

[25] I. Şimşek and H. Yıldızlı, "The Effects of Software-Aided Mind and Argument Mapping on Learning in Higher Education," *International Journal of Contemporary Educational Research*, 2020, [Online]. Available: https://doi.org/10.1007/s11409-018-9187-2

[26] R. M. Martinez, "Case study of mind mapping as an educational tool for a pharmaceutical course on drug formulation design," 2021, [Online]. Available: https://doi.org/10.1080/10837450.2018.1480773

[27] S. Sabarun, "The Effect of Flow Mind Map on Writing Accuracy and Learning Motivation at Islamic Higher Education," 2021, [Online]. Available: https://doi.org/10.2991/assehr.k.191217.080

[28] M. Debbağ, B. Cukurbas, and M. Fidan, "Use of Digital Mind Maps in Technology Education: A Pilot Study with Pre-Service Science Teachers," 2021, [Online]. Available: https://doi.org/10.15388/INFEDU.2021.03

[29] A. A. Elsayed, N. E. M. M. Eldiasty, F. A. M. El Salam, S. H. Mohamed, and M. M. A. E. Younes, "Effect of Using Mind Mapping Learning Technique among Undergraduate Nursing Students," 2022, [Online]. Available: https://doi.org/10.21608/ejhc.2022.270425

[30] Mr. D. S. Nikam, "An Experimental Study To Assess The Effectiveness Of Mind Mapping VS. Lecture Method On Knowledge Regarding Mood Disorder Among Nursing Students In Selected Nursing Colleges Of Selected City," *International Journal of Creative Research Thoughts*, vol. 11, no. 7, 2023.