

ENHANCING CREATIVE THINKING IN NON-MAJOR COMPUTER SCIENCE STUDENTS THROUGH INTERACTIVE VISUAL LEARNING ENVIRONMENTS

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Abstract. This study investigates the impact of an interactive visual learning environment on creative thinking and performance among non-major computer science students. Utilizing the Torrance Incubation Model (TIM) and visual interactive tools, the research aimed to enhance creative thinking skills. A pre-experimental, single-group, pre-post-test design was employed, involving sixteen non-random, non-major undergraduate computer science students. Participants were exposed to a visual interactive learning environment using visualization for five weeks. Before and after the intervention, participants completed Torrance Tests of Creative Thinking (TTCT). Descriptive and inferential statistical analyses were conducted on the data. The findings indicated that, except for verbal fluency and certain verbal dimensions of creative thinking, students' performance and creativity significantly improved after learning in the visually interactive environment. However, no significant correlation was found between different domains of creative thinking (figurative and verbal) and performance. The study's implications suggest that learners effectively adapt to interactive visual tools to enhance comprehension, also positively influences learners' creative capabilities, indicating the efficacy of integrating visual interactive tools in educational settings. This study contributes to the growing body of research on educational technology and creative pedagogy, providing insights for educators and policymakers on effective strategies to enhance creativity and performance in higher education.

Keywords: *innovative visual learning environment, non-major Computer Science, creative thinking, Torrance Tests of Creative Thinking, Torrance Incubation Model*

Introduction

Advancements in society and economy necessitate that educational systems equip students with 21st-century skills and competencies. These skills are essential for participation in the fourth industrial revolution, emphasizing knowledge management, information selection, acquisition, integration, analysis, and sharing. Educational systems must evolve to prepare students to face these challenges by fostering creative thinking, communication, and collaboration skills. The integration of information and communication technology (ICT) in education has been pivotal in this transformation. ICT not only supports but enhances the acquisition of 21st-century skills. For many young people, schools are the primary venues for learning these competencies. As such, there is a pressing need for educational institutions to adopt innovative teaching methods that align with the demands of the modern economy.

Literature review

Creative thinking in education

Creative thinking is a critical skill that has been emphasized in numerous studies. According to Rubenstein et al. (2018), creativity can be enhanced through various techniques and training programs. Their research shows that creativity training can be effective for all students, regardless of their initial level of talent. Despite this, there remains a pervasive belief among educators that creativity is a trait reserved for exceptionally gifted individuals (Mann et al., 2017). Creative thinking is increasingly recognized as a vital competency for the 21st century. The rapid pace of technological advancement and globalization requires individuals who can think creatively and adapt to new challenges. However, traditional educational methods often fail to nurture these skills. Various models have been proposed to enhance creative thinking, including the Torrance Incubation Model (TIM), Osborn's Creative Problem Solving, Creative Habit of Mind (CHoM), and Mumford's Eight-Stage Process Model (Wahyudi et al., 2020; Lucas, 2016; Smith, 2012; Murdock and Keller-Mathers, 2008; Hunter et al., 2006; Hebert et al., 2002). The Torrance Incubation Model (TIM) is a well-established framework that emphasizes the importance of incubation in the creative process. TIM consists of three stages: Heightening Anticipation, Deepening Expectations, and Keeping It Going. Each stage involves specific activities designed to stimulate creative thinking. According to Hebert et al. (2002), TIM is not merely a formula for instruction but a shift in thinking that promotes creativity by engaging students in active learning and exploration.

Osborn's Creative Problem Solving (CPS) model is another widely used approach to foster creative thinking. CPS involves several stages, including understanding the challenge, generating ideas, and preparing for action. This model emphasizes the importance of divergent thinking and the generation of multiple solutions to a problem. Treffinger et al. (2003) highlights the effectiveness of CPS in supporting creative problem-solving skills. The Creative Habit of Mind (CHoM) model, proposed by Lucas (2016), identifies five core habits that are essential for creativity: inquisitiveness, imagination, persistence, collaboration, and discipline. These habits are cultivated through various activities and exercises that encourage students to think creatively and develop innovative solutions. Mumford's Eight-Stage Process Model, described by Hunter et al. (2006), outlines the stages of the creative process, from problem construction to implementation and monitoring. This model provides a comprehensive framework for understanding how creative ideas are generated and developed.

Interactive visual learning environments

In the context of education, creative teaching practices refer to the application of innovative and imaginative strategies that go beyond traditional methods. These practices involve the integration of various instructional techniques, technological tools, and dynamic content delivery methods designed to foster student engagement, critical thinking, and problem-solving skills (Saili and Taat, 2024; Fan and Cai, 2022; Rubenstein et al., 2018). Creative teaching practices are not merely about introducing novel ideas but about creating an environment where students are actively involved in the learning process, encouraged to think critically and creatively, and provided with opportunities to explore and express their ideas in diverse ways. The integration of interactive visual tools in education has been shown to enhance students' creative thinking and engagement (Saili and Taat, 2024). These tools help visualize complex

concepts, making learning more engaging and effective. Studies have demonstrated that interactive technologies can improve students' performance and creativity. For example, visualization and interactivity in education have been recognized as powerful tools for enhancing creative thinking skills. Teachers' visual strategies positively impact learners' creativity, academic performance, and independence (Abegglen et al., 2018).

Web-based instructional modules that incorporate visualization and simulation have proven to be highly effective in enhancing learning experiences. Studies have shown that these tools not only improve the understanding of complex concepts but also increase student engagement and retention of information (Campos et al., 2020). Interactive books containing visual elements such as simulations, animations, and videos can significantly increase students' creativity (Adawiyah et al., 2019). Visualization technology, digital storytelling, and interactive boards tap into students' creative abilities and enhance their understanding of complex concepts. Moreover, interactive visual tools can increase learners' motivation. Osman and Lee (2014) found that incorporating an interactive multimedia module helps students visualize abstract chemistry topics and increase extrinsic goal orientation, leading to a better understanding of the subject. Bishara (2016) identified a positive correlation between creativity and motivation, demonstrating that higher motivation levels lead to increased creative thinking and problem-solving abilities. This study seeks to address the gap between the need for creative thinking skills and the current state of educational practices. By developing and implementing an interactive visual learning environment based on the Torrance Incubation Model (TIM), this research aims to enhance the creative thinking and performance of non-major computer science students. The study also explores the students' preferences for various visual interactive tools, providing valuable insights for educators and curriculum developers.

The objectives of this study are: (1) To assess the impact of Interactive Visual Learning environment on students' creative thinking; (2) To assess the impact of Interactive Visual Learning environment on students' performance; and (3) To identify preferred visual interactive tools among the students. These objectives aim to address the gap between the need for creative thinking skills and the current state of educational practices. By focusing on non-major computer science students, the study seeks to demonstrate the broad applicability of interactive learning environments and the potential for enhancing creativity across disciplines. This research applied a pre-experimental research design: one group pre-test-post-test. Experimental research design is the class of research where the interactive learning environment through visualisation was manipulated to measure the level of creative thinking skills and learning performance.

Materials and Methods

The participants in this study are undergraduate students enrolled in a non-major computer science course. A total of 16 students registered in the Authoring course in semester 1 Session 2022/2021 were selected through purposive sampling. The selection criteria included students who had no prior experience with interactive visual tools and those who expressed a willingness to participate in the study.

Intervention

The intervention involved the development and implementation of an interactive learning environment based on the TIM framework. This environment included various visual interactive tools, such as simulations, animations, and digital storytelling. The tools were designed to engage students in active learning and stimulate their creative thinking. The learning activity involves students generating different ideas through brainstorming activities using Padlet and Sketchpad, interactive learning using H5P video and designing the Apps interface using Figma, as interactive visual tools in groups (Table 1). Sketchpad is designed to create simple sketches that users can save as PNG files for use with other apps. Sketchpad features allow students to draw using a ballpoint pen, pencil, or highlighter tool, similar to a traditional pencil. Users can use the application even do not have a stylus pen to sketch. This open-source application provides shapes, clipart, and varieties of brushes to make sketching and brainstorming easier. Shapes and clipart can be used in many ways to create exactly what users have in mind or expanding imagination (Figure 1).

Table 1. Learning activities, materials and goals based on Torrance Incubation Model Stage 1.

Topic	Learning materials	Learning activities	TIM Learning goal
Introduction topic and aims. Hardware & Software Requirement.	H5P Interactive Lecture Slide. Short Video entitles "Inspirational Video by the young developer."	Students go through the learning material to understand the course.	Creating the desire to know.
Introduction to Mobile Application	H5P Interactive Lecture Slide. H5P Interactive Lecture Video on Types of Mobile Apps.	Asynchronous Interactive Learning session.	Arouse curiosity.
What mobile app you want to build?	Interactive Lecture Slide. H5P Interactive notes on how to use Sketchpad Software using H5P.	Brainstorming session in a group through forum and Padlet. Sketch ideas using Sketchpad individually. Discuss with the group to select only one idea and refine the idea using Sketchpad and design the apps user interface using Figma collaboratively. Feedback with instructor, finalised the idea and submitted on LMS.	Get Attention. Tickling the imaginations. Heightening Anticipation and Expectation. Giving Purpose and Motivation.



Figure 1. Example of students' design using Sketchpad in Stage 1 of the Torrance Incubation Model-Apps for learning Korean language.

H5P is an abbreviation for the HTML5 package that provide interactive visual content such as navigable timelines, flip cards, visual drag-and-drop matching, quizzes, interactive videos, and more (Figure 2). According to Onofre and Meulen (2018), Figma is a digital design tool with an interactive interface, to create a prototype of web or mobile application. The visual tools can create interactive interface to allow user to interact with the design (Figure 3). Data were collected through a combination of pre-and post-tests, surveys and semi structured interview. The pre-and post-tests measured changes in students' creative thinking and performance. The surveys collected information on students' preferences for different visual interactive tools. Instrument involves in this research are Performance Test consisting of 20 multiple questions related to the syllabus and Torrance Test of Creative Thinking (TTCT) : Figural and Verbal creative test adapted from (Kim, 2017; 2006). Quantitative data were analyzed using statistical methods, including Wilcoxon Signed Ranks, Spearman Correlation and Decision Tree analysis, to determine the significance of changes in creative thinking and performance. Qualitative data from the surveys and focus group discussions were analyzed using thematic analysis to identify common themes and patterns in students' experiences and preferences.

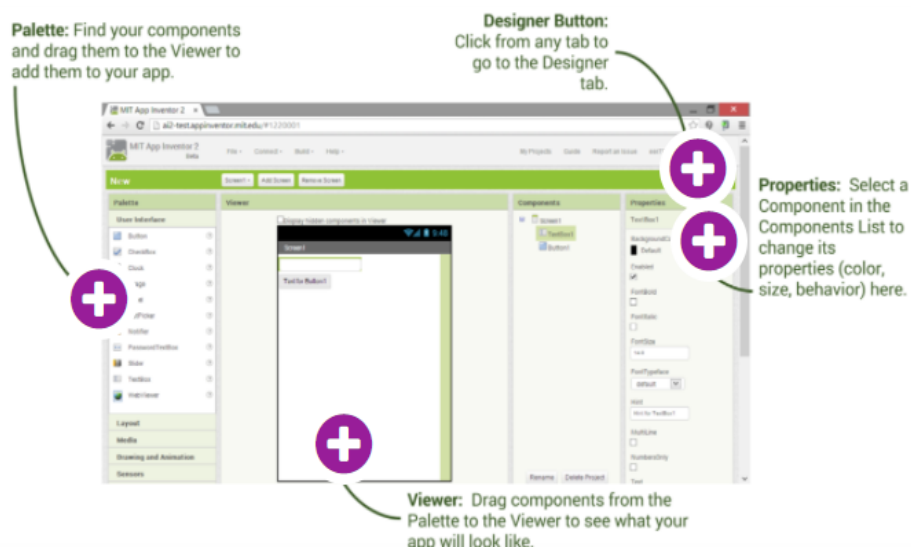


Figure 2. Example of Interactive Notes in H5P interactive visual content.

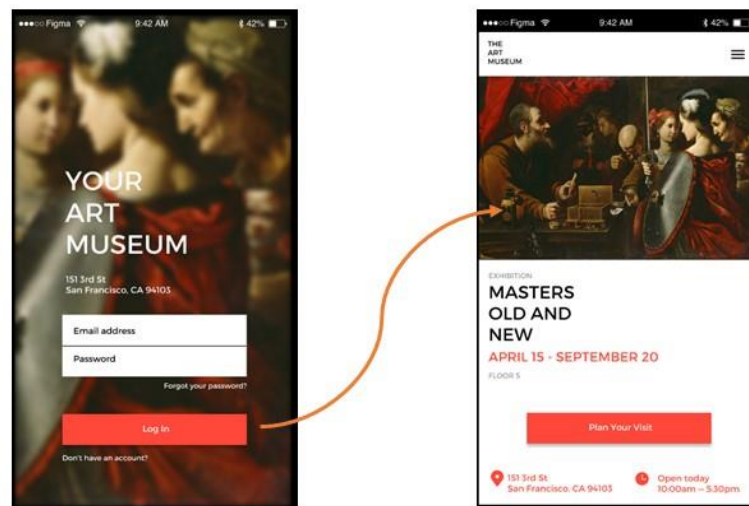


Figure 3. Example of Interactive Mobile Apps prototype using FIGMA.

Results and Discussion

Impact of interactive visual learning environment on students' creative thinking

The result indicates that all means for the post-test on Creative Thinking-Figural are higher when compared to the mean for the pre-test. The standard deviation value also improved in the post-test compared to the previous test. Data exhibits the descriptive statistic among respondents based on the post-test result. The result indicates that the mean of the treatment groups is higher (4.15 to 25.84) than before treatments (0.37 to 13.3) for all measured variables. As shown in *Table 2*, pre and post-test creative thinking scores (Figural) among non-major computer science students were measured and ranked accordingly. The output shows significant evidence of a difference between the scores for the pre-figural creative test and the after treatments. A Wilcoxon signed-rank test showed a significant difference ($Z=-2.689$, $p<0.007$) between scores for the average pre-figural creative test in the fluency norms compared to the new treatment's method (*Table 3*). Significant score originality norms difference ($Z=-3.517$, $p<0.000$) after the treatments. The abstractness of title creative figural norms correspondingly significance ($Z=-2.637$, $p<0.008$). Elaboration score norms difference ($Z=-3.466$, $p<0.001$, subsequent the significance of resistance to premature closure pre and post-treatment are ($Z=-3.517$, $p<0.000$). Consequently, between the five norms of figural creative before and after treatments, effects exist between two variables.

Table 2. Wilcoxon Signed Rank for figural creative thinking.

Category		N	Mean rank	Sum of ranks
Post Fluency – Pre-Fluency	Negative Ranks	3 ^a	5.33	16.00
	Positive Ranks	13 ^b	9.23	120.00
	Ties	0 ^c		
	Total	16		
Post Originality – Pre-Originality	Negative Ranks	0 ^d	.00	.00
	Positive Ranks	16 ^e	8.50	136.00
	Ties	0 ^f		
	Total	16		
Post Abstractness of Title – Pre-Abstractness of Title	Negative Ranks	1 ^g	3.50	3.50
	Positive Ranks	10 ^h	6.25	62.50
	Ties	5 ⁱ		
	Total	16		
Post Elaboration – Pre-Elaboration	Negative Ranks	1 ^j	1.00	1.00

	Positive Ranks	15 ^k	9.00	135.00
	Ties	0 ^l		
	Total	16		
Post Premature closure – Pre-Premature closure	Negative Ranks	0 ^m	.00	.00
	Positive Ranks	16 ⁿ	8.50	136.00
	Ties	0 ^o		
	Total	16		

Table 3. Wilcoxon Signed-rank significant test on creative thinking-figural.

Category	Post-Pre F1	Post-Pre F2	Post-Pre F3	Post-Pre F4	Post-Pre F5
Z	-2.689 ^b	-3.517 ^b	-2.637 ^b	-3.466 ^b	-3.517 ^b
Asymp. Sig. (2-tailed)	.007	.000	.008	.001	.000

Note: a. Wilcoxon Signed ranks test; b. Based on negative ranks.

Analysis of creative thinking-verbal

The results show that the post-test mean is greater than the pre-test mean. The standard deviation value improved in the post-test compared to the previous test. The mean of the verbal creative test treatment has increased across three dimensions: fluency (3.20 to 3.66), flexibility (2.04 to 2.60), and Originality (1.18 to 1.89). In Verbal Fluency, respondents' standard deviations range from 1.10 to 2.0. While Flexibility grew from 0.76 to 1.34, Originality increased from 0.91 to 1.08. As shown in Table 4, pre and post-test scores of creative thinking (Verbal) among non-major computer science students were measured and ranked accordingly. Data shows that positive ranks for all three (3) Verbal Creative Thinking elements is higher than negative rank on the post-test. The Wilcoxon signed-rank test in Table 5 demonstrated no significant difference ($Z=-0.699$, $p=0.484$) between pre-creative verbal-fluency scores before and after the treatment. There are also no significant differences between pre-creative verbal-flexibility scores before and after the treatment ($Z=-1.320$, $p=0.187$). However, there are significant differences between pre-creative verbal-originality scores before and after the treatment ($Z=-2.169$, $p=0.030$).

Table 4. Wilcoxon Signed ranks for verbal creative thinking.

Category		N	Mean Rank	Sum of ranks
Post_Fluency –	Negative Ranks	5 ^a	7.10	35.50
Pre_Fluency	Positive Ranks	8 ^b	6.94	55.50
	Ties	3 ^c		
	Total	16		
Post_Flexibility –	Negative Ranks	6 ^d	5.25	31.50
Pre_Flexibility	Positive Ranks	8 ^e	9.19	73.50
	Ties	2 ^f		
	Total	16		
Post_Originality –	Negative Ranks	4 ^g	5.50	22.00
Pre_Originality	Positive Ranks	11 ^h	8.91	98.00
	Ties	1 ⁱ		
	Total	16		

Table 5. Wilcoxon Signed-rank significant test on creative thinking-verbal.

Category	Post_Fluency – Pre_Fluency	Post_Flexibility – Pre_Flexibility	Post_Originality – Pre_Originality
Z	-.699 ^b	-1.320 ^b	-2.169 ^b
Asymp. Sig. (2-tailed)	.484	.187	.030

Note: a. Wilcoxon Signed Ranks Test; b. Based on negative ranks.

Findings showed a significant increase in students' creative thinking scores after the learning within the Interactive Learning Environment. The TIM framework's emphasis on incubation and exploration stages allowed students to engage deeply with the

material, leading to more original and innovative ideas. Similar findings were also found by Fan and Cai (2022) where a creative learning environment is significantly associated with student creativity by enhancing students' learning goal orientation, network ties, and knowledge sharing. Giving respondents opportunities to be creative requires allowing them to innovate and communicate ideas with a new approach. The visual interactive tools provided a dynamic and engaging platform for students to experiment with different concepts and ideas. According to previous study, Mind mapping is a presentation form of radiant thinking, utilizing lines, colours, characters, numbers, symbols, images, pictures or keywords, etc., to associate, integrate and visualize the learned concept and evoke brain potential.

Impact of interactive learning environment on students' performance

In addition to improvements in creative thinking, the students' performance in the course also showed significant enhancement. All respondents progressed in the post-test score around 10% to 45 %. Using the Wilcoxon test, there is a significance value of $p < 0.05$ with Mean Rank=8.50 and $Z=3.526$, as stated in *Table 6*. This finding indicates that there is a difference between the pre-test and post-test of the respondents. The test results revealed that the performance level scores of the students were significantly higher than the students' scores before instruction. The Visual interactive learning environment does helped students better understand complex programming concepts, resulting in higher test scores and project outcomes. The use of visual tools, such as animations and interactive boards, made abstract concepts more tangible and easier to grasp.

Table 6. Wilcoxon Sign Rank test on students' performance before and after learning using a visual interactive learning environment through visualisation.

Measurement of pre and post-test	N	Mean Rank	Sum of Ranks	Z	Asymp. Sig. (2-tailed)
Negative Ranks	0	.00	.00	-3.526 ^b	.000
Positive Ranks	16	8.50	136.00		
Ties	0				

Note: a. Wilcoxon Signed Ranks Test; b. Based on negative ranks.

Student preferences for visual interactive tools

The preferences for visual interactive tools in an asynchronous learning environment have been explored, and respondents were interviewed to answer Research Question 4, "What interactive visual tools are preferred among undergraduate's non-major computer science students in an Interactive Learning Environment through Visualisation?" *Table 7* explains user preferences for selected visual interactive tools in an asynchronous learning environment. The respondent shows positive preferences for all three tools prepared in the online asynchronous learning environment based on three categories of visual interactive tools. Sketchpad was the highest preference, with 14 out of 16 respondents agreeing that the tools are helpful. Some of the statements from respondents that show they prefer the tool are as follows:

Table 7. Preferences on selected visual interactive tools.

Visual interactive tools	Positive	Negative	Neutral
Sketchpad – brainstorming	14	0	2
Figma design	11	0	0
H5P Video – content	8	0	2

Respondent S4: I'm not good at drawing.. that is all.. aa.... Sketchpad already has many features; for example, there is all that clip art..so..if I want to decorate.....easy..want to find what I want exactly

Respondent S9: Sketch pad also has a stabiliser; we can measure the size and how many degrees we want to shorten it

The second tool preferred by the respondents is Figma. All 11 respondents responded positively that Figma is very user-friendly and showed positive preferences for using Figma as a tool that helps in exploring ideas to build Mobile Learning Apps. Some of the statements from respondents that show they prefer Figma as a visual interactive tool are as follows:

Respondent S2: ... colour using Figma is really easy

Respondent S3: I think the mobile application interface to be developed is even more beautiful using this Figma. I can visualise the final product

Respondent S5: I like to use Figma to design mobile apps

Finally, eight respondents show positive preferences towards H5p elements. Respondents also describe the element of the h5p that help them more in comprehension. Some of the feedback are as follows:

Respondent S11: After that button, the question came out during the video; oh, then I understand

Respondent S13: The video will stop in the middle and then ask questions about what we understand

All respondent shows positive preferences for all three visual interactive tools prepared in the online asynchronous learning environment. Examples of respondent feedback that shows they prefer the visual interactive tools to improve their learning are as follows:

Respondent S4: Okay, in my opinion..... interactive visual tools really helped me generate ideas because I can do it on the spot (referring to converting the insight idea and imagination to the rough sketch digital paper platform),....for example, I got an idea, need to be like a draw manually (referring to interpreting the idea easily) It is like if we use paper, it's like that thing was disappearing, so if we sketch using this digital. It helps; that means the idea is there. Moreover, it's not difficult, it's a new way, it's...it is practical to get ideas when we get it, we type and type to design it.

Research by Adawiyah et al. (2019) as well as Ma and Shi (2016), also supports these findings that interactive tools can promote learner interaction with the subject matter, improve student idea visibility, and boost student motivation. Researchers try to explore further by identifying which visual interactive learning tools affect student performance using user log data while learning in the learning management system

(LMS), as well as data from post-learning test scores. The scores were categorised into three (3) categories which are High(T), Medium(S) and Low(R) (*Figure 4*), which then transformed into categories and codes to facilitate the classification process. The letters 'K' and 'L' found behind each activity data category code mean 'less' and 'more'. This item refers to the total frequency of activities collected from the user log data that the respondent performs in the LMS. The tree analysis of the results for post-test scores and activities showed that four pathways were produced through the tree diagram of the results. All four routes contain a combination of activities to achieve a high post-test score, as shown in *Table 8*. Among the activities involved are: (1) IV (H5P Interactive Video and Content); (2) P (Padlet); (3) FD (Figma Design).

Table 8. High-level post-test score path (PTT).

Post-test score level	Path number	n	Activity combination
PTT	1	2	IVK > PL > FDL
	2	1	IVK > PL > FDK
	3	3	IVK > PK
	4	10	IVL

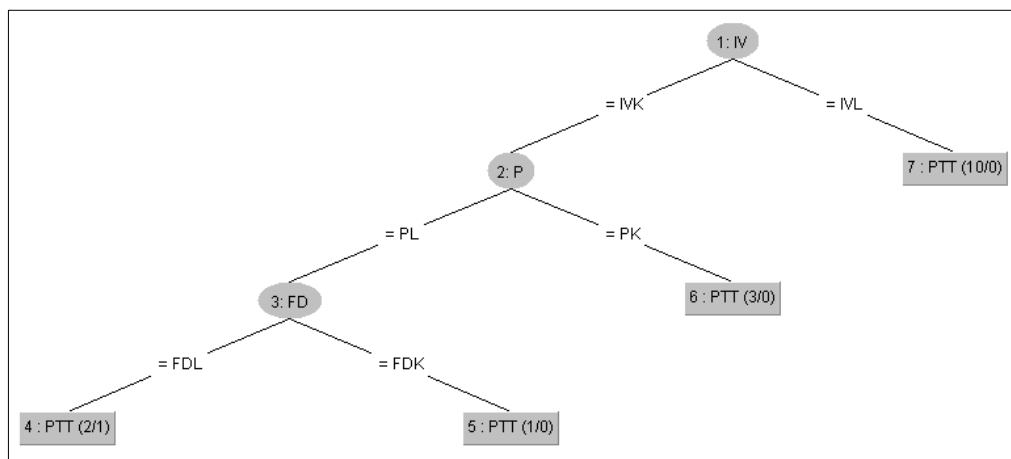


Figure 4. Results Tree of activities that affect Post-test score (PT).

Creative thinking can be taught by allowing learners to explore images and apply them in solving tasks (Yang and Zhao, 2021). Based on data collected from 2,355 high school students, researchers found a positive relationship between creative thinking and performance. Similarly, as found in this research, the visual interactive learning environment did influence creative thinking which then contributes to their achievement. Again, researchers use user log data while learning in the learning management system (LMS), as well as data from post-learning test scores, to identify which visual interactive learning tools affect the component of Creative Thinking using decision tree analysis. The decision tree summary in *Table 9*, revealed that all high-level components of Figural Creative Thinking, based on Torrance, are influenced by more activities involving Figma Design (FDL), H5P Interactive Video and Content (IVL), Sketchpad-Brainstorming (SBL), and Padlet-discussion (PL). Although a Discussion Forum (DF) was available in the LMS for discussion, it was not significant, possibly due to its non-visual format, except for its impact on Originality. Interestingly, for the Elaboration-figural level, more activities related to Lecture Notes Non-Video (LNL) were found in the path, possibly indicating that students revisited the notes for better understanding. Decision tree analysis reveals that the creative verbal test has no impact

or correlation with enhancing creative thinking skills, nor does it contribute to high performance in the verbal test. Consequently, the researcher emphasizes using only the Figural creative and Creative visual tools to achieve the goal of promoting creative thinking and performance.

Table 9. Decision tree path on figural creative thinking based on interactive learning environment.

Creative thinking-figural	Path number	Total path	n	Activity combination
High Fluency Level (F1T)	1	8	2	FDL > IVK > SBL
	2		1	FDL > IVK > SBK
	3		4	FDL > IVL > SBL > PL
	5		1	FDL > IVL > SBK
	4		1	FDL > DFK > IVL > SBK
High Originality Level (F2T)	4	6	1	FDL > DFL
	5		1	FDL > DFL
High Abstractness of Title Level (F3T)	2	6	1	SBL > IVK > PL > FDK
High Elaboration Level (F4T)	4	7	1	LNL > SBK > DFK > FDL
High Resistance to Premature Closure Level (F5T)	5	8	1	FDL > SBK > IVL

Conclusion

The integration of interactive visual tools in educational settings significantly enhances students' creative thinking and performance. Based on TIM, provides a structured approach to incorporating these tools effectively was suggested which is the Figural creative and Creative visual tool to achieve the research objective of fostering creative thinking and performance. Future research should explore the long-term impacts of such interventions across different disciplines and educational levels. The use of interactive visual tools in educational environments greatly improves students' creative thinking and performance. The Torrance Incubation Model (TIM) recommends a systematic method for implementing these tools, specifically the Figural creative and Creative visual tool, to enhance creative thinking and performance as set out in the research objectives. Future studies should investigate the sustained effects of these interventions across various fields and educational stages.

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Conflict of interest

The authors confirm that there is no conflict of interest involve with any parties in this research study.

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