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Integrating the STEAM-6E Model with Virtual Reality Instruction: The Contribution to Motivation, Effectiveness, Satisfaction, and Creativity of Learners with Diverse Cognitive Styles

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Abstract: In today's digital age, where smartphones are ubiquitous among the younger generation, they can add to the cognitive load on the brain, even when not in use. This can affect students' learning outcomes and creativity, leading to negative emotions or creativity blocks during the learning process. Thus, this study investigates the relationship between differences in students' cognitive styles and their learning motivation, learning outcomes, creativity, and learning satisfaction. The primary objective is to use the STEAM-6E instructional model in virtual reality (VR) courses to understand how students with different cognitive styles can be stimulated to unleash their diverse and vibrant creativity based on their learning preferences during hands-on experiences. The study also aims to explore whether there are disparities in their learning motivation and learning outcomes, and whether there are differences in their overall learning satisfaction. The findings of the study indicate that for the two cognitive styles of holistic and sequential, the subjects showed significant differences in their learning motivation regarding intrinsic goals, extrinsic goals, task value, control beliefs, self-efficacy, and test anxiety. Significant differences were also observed in their learning preferences, learning outcomes, and creative performance. However, the two groups had no significant differences in the effectiveness, efficiency, and overall satisfaction of the learning activities.

Keywords: cognitive style; STEAM-6E model; virtual reality; motivation for learning; creativity

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Citation: Lin, Y.-H.; Lin, H.-C.K.; Wang, T.-H.; Wu, C.-H. Integrating the STEAM-6E Model with Virtual Reality Instruction: The Contribution to Motivation, Effectiveness, Satisfaction, and Creativity of Learners with Diverse Cognitive Styles. *Sustainability* **2023**, *15*, 6269. https://doi.org/10.3390/su15076269

Academic Editor: Antonio P. Gutierrez de Blume

Received: 1 March 2023
Revised: 19 March 2023
Accepted: 3 April 2023
Published: 6 April 2023

1. Introduction

The responsibility of education is to effectively guide learners in improving their knowledge, being willing to imagine and develop creativity, and preparing for the future. Therefore, it is important to discuss how to motivate students with different cognitive styles and learning preferences to learn and stimulate their creativity. This study enriches digital learning technology literacy through STEAM-6E instructional scaffolding to improve learning effectiveness through hands-on experience and group dynamics of cooperate promotion because the recent integration of the STEAM-6E model and VR (virtual reality) into digital courses rarely includes the "differences in cognitive styles of learners". Moreover, students in Taiwan are digital natives, and cannot live without their mobile phones. Studies have shown that even if we do not use our phones and there is no notification sound, the normal functioning of our brains may still be disturbed. The reason is that individuals need extra effort to self-control to avoid reaching or using mobile phones [1,2], which can affect the proper working memory, cognitive capacity, and hinder the generation of flow. It will produce creative blocks in the process of inspiration or imagination, which eventually makes it hard for the individual to applicate his inner internal creativity. Winterstein and Jungwirth [3] studied the drawings of 1859 children through the Menschenzeichentest to analyze the impact on children's "visual perception" and "hand-eye coordination" based on the amount of time spent watching TV, and then they found differences in internal cognitive abilities and emotional development ensued. Przybylski and Weinstein [4] pointed out that mobile devices, such as smartphones, will interfere with the ideal relationship between team members, and may impair group creativity. Based on the above, such issues hinder the normal development of children's creative ability, which gives the researcher the motivation to explore these issues in depth.

This research takes junior high school students as a primary group using the hands-on experience of a VR campus-guiding course combined with immediate issues in daily life based on their two cognitive styles, holist and serialist, in response to the new era led by digital technology. This study plans STEAM curriculum content with participation, exploration, explanation, construction, deepening, and evaluation in 6E multi-axis teaching strategies. We conducted VR problem-based learning based on tasks at each stage, from finding the problem, collecting, analyzing, designing coordination, executive management, and posting comments to reflective corrections and other cross-domain integrated dynamic learning knowledge.

Combining the STEAM-6E model with virtual reality instruction can help students better understand and apply knowledge in science, technology, engineering, arts, and mathematics. This teaching method can stimulate students' learning motivation and creativity, helping them better respond to future challenges and opportunities. At the same time, this teaching method can also help students cultivate environmental awareness and concepts of sustainable development, as it can educate them on how to solve real-life problems in the fields of science and technology to achieve economic, social, and environmental sustainability. In addition, we conducted VR courses through the STEAM-6E teaching model and implemented a VR campus tour. Using virtual reality technology on campus tours can provide a more realistic, interactive, and vivid experience while also reducing the consumption of natural resources, thereby better adhering to the principles of sustainable development.

The study will investigate the effects of implementing the STEAM-6E model for VR courses on learning motivation and creativity, and whether there are significant differences in learning preferences, outcomes, and satisfaction of junior high school students with different cognitive styles. The study hypothesizes that implementing STEAM-6E for VR courses positively affects learning motivation and creativity, and significant differences in learning preferences, outcomes, and satisfaction exist among students with different cognitive styles. The rationale for each hypothesis will be based on the literature review.

Based on the purpose of this study, the following research questions are proposed:

1. Does implementing the STEAM-6E model for VR courses affect the learning motivation of junior high school students with different cognitive styles?
2. Does implementing the STEAM-6E model for VR courses impact the creativity of junior high school students with different cognitive styles?
3. After conducting VR courses in the STEAM-6E model, are there any significant differences in the learning preferences, learning outcomes, and learning satisfaction of junior high school students with different cognitive styles?

2. Literature Review

2.1. The Influence of Cognitive Style on Learning Strategies

Pask's team [5] proposed the concept of "Holist-Serialist." The learning strategies of the holistic cognitive style tend to adopt an overall considerate orientation, and their behavioral traits prefer a hypothesis-based method. On the other hand, the serialist cognitive style preference adopts hierarchical focusing and has a step-by-step behavior. Messick [6] pointed out that cognitive style is the behavioral trait of individuals' organizing or processing information, different from intelligence. Riding and Sadler-Smith [7] defined cognitive style as an individual's inertial strategy for information construction during the learning process. It has a general structure, it is stable, and it is deeply rooted, reflecting qualitative differences in the thought processes of different individuals. In addition, cognitive style is a preferred information-processing mode of individuals, and it is also the most habitual or preferred strategy in the learning process [8]. The serialist cognitive style is more active, focusing on deep and partial sequential learning strategies; the holistic cognitive style is more passive, learning with breadth and overview [9]. Therefore, teachers' in-depth understanding of students' learning preferences would be able to contribute to teaching effectiveness, while learners' cognitive style can affect their preference for Web-based instruction [10]. Chen and Tseng [11] found that holist and serialist cognitive style learners showed similar learning perceptions through E-based scaffolding assessment on English grammar learning. However, they exhibited differences in learned behavior that corresponded to their cognitive style characteristics. Naseer et al. [12] describe an ideal creative cognitive style that helps individuals focus their attention and engage their imagination, thereby fostering creativity and innovation. Therefore, the ideal of an educator lies in realizing the careful planning of lesson preparation, timely adjusting strategies during the teaching process according to individual differences in adaptive practice activities. It aims to provide the most effective and multi-functional learning scaffold customized for different cognitive styles and learning preference behaviors, and eventually achieve ideal learning effects and realize personal dreams through multiple growth paths.

2.2. Creativity in Education

Creativity is a phenomenon that creates new ideas and value, and it is also the ability to make or use new thoughts. In the field of education, Csikszentmihalyi [13] pointed out that creativity is a mental activity, mastering the original insights of people's unique minds through dedicated learning and by imitating others. Therefore, the ways in which education can implement teaching strategies effectively, assisting students in launching creative thinking skills, originality, flexibility, refinement, and productivity through teachers' metacognition has become the focus of today's creativity education.

The importance of creativity can be further explored in the classroom through the interweaving of students, teachers, and teaching materials. Students' curiosity and interests are primary sources of potential creativity [14]. Hu [15] indicates that creative thinking teaching is more sensitive and fluent than traditional teaching since students can demonstrate their highest levels of sensitivity and fluency in creative thinking while using immersive VR. Saorin [16] pointed out that innovative ideas can be stimulated through the STEAM maker offices and creative thinking ability can be improved by turning ideas into actual products. Nikkola [17] indicates that children's creativity and thinking ability are closely related to whether they are willing to participate in activities. They will change their will by paying attention to their surroundings. Jumadi et al. [18] proposed an instructional design that allows students to develop problem-solving and creativity. This can help students enhance their system's thinking, and intensify their creative performance by engaging in meaningful reflection and taking action through questioning and discussing critical thinking situations

In summary, creativity means a process that produces original and unique ideas or creations to integrate knowledge for problem-solving, and eventually achieves the real purpose of solving problems. Individuals, based on prior knowledge or experience, can have the ability to break through the framework with an unprecedented perspective, urging them to bring out new theories and dare to unlock the unknown through continuous practice, perceiving, understanding, and exploring the essence of questions.

2.3. STEAM and 6E Instructional Scaffolding Model in Education

Radziwill et al. [19] proposed that the STEAM learning development plan is divided into four stages, the cumulative sum of knowledge, creating knowledge exchange between individuals and organizations, self-awareness and update, and the recognition and value obtained by the previous knowledge and ability. STEAM education aims to ensure that lifelong learning takes place at all times accessible to learners, allowing them to unleash their potential and creativity, continuing to utilize the integration of multi-stakeholder dialogue and cross-domain literacy to activate actual learning experiences and eventually bring maximum benefit to society through teamwork and problem-solving.

The 6E (engage, explore, explain, engineer, enrich, and evaluate) instructional scaffolding model emphasizes that students are the main body of learning. It is a sequential teaching model that combines science education and engineering design processes combining students in heterogeneous groups to stimulate design, practice, inquiry, and reflection. Sanjayanti et al. [20] found that the 6E design learning program can improve students' logical thinking and awareness. Hashim et al. [21] illustrated that science educators should emphasize meaningful learning environments to stimulate students' creativity. Cultivating sophisticated thinking skills from learning by design according to their diverse background knowledge, cognitive style, and learning tendency is believed to be the basis for stimulating students' creativity. In executing the 6E model, students repeatedly deepen their thinking, which is especially suitable for STEAM courses, learning STEAM knowledge sequentially and competently through hands-on subject content and teacher step-by-step guidance. As a result, it can improve the learning effect of various disciplines and interdisciplinary subjects, and improve collaborative learning, professional knowledge, and self-confidence [22].

To sum up, based on the core concept of STEAM education, this study deeply explores and carefully plans the activation curriculum that can break through the subject framework. It strengthens the basis of student engagement as the primary body of learning, combined with the 6E teaching model interwoven into the STEAM-6E pedagogy to guide students to actively participate, explore, explain, build, enrich and evaluate. It guides students step by step to use their imagination, self-control their learning strategies, develop their learned and practical concepts, and develop their skills in innovative and creative thinking, action response, and problem-solving.

2.4. The Application of VR in Education

For educational applications, the initial stage of VR is often used as a high-risk training tasks. It can be seen in the standard operation procedure (SOP) training that is widely used in the daily duties of the police, firefighters, medical staff, actual combat simulation or logistics special training courses for military officers and soldiers, precision microscopic medical practice training for brain surgery, etc. The purpose is to provide a safe and secure educational environment where mastery can be practiced. Walcutt et al. [23] pointed out that with the maturity of waterproof hardware and educational software technology, VR is more and more widely used in marine science as educational materials for scientific exploration. VR is an extraordinarily engaging educational tool compared to data analysis or flat images. Shim [24] mentioned that the fusion of VR and educational applications are based on three basic principles: immersion, interaction, and user participation in the environment and story. These elements make the learning process more engaging and improve student motivation, offering exciting educational potential. Chen et al. [25] pointed out that students using VR technology while learning has significantly improved academic performance and hands-on ability. Demonstrating virtual reality can help students understand abstract scientific concepts and build mental conceptual models to help them internalize and organize into knowledge structures. Looking forward, the combination of VR and education in the future, may be able to carry out an international virtual course that allows teachers and students around the world to discuss language, culture, or science all together without distance and time problems to conduct self-directed flipped learning and mastery training. It can also be used in a digital guided tour of museums before the outdoor education starts as a knowledge preview, or as pre-fire fire extinguishing and escape simulation training. In conclusion, as VR and related technologies mature, the only thing that can slow their evolution is human imagination.

Therefore, this study plans a set of "STEAM-6E Teaching Methods" for VR teaching and aims to enrich the diversified content of STEAM education. We adopt the 6E model to expand the spectrum of interdisciplinary thinking and deepen the learning experience while combining school-based characteristic courses and actual conditions. Engaging in meaningful observation and reflection to stimulate learning motivation and team dynamics further initiates unlimited imagination for original and unique innovation output. Knowledgeable and systematic self-examination, internal management growth, and dynamic learning from the design process eventually produces original and interesting VR guide works, guiding students with different cognitive styles to deeply perceive and feel the beauty of the campus, and also make good use of creative thinking skills to solve practical problems in life. We hope students can improve their learning effect and learning satisfaction, enhance self-efficacy, and affirm their self-worth after taking this course.

2.5. Learning Motivation

Motivation refers to the activities that can arouse the learners and prompt the learners to lead the activities to a certain goal that is to be achieved, and towards an internal motivation of learning with active participation. This has a considerable impact on the positive correlation of learning outcomes. Additionally, Some studies also pointed out that there is a highly positive relationship between learning motivation and achievement [26–28].

According to MSLQ, the motivation scale section consists of six components: intrinsic motivation, extrinsic motivation, task value, control of learning beliefs, self-efficacy, and test anxiety [29]. Learning motivation is an important factor affecting students' learning behavior [30], which represents students' motivation to pursue their learning goals. Therefore, educators should understand students' learning motivation and adopt appropriate teaching strategies and methods to improve students' learning motivation and promote their learning achievement and growth.

2.6. Learning Satisfaction

Learning activity satisfaction refers to learners' satisfaction with the activities they participate in during the learning process. The level of satisfaction with learning activities will have an impact on learning motivation and learning outcomes [31]. According to Tough [32] students exhibit positive and enthusiastic attitudes toward learning activities can be seen as a measure of satisfaction in learning. Conversely, showing negative and pessimistic emotions can be viewed as a measure of dissatisfaction.

ASQ (after-scenario questionnaire) is a measurement tool that was first proposed and used by Lewis [33] for post-task ratings. The ASQ scale includes three questions that represent effectiveness, efficiency, and overall satisfaction [34]. This questionnaire has been widely used in evaluating user experience in various scenarios, including learning activities. Cabral's [35] results of the ASQ questionnaire indicated high levels of user satisfaction with the virtual experience.

3. Methods

3.1. Research Design

In this study, we use the experimental method of one-group pretest–posttest design from pre-experimental design, focusing on learners with the two cognitive styles of "Holist" and "Serialist", and integrating STEAM-6E to the VR campus tour practice course. We designed the course based on the essential techniques of VR to plan the teaching material required in curriculum planning, prepare for teaching materials, and then, assessment. We have taken the STEAM-6E teaching model as our main axis and choosing the VR campus guiding as the research category to explore the quality of the impacts on creative thinking, learning effectiveness, learning motivation, and learning satisfaction related to learners with different cognitive styles. According to the VR courses planned in the life and technology courses in senior, junior, and elementary schools, most of the teaching materials only have basic introductions, lacking application reflection and practical activities. Therefore, in terms of practical application value, participants can acquire a VR design project through the course, and plan the ideal guiding route on the campus where they live every day. This plan can not only allow the trainees to express their ideas and creativity through their cognitive style and develop independent creative thinking skills and practical problem-solving knowledge that resonates with their learning and life to carry forward into meaningful learning, but also help the school to build its resources. This course is planned for 40 min per week, and 8 weeks in total, including 320 min altogether. Figure 1 shows the plan of this course, Figure 2 shows the implementation records in this course, Table 1 is the correspondence table between STEAM fields and students' learning performance.

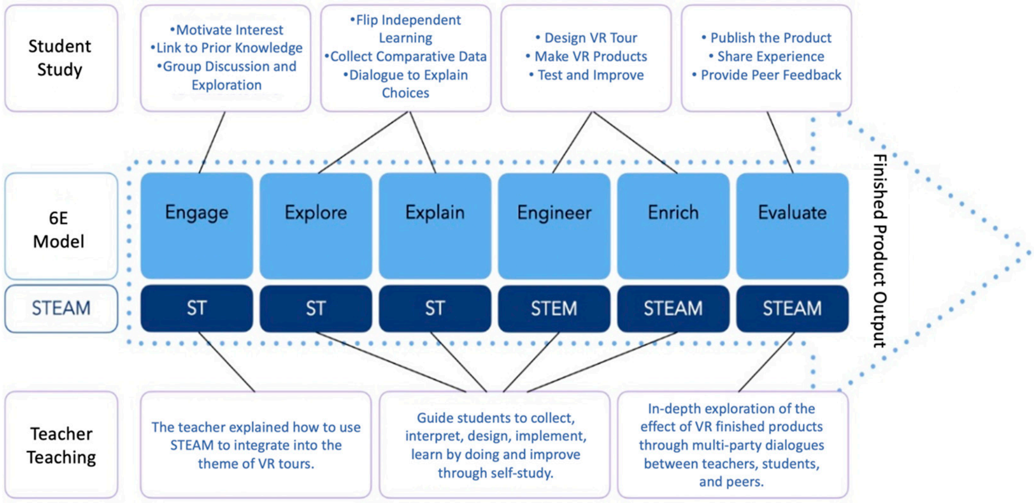

Figure 1. The planning process of STEAM-6E integrated into the VR campus tour practice course.

Figure 2. Implementation records of the integration with STEAM-6E and Google Cardboard VR school guiding campus. (**a**) After the explanation, they conducted research in groups. (**b**) Making the Google Cardboard with members. (**c**) Students finishing and publishing their work of VR guiding. (**d**) Group discussion for peer feedback and work improvement.

Table 1. Corresponding to the learning performance of students in the STEAM field.

STEAM Field	Students' Performance
Science	• Understand the principle of 3D Stereo Vision/Tour Creator.
Technology	• Learn the basics of virtual reality. • Learn about the applications of virtual reality in real life.
Engineering	• VR guiding map. • Identify the problems at work then improve and optimize them.
Art	• Beautify the VR map. • Discover the beauty of the school through the guiding map.
Math	• Three-dimensional coordinates with latitude and longitude.

3.2. Research Tool

In the beginning, we identified the two cognitive styles of holistic and serialist by using the study preference questionnaire (SPQ); then, we sorted out the comparison table proposed by Mampadi et al. [36]. Consulting the version used by Tsai and Lin [37], we described the content of each question in two sentences or pairs. After the respondents answered based on first intuition, we distinguished them as holists or serialists by calculating which type of choice was selected in more than half of their answers.

Next, we used MSLQ to explore their intrinsic goal orientation, extrinsic goal orientation, control of learning beliefs, task value, test anxiety, and self-efficacy, etc. We also added three dimensions of value, expectation, and emotion to explore the shift in their learning motivation. In addition, we applied the learning activity satisfaction scale learning activity satisfaction scale (ASQ) in the assessment questionnaire after the post-task ratings and gave a score based on the 7-point scale to investigate effectiveness, efficiency, and satisfaction [34]. We used the pre- and post-test prepared by IT teachers based on the STEAM-6E VR learning effect, including 6 true or false questions with 30 points and 10 multiple choice questions with 70 points, 100 points in total. Pre-test papers were used to see if there are any differences between students' prior knowledge. The post-test paper was used to understand the impact on students' learning after adding the STEAM-6E teaching method to the VR practice. Finally, we explored whether their creative thinking ability changes during the teaching activities by five normative reference scores, including fluency, elaboration, originality, titles, and closure, from the TTCT graphic and streamlined scoring.

3.3. Experimental Procedure

Figure 3 shows the flow chart of the STEAM-6E teaching method in the VR course teaching experiment: (1) Before the course, take a pre-test for 40 min. The questionnaires include: learning performance scale, TTCT(A), MSLQ, SPQ; (2) Subsequent teaching courses will last for 240 min, with a total of 6 lessons. Integrate the VR course with the STEAM-6E scaffolding teaching mode and use Google Cardboard to watch the finished VR campus tour produced by the course; (3) After the course is over, there will be a 40 min post-test. The questionnaires include: learning performance scale, TTCT(B), MSLQ, ASQ. Evaluate the students' learning effects according to the learning effect test paper, use the TTCT graphic version to evaluate the impact of the students' creative thinking ability after passing the course, and analyze the students' learning motivation and satisfaction with the learning activities.

3.4. Participants

The participants of this study were in a junior high school in Tainan city. A total of 44 students participated in this study, with an average age of 13 to 14 years. However, three students asked to leave during the pre- and post-test for two sessions. Therefore, a total of 41 participants were in this study.

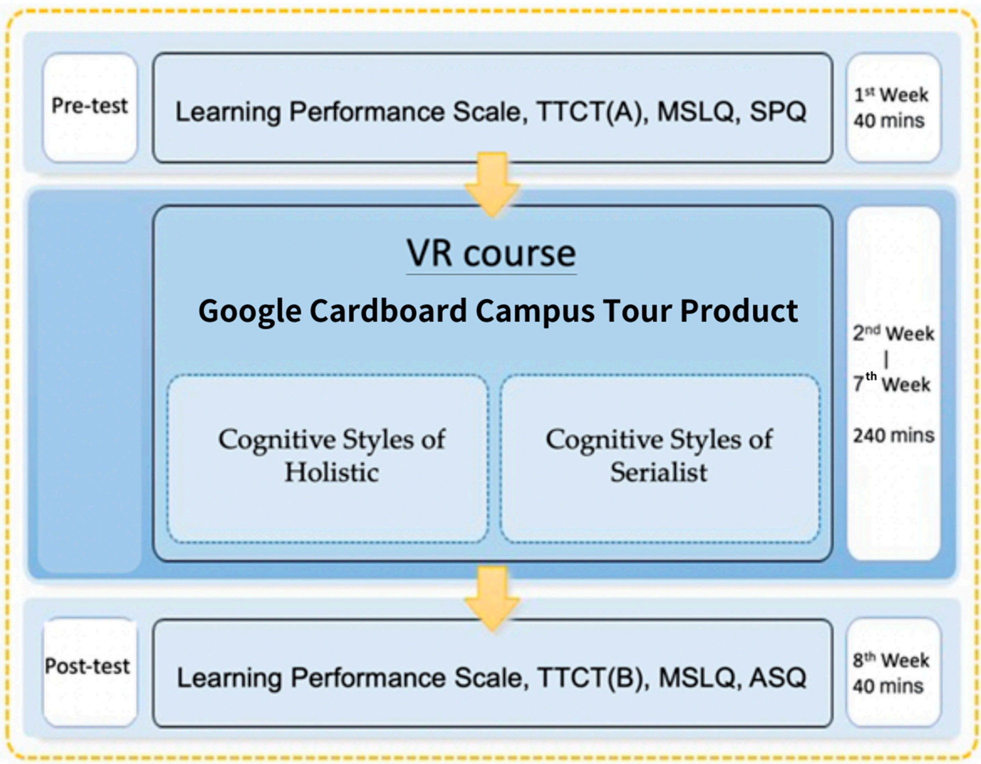

Figure 3. Experimental flow chart.

4. Results

The study aims to investigate the differences in learning motivation, learning effectiveness, and creativity among junior high school students with different cognitive styles who participated in a VR campus tour course integrated with the STEAM-6E model. A total of 41 students participated in the study. Before the course, the students completed questionnaires on the learning performance scale, TTCT(A), MSLQ, and SPQ. Then, all participants took the course, which involved using Google Cardboard to watch the finished VR campus tour produced by the course with the STEAM-6E scaffolding teaching mode. After completing the course, the students completed the post-test, which included the learning performance scale, TTCT(B), MSLQ, and ASQ questionnaires. We analyzed the data collected from the experiment based on the SPQ, and explored the differences in learning motivation, learning effectiveness, and creativity among students with different cognitive styles. Due to a pre-existing difference between holistic and serialist learners, ANCOVA was conducted to ensure the accuracy of the results.

4.1. Analysis of the Current Situation of Participants

This study used SPQ to differentiate the types of cognitive styles: holist and serialist. There were 44 participants involved in the experiment, but 3 were excluded due to being unable to fully complete the experiment. Therefore, a total of 41 participants comprised the valid sample; 21 participants with the serialist cognitive style and 20 participants with the holist cognitive style, as seen in Table 2.

Table 2. Distribution of the number of respondents' cognitive styles.

Cognitive Style	Numbers of Participants
Serialist	21
Holist	20

4.2. The Difference in the Learning Motivations for Different Cognitive Styles in the Combined STEAM-6E VR Course

This section is to discuss the differences in learning motivations between the different cognitive styles of students in the combined STEAM-6E VR-guided course. Learning motivation involved several dimensions, including intrinsic goal orientation, extrinsic goal orientation, task value, control of learning beliefs, self-efficacy, and test anxiety.

Analysis of Learning Motivations in the Different Cognitive Styles

This study was conducted to clarify the difference in learning motivation between the holist (N = 20) style and the serialist (N = 21) style in the combined STEAM-6E VR-guided course. The homogeneity of regression was examined according to the motivated strategies for learning questionnaire, MSLQ.

Table 3 shows the result of the assumption of homogeneity of regression. From the result, no significant levels were found in the pre-test of intrinsic goal orientation ($F = 2.536$, $p = 0.120 > 0.05$), the pre-test of extrinsic goal orientation ($F = 2.825$, $p = 0.101 > 0.05$), the pre-test of control of learning beliefs ($F = 0.219$, $p = 0.642 > 0.05$), the pre-test of task value ($F = 2.255$, $p = 0.142 > 0.05$), the pre-test of self-efficacy ($F = 1.191$, $p = 0.282 > 0.05$), and the pre-test of test anxiety ($F = 0.509$, $p = 0.480 > 0.05$). It showed the variables of the group, pre-test, and group*pre-test accorded with the hypothesis of homogeneity (homogeneity of variance was not violated when using the pre-test as a covariate and the post-test as the dependent variable), and suggested that a common slope of regression was appropriate for the three groups. Therefore, the analysis of covariance (ANCOVA) was adopted, where the assumption of homogeneity of regression was met, and the pre-test acted as a covariate to reduce the effect of any existing differences on the results.

Table 3. Results of the homogeneity for the within-group regression coefficients regarding the pre-test of each dimension of learning motivation.

Dimension	*SS*	*df*	*MS*	*F*	*p*
Intrinsic goal orientation	0.866	1	0.866	2.536	0.120
Extrinsic goal orientation	0.877	1	0.877	2.825	0.101
Control of learning beliefs	0.038	1	0.038	0.219	0.642
Task value	0.623	1	0.623	2.255	0.142
Self-efficacy	0.209	1	0.209	1.191	0.282
Test anxiety	0.164	1	0.164	0.509	0.480

Descriptive statistics for the means regarding the pre-test of intrinsic goal orientation were the means of the original post-test: 4.345 for the serialist style and 3.788 for the holist style. The descriptive statistics for the means regarding the pre-test of extrinsic goal orientation were the means of the original post-test: 3.964 for the serialist style and 3.325 for the holist style. The descriptive statistics for the means regarding the pre-test of control of learning beliefs were the means of the original post-test: 4.262 for the serialist style and 3.838 for the holist style. The descriptive statistics for the means regarding the pre-test of task value were the means of the original post-test: 4.175 for the serialist style and 3.792 for the holist style. The descriptive statistics for the means regarding the pre-test of self-efficacy were the means of the original post-test: 4.202 for the serialist style and 3.750 for the holist style. The descriptive statistics for the means regarding the pre-test of test anxiety were the means of the original post-test: 2.295 for the serialist style and 2.850 for the holist style. The above data did not exclude the influence of covariates (the pre-test), nor did it present the adjusted means.

The result of Levene's test of error variances for the pre-test of intrinsic goal orientation was not found to be significant ($F = 3.036$, $p = 0.089 > 0.05$). The result of Levene's test of error variances for the pre-test of extrinsic goal orientation was not found to be significant ($F = 0.050$, $p = 0.824 > 0.05$). The result of Levene's test of error variances for the pre-test of control of learning beliefs was not found to be significant ($F = 2.673$, $p = 0.110 > 0.05$).

The result of Levene's test of error variances for the pre-test of task value was not found to be significant ($F = 3.457$, $p = 0.071 > 0.05$). Levene's test of error variances for the pre-test of self-efficacy was not found to be significant ($F = 2.047$, $p = 0.160 > 0.05$). The result of Levene's test of error variances for the pre-test of test anxiety was not found to be significant ($F = 1.583$, $p = 0.216 > 0.05$). The above results suggested that homogeneity of variances was met, as error variances were equal across groups regarding the dependent variables of the post-test.

Table 4 reports the analysis of ANCOVA regarding each dimension of learning motivation, indicating the results of dependent variables (post-test scores) on the independent variables after eliminating the effects of the pre-test scores (covariates). According to the results, a significant difference was found between the two different cognitive styles ($F = 5.082$, $p = 0.03 < 0.05$) in terms of intrinsic goal orientation, indicating that there was a significant level of intrinsic goal orientation between the two different cognitive styles regarding involvement in the combined STEAM-6E VR-guided course. The adjusted mean value of post-test scores was 4.284 for the serialist style and 3.852 for the holist style. Students with the serialist style appear to have learnt significantly more than those with the holist style via the combined STEAM-6 combined course (Table 4).

Table 4. ANCOVA results of each dimension of learning motivation.

Dependent Variable: Post-Test Scores							
Dimension	***SS***	***df***	***MS***	***F***	***p***	**Effect Sizes**	**Partial Eta Square**
Intrinsic goal orientation	1.805	1	1.805	5.082	0.030	0.394	0.118
Extrinsic goal orientation	4.231	1	4.231	13.004	0.001	0.493	0.255
Control of learning beliefs	2.606	1	2.606	15.244	0.000	0.424	0.286
Task value	1.245	1	1.245	4.360	0.044	0.533	0.103
Self-efficacy	2.103	1	2.103	11.947	0.001	0.477	0.239
Test anxiety	3.254	1	3.254	10.212	0.003	0.430	0.212

As for the extrinsic goal orientation, there was a significant difference in intrinsic goal orientation across the two different cognitive styles ($F = 13.004$, $p = 0.001 < 0.05$). This indicates that there was a significant level of extrinsic goal orientation between the two different cognitive styles regarding involvement in the combined STEAM-6E VR-guided course. The adjusted mean value of post-test scores was 3.967 for the serialist style and 3.323 for the holist style. Students with the serialist style appear to have learnt significantly more than those with the holist style via the combined STEAM-6E VR-guided course (Table 4).

In terms of control of learning beliefs, there was a significant difference in intrinsic goal orientation across the two different cognitive styles ($F = 15.244$, $p = 0.000 < 0.05$). This indicates that there was a significant level of control of learning beliefs between the two different cognitive styles regarding involvement in the combined STEAM-6E VR-guided course. The adjusted mean value of post-test scores was 4.309 for the serialist style and 3.788 for the holist style. Students with the serialist style appear to have learnt significantly more than those with the holist style via the combined STEAM-6E VR-guided course (Table 4).

Regarding task value, there was a significant difference in task value across the two different cognitive styles ($F = 4.36$, $p = 0.044 < 0.05$), indicating that there was a significant level of task value between the two different cognitive styles regarding involvement in the combined STEAM-6E VR-guided course. The adjusted mean value of post-test scores was 4.159 for the serialist style and 3.808 for the holist style. Students with the serialist style appear to have learnt significantly more than those with the holist style via the combined STEAM-6E VR-guided course (Table 4).

As for self-efficacy, there was a significant difference in self-efficacy across the two different cognitive styles ($F = 11.947$, $p = 0.001 < 0.05$), indicating that a significant level of self-efficacy was in self-efficacy between the two different cognitive styles when involved in the combined STEAM-6E VR-guided course. The adjusted mean value of post-test scores was 4.205 for the serialist style and 3.748 for the holist style. Students with the serialist style appear to have learnt significantly more than those with the holist style via the combined STEAM-6E VR-guided course (Table 4).

In terms of test anxiety, there was a significant difference in task anxiety across the two different cognitive styles ($F = 10.212$, $p = 0.003 < 0.05$), indicating that a significant level of task anxiety was found between the two different cognitive styles when involved in the combined STEAM-6E VR-guided course. The adjusted mean value of post-test scores was 2.291 for the serialist style and 2.855 for the holist style. Students with the serialist style appear to have learnt significantly more than those with the holist style via the combined STEAM-6E VR-guided course (Table 4).

4.3. The Difference in the Learning Preference for Different Cognitive Styles in the Combined STEAM-6E VR-Guided Course

The study aimed to explore the difference in learning preference between the holist (N = 20) style and the serialist (N = 21) style in the combined STEAM-6E VR-guided course. The homogeneity of regression was examined and not violated, as shown in Table 5. The variables of the group, pre-test, and group*pre-test, accorded with the hypothesis of homogeneity, were presented (homogeneity of variance was not violated when using the pre-test as a covariate and the post-test as the dependent variable, $F = 3.420$, $p = 0.072 > 0.05$), and suggested that a common slope of regression was appropriate for the three groups.

Table 5. Results of the homogeneity for the within-group regression coefficients regarding the pre-test of each dimension of learning preference.

Variable	*SS*	*df*	*MS*	*F*	*p*
Group	0.323	1	0.323	3.862	0.057
Pre-test	0.074	1	0.074	0.882	0.354
Group*pre-test	0.286	1	0.286	3.420	0.072

The descriptive statistics for the means regarding the pre-test of learning preference were the means of the original post-test: 3.874 for the serialist style and 3.557 for the holist style. The above data did not exclude the influence of covariates (the pre-test), nor did they present the adjusted means. The result of Levene's test of error variances for the pre-test of learning preference was not found to be significant ($F = 3.036$, $p = 0.089 > 0.05$), indicating that the null hypothesis is accepted and homogeneity of variances was met, as error variances were equal across groups regarding the dependent variables of the post-test.

Table 6 reports the ANCOVA results of learning preference, indicating the results of dependent variables (post-test scores) on the independent variables after eliminating the effects of the pre-test scores (covariates). According to the result, there was a significant difference in learning preference across the two different cognitive styles ($F = 11.791$, $p = 0.001 < 0.05$), indicating that a significant level of learning preference was found between the two different cognitive styles when involved in the combined STEAM-6E VR-guided course. The adjusted mean values of post-test scores in learning preference were 3.878 for the serialist style and 3.553 for the holist style. Students with the serialist style appear to have better learning preference than those with the holist style in the combined STEAM-6E VR-guided course (Table 6).

Table 6. ANCOVA results of learning motivation.

Variables	*SS*	*df*	*MS*	*F*	*p*	Effect Sizes	Partial Eta Square
Group	1.048	1	1.048	11.791	0.001	0.474	0.237

4.4. The Difference in the Learning Satisfaction for Different Cognitive Styles in the Combined STEAM-6E VR-Guided Course

The study aimed to discuss the difference in learning satisfaction with the three dimensions of effectiveness, efficiency, and overall satisfaction between the holist (N = 20) style and the serialist (N = 21) style in the combined STEAM-6E VR-guided course. In terms of the first dimension of learning satisfaction, the independent sample *t*-test was employed to analyze the effectiveness of learning satisfaction for the two styles. As seen in Table 7, the mean and standard deviation of the effectiveness scores were 6.19 and 0.873, respectively, for the serialist style, while the effectiveness scored 6.15 and 1.348, respectively for the holist style. The *t*-test results showed that there was no significant difference in the effectiveness of learning satisfaction between two different cognitive styles regarding involvement in the combined STEAM-6E VR-guided course (t (39) = 0.115, p = 0.070 > 0.05).

Table 7. The independent sample *t*-test result of the learning satisfaction.

	Mean (SD)		*df*	*t*	*p*
	Serialist (N = 21)	**Holist (N = 20)**			
Effectiveness	6.19 (0.873)	6.15 (1.348)	39	0.115	0.070
Efficiency	6.10 (0.995)	5.85 (1.461)	39	0.631	0.532
Overall satisfaction	6.14 (0.964)	5.70 (1.525)	39	1.117	0.271

As for the second dimension of learning satisfaction, the independent sample *t*-test was employed to analyze the efficiency of learning satisfaction for the two styles. As seen in Table 7, the mean and standard deviation of the effectiveness scores were 6.10 and 0.995, respectively, for the serialist style, while the effectiveness scored 5.85 and 1.461, respectively, for the holist style. The *t*-test results showed that there was no significant difference in the efficiency of learning satisfaction between the two different cognitive styles when involved in the combined STEAM-6E VR-guided course (t (39) = 0.631, p = 0.0531 > 0.05).

Regarding overall learning satisfaction, the independent sample *t*-test was employed to analyze the overall learning satisfaction for the two styles. As seen in Table 7, the mean and standard deviation of the effectiveness scores were 6.14 and 0.954, respectively, for the serialist style, while the effectiveness scored 5.70 and 1.525, respectively, for the holist style. The *t*-test results showed that there was no significant difference in the efficiency of learning satisfaction between the two different cognitive styles regarding their involvement in the combined STEAM-6E VR-guided course (t (39) = 1.117, p = 0.271 > 0.05).

4.5. The Difference in the Learning Achievement for Different Cognitive Styles in the Combined STEAM-6E VR-Guided Course

The study explored the difference in learning achievement between the holist (N = 20) style and the serialist (N = 21) style in the combined STEAM-6E VR-guided course. The homogeneity of regression was examined and not violated, as shown in Table 8. The variables of the group, pre-test, and group*pre-test, accorded with the hypothesis of homogeneity, were presented (homogeneity of variance was not violated when using the pre-test as a covariate and the post-test as the dependent variable, F = 3.350, p = 0.075 > 0.05), and suggested that a common slope of regression was appropriate for the three groups.

Table 8. Results of the homogeneity for the within-group regression coefficients regarding the pre-test of learning achievement.

Variable	*SS*	*df*	*MS*	*F*	*p*
Group	851.082	1	851.082	10.924	0.002
Pre-test	260.979	1	260.979	3.350	0.075
Group*pre-test	260.979	1	260.979	3.350	0.075

The descriptive statistics for the means regarding the pre-test of learning achievement were the means of the original post-test: 78.571 for the serialist style and 59.688 for the holist style. The above data did not exclude the influence of covariates (the pre-test), nor did they show the adjusted means. The result of Levene's test of error variances for the pre-test of learning achievement was not found to be significant (F = 1.314, p = 0.259 > 0.05), indicating that the null hypothesis is accepted and homogeneity of variances was met, as error variances were equal across groups regarding dependent variables of the post-test.

Table 9 shows ANCOVA results of learning achievement, indicating the results of dependent variables (post-test scores) on the independent variables after eliminating the effects of the pre-test scores (covariates). According to the result, there was a significant difference in the learning achievement across the two different cognitive styles ($F = 43.128$, $p = 0.000 < 0.05$), indicating that a significant level of learning achievement was found between the two different cognitive styles when involved in the combined STEAM-6E VR-guided course. The adjusted mean values of post-test scores in the learning achievement were 78.476 for the serialist style and 59.788 for the holist style. Students with the serialist style appear to have a significantly higher learning achievement than those with the holist style in the combined STEAM-6E VR-guided course (Table 9).

Table 9. ANCOVA results of learning achievement.

Variables	*SS*	*df*	*MS*	*F*	*p*	Effect Sizes	Partial Eta Square
Group	3567.920	1	3567.920	43.128	0.000	0.718	0.532

4.6. The Difference in the Creativity for Different Cognitive Styles in the Combined STEAM-6E VR-Guided Course

This study aimed to understand the difference in creativity between the holist (N = 20) style and the serialist (N = 21) style in the combined STEAM-6E VR-guided course. The homogeneity of regression was examined according to the Torrance tests of creative thinking (TTCT), and the result was not violated, as shown in Table 10. The variables of the group, pre-test, and group*pre-test, accorded with the hypothesis of homogeneity, were presented (homogeneity of variance was not violated when using the pre-test as a covariate and the post-test as the dependent variable, $F = 2.909$, $p = 0.096 > 0.05$), and suggested that a common slope of regression was appropriate for the three groups.

Table 10. Results of the homogeneity for the within-group regression coefficients regarding the pre-test of the creativity.

Variables	*SS*	*df*	*MS*	*F*	*p*
Group	146.523	1	146.523	1.789	0.189
Pre-test	1409.147	1	1409.147	17.202	0.000
Group*pre-test	238.296	1	238.296	2.909	0.096

Descriptive statistics for the means regarding the pre-test of the creativity were the means of the original post-test: 83.990 for the serialist and 78.070 for the holist style. The above data did not exclude the influence of covariates (the pre-test), nor did they present the adjusted means. The result of Levene's test of error variances for the pre-test of creativity was not found to be significant ($F = 2.945$, $p = 0.094 > 0.05$), indicating that the null hypothesis is accepted and homogeneity of variances was met, as error variances were equal across groups regarding dependent variables of the post-test.

Table 11 presents ANCOVA results of learning preferences, indicating the results of dependent variables (post-test scores) on the independent variables after eliminating the effects of the pre-test scores (covariates). According to the result, there was a significant difference in creativity across the two different cognitive styles ($F = 6.840$, $p = 0.013 < 0.05$), indicating that a significant level of creativity was found between the two different cognitive styles when involved in the combined STEAM-6E VR-guided course. The adjusted mean values of post-test scores in creativity were 84.841 for the serialist style and 77.177 for the holist style. Students with the serialist style appear to have better learning creativity than those who with the holist style in the combined STEAM-6E VR-guided course (Table 11).

Table 11. ANCOVA results of the creativity.

Variables	*SS*	*df*	*MS*	*F*	*p*	Effect Sizes	Partial Eta Square
Group	588.440	1	588.440	6.840	0.013	0.262	0.153

5. Discussion

When talking about the learning motivation of respondents with different cognitive styles, a serialist is yields better results compared to a holist and has remarkable differentiation. Therefore, teachers can arrange more efficient learning strategies for individual differences between students by planning and implementing adaptive teaching. Learners finish tasks based on self-motivation or outer encouragement to pursue self-affirmation and others' approval to further identify with the core value of the work. This theory also works in concert with the research [38–40]. Furthermore, learning preference is not associated with good or bad. It is just the skill they are used to applying based on their personality, background, and culture. In an environment that meets their learning preferences, the serialists' results have a notable discrepancy compared to the results of the holist cognitive style. Therefore, learners can achieve better absorption efficiency through real experiences or generalization techniques to transform learning content into knowledge. This self-efficacy helps them reach learning goals, in accordance with the research [41,42]. The only domain where there are no significant differences is satisfaction with learning activities. Adaptive teaching is carried out through teachers' close observation of learners, in line with Confucius' philosophy of teaching students according to their aptitude, as well as the Socratic method, providing students the opportunities for self-exploration and growth, conforming to research [43]. Furthermore, to improve learning results, such as cognitive strategies and intrinsic motivation, the analysis showed that serialists with higher learning motivation performed better than holists. It shows that the suitability of the cognitive method is positively correlated with learning outcomes, reflecting [44–46], that point out that adaptive learning can effectively promote learning results.

This study allows respondents with different cognitive styles to engage in a creative process with their exploration and development through hands-on experiential learning. There are significant disparities in creativity performance between different cognitive styles that also conform to studies [47,48]. These confirm that the serialist cognitive style is suitable for this research's creative practice activities. In short, previous studies [49,50] have pointed out that the satisfaction of learning activities often varies significantly due to individual differences. Nonetheless, the method used in this study improves the problems in this aspect thanks to the adoption of the STEAM-6E model and teaching strategies that accommodate cognitive style preferences. Taking students as the most important element of learning, we provide them with the necessary support at different levels according to their learning abilities.

This research aims to enhance children's learning motivation and creativity by using digital technology, leading them to find a better future and serving as role models for educators. The students in this study were from a small junior high school in Tainan city. Because the total number of students is not large, only 44 students could participate in this experiment. Therefore, the results of this experiment cannot be extrapolated to all situations. The recommendation of this study is to expand the sample size to obtain complete and diverse statistics. This research only focuses on the VR course due to time considerations, so other digital learning technologies are not addressed in this discussion. It is suggested that the STEAM-6E scaffolding instructional method is used in further experiments and that the scope of VR teaching resources is expanded, such as mixed reality, augmented reality, and tangible interaction. They can strengthen digital learning literacy gradually to improve the effectiveness of hands-on and experiential learning activities through the process they designed based on the 6E model. They can improve their concentration in learning and promote knowledge integration to make the process more impressive and attractive through the sense of touch and movement from touchable materials. In addition, fully immersive experiential learning products can achieve educational value in museums, exhibitions, sightseeing, and even space travel by applying them in multiple industries. Especially during the pandemic, they can help us obtain a balance between distance prevention and sustainable learning. In short, follow-up research can focus on an in-depth analysis of learners' flow and self-efficacy to further discuss understanding their learning status. Adding in a learners' interview supplement would be a feasible method. Qualitative texts can help us comprehend their psychological state and feelings during the process more accurately, and carry out instant and precise fit correction according to the slight changes in learners' cognitive experience to achieve effective teaching and intrinsic motivation in active learning processes.

6. Conclusions

This research focuses on learners with holistic and sequential cognitive styles and learning preferences, using the STEAM-6E model to set up an instructional scaffolding, adding VR digital technology to integrate into the school guiding program. Through the previous analyses, we found out that goal orientation, extrinsic goal orientation, task value, control of learning beliefs, self-efficacy, and test anxiety differed between the two cognitive styles. There is also significant discrepancy in learning orientation, effectiveness, and creative performances. However, in terms of satisfaction with learning activities, there was no significant difference between the two groups in effectiveness, efficiency, and overall satisfaction. The learning goal of this research is to combine VR with real-life situations and integrate the STEAM-6E mode to create a clear and potent instructional scaffold to help learners complete their tasks.

The scope and limitations of this study are described in detail as follows:

1. Scope and Limitations of the Study:

This study focuses on students from a junior high school in southern Taiwan. Students of different educational levels and living in other areas were not included in the this study. Therefore, the inferences drawn from this study should be limited to students with similar backgrounds and should not be overgeneralized to other populations;

2. Scope and Limitations of Cognitive Styles:

This study focuses mainly on the cognitive styles of "holistic" and "serialist", and other types of cognitive styles were not included in this study. The classification of cognitive styles is based on the "Study Process Questionnaire (SPQ)", which is filled out freely by learners and is subject to individual subjective thinking. Therefore, individual biases may exist and affect the research results;

3. Scope and Limitations of the Study:

This study aims to investigate the performance differences in learning effectiveness and creativity between "holistic" and "serialist" learners. The curriculum content is based on the emerging technologies mentioned in the Ministry of Education's news release, such as "VR virtual reality/AR augmented reality, AI artificial intelligence, IoT Internet of Things, big data, smart machinery, and green energy". The study selected the "VR virtual reality" course content to produce digital multimedia hands-on teaching materials for experimentation. The digital learning materials should be primarily composed of graphic, video, and textual content, while materials consisting of only pictures or text were not included in this study.

Author Contributions: Conceptualization, Y.-H.L. and T.-H.W.; methodology, H.-C.K.L.; software, C.-H.W.; validation, T.-H.W.; formal analysis, C.-H.W.; investigation, C.-H.W.; resources, T.-H.W.; data curation, H.-C.K.L. and T.-H.W.; writing—original draft preparation, Y.-H.L.; writing review and editing, Y.-H.L.; visualization, T.-H.W.; supervision, H.-C.K.L. and Y.-H.L.; project administration, Y.-H.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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