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# APPLICATION OF PYTHON FOR DESIGNING VISUAL AIDS AND INTEGRATION OF ARTIFICIAL INTELLIGENCE (AI) TO TEACHING MATHEMATICS AT HIGH SCHOOLS

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**Abstract**. This research investigates the effective integration of Python programming and visual aids in teaching mathematics at high schools in the Mekong Delta region. Recognizing the transformational power of technology in education, the study utilizes Python's capabilities to design interactive and engaging visual tools for mathematics instruction. The theoretical framework draws on insights from scholars such as Hyerle, Bui Anh Tuan, and Giardino, emphasizing the cognitive benefits of non-linguistic sign systems in mathematics learning. The experiment follows a structured process involving content research, lesson plan development, and real-world application in high school classrooms. The impact is assessed through a comprehensive survey, employing Cronbach's Alpha for reliability analysis. Results indicate a positive reception among students, who showed a preference for the visual and Python-integrated teaching approach.

***Keywords:*** visual aids, mathematics education, Python application, high school.

## 1. Introduction

According to Hafni et al. (2020) [1], the Fourth Industrial Revolution has driven the rapid development of science and technology, significantly impacting various sectors, including education. The General Education Program (2018) [2] has been widely implemented across all 63 provinces and cities in Vietnam, ensuring uniform application across localities, regions, and areas, with no educational institutions excluded. The comprehensive development outlined in the overall program for high school students is closely linked to the use of visual aids in teaching, particularly in Mathematics.

Moreover, the Ministry of Education and Training (2018) [2], in the 2018 General Education Program, emphasized the use of visual aids in teaching and highlighted their critical role in mathematics education. Visual aids are invaluable in mathematics instruction, not only because they provide students with accurate, long-term information, but also because they help validate theoretical knowledge, correct misconceptions, and foster the creation of new knowledge. Previously, the use of visual aids in mathematics teaching was relatively basic, involving crude assembly models, unimaginative pre-made videos, self-designed sideboards, or simple illustrations drawn with chalk on blackboards.

According to Pepin et al. (2017) [3], teachers now have opportunities to independently create and publish educational resources on websites, either as individuals or as part of a community. Pepin et al. (2013) [4] further note that teachers, as users, have new tools to search for documents, adapt them for classroom use, modify content, and share resources. Similarly, Sadiman et al. (2010) [5] define media as tools capable of conveying messages and information from senders to recipients, stimulating thinking, emotions, attention, and interest, particularly in education, where they help learners achieve their goals.

Artificial intelligence (AI) is a field of research dedicated to innovations and developments that have enabled machines, computers, and artifacts to exhibit human-like intelligence, including cognition, learning, adaptation, and decision-making capabilities (Chen et al., 2020) [6]. The remarkable advancements in AI and its application in education have significantly improved teaching processes for educators while enhancing learning quality for students (Huang et al., 2021) [7]. AI has introduced new opportunities, potential, and challenges to educational activities (Ouyang & Jiao, 2021) [8].

Harry and Sayudin (2023) [9] assert that AI has the potential to transform education by making learning more personalized, engaging, and efficient. One of AI's most notable benefits in education is its ability to tailor learning experiences to individual students. Personalized learning allows students to progress at their own pace and in ways that align with their unique learning styles, often leading to improved educational outcomes. AI-driven tools, such as intelligent tutoring systems, chatbots, and automated grading systems, enhance efficiency by saving teachers time and providing consistent, accurate feedback. However, the integration of AI into education also poses challenges. Concerns related to privacy, security, and the trustworthiness of AI systems, as well as their costs and potential biases, must be carefully addressed. Ethical considerations, including ensuring accessibility, transparency, and fairness in AI-based education systems, are also crucial. Despite these challenges, AI holds immense promise for education. Its capacity for advanced data analysis enables educators to make more informed, data-driven decisions, further optimizing the learning process.

Visual aids are highly effective resources that significantly enhance the teaching of mathematical concepts, much like their application in foreign language instruction. The benefits of incorporating visuals into mathematics education extend beyond capturing and maintaining students' attention. Visual tools play a pivotal role in motivating learners to actively engage with the subject matter while aiding in the retention of complex information (Pateşan et al., 2018) [10].

This paper proposes integrating the Python programming language with artificial intelligence to design visual aids for teaching mathematics at the high school level in Vietnam. The insights presented in this paper aim to guide future trends in the application of AI in high school education.

# 2. Content

## 2.1. Literature review

### 2.1.1. Visual aids in teaching mathematics

According to Hyerle (2008) [11], visual aids are non-linguistic symbol systems utilized by learners, educators, and leaders to connect mental images with physical images and emotions, thereby creating and conveying rich patterns of thinking. These visual forms also serve as metacognitive tools for self-assessment within specific topics as well as for interdisciplinary learning. Non-linguistic representation is an essential tool for enhancing students' learning.

Bui Anh Tuan et al. (2022) [12] define visual aids as objects, phenomena, symbols, models, and other resources directly used by teachers and students during instruction to facilitate the comprehension of new knowledge and the development of intellectual abilities. The application

of visual aids in teaching is a method to improve teaching effectiveness and provide students with supplementary tools for processing subject information.

According to Giardino (2010) [13], visualization is a method of presenting information in a way that enables learners to generate symbols. This process helps them understand the common and general elements of the given material through visual representation, instinctively identify difficulties, and draw new conclusions. Visual tools stimulate thinking and perception (Kishore, 2003) [14].

#### 2.1.2. Python software

According to Tollervey (2015) [15], Python is a primary programming language in computer science, and teaching programming using Python helps learners develop thinking, foster creativity, and achieve high efficiency in learning. Python is a high-level programming language that supports multiple programming paradigms, including imperative, functional, and object-oriented, with a clear, understandable, and simple syntax (Marowka, 2018) [16].

Myers et al. (2007) [17] state that a course on computational methods using Python, along with related numerical and visual libraries, enables learners to deploy simulations for various modules, showcasing the breadth and flexibility of the computational environment.

Guo (2013) [18] highlights the Online Python Tutor, a web-based program visualization tool for Python that has become a popular resource for teaching basic computer science courses. With this tool, both instructors and learners can write Python programs directly in the web browser (without requiring any plugins), step forward and backward through the execution process to observe the runtime state of data structures and share their program visualizations online. The Online Python Tutor has been widely used in CS1 courses by instructors at numerous universities, including UC Berkeley, MIT, the University of Washington, and the University of Waterloo. Visualizations from the tool have also been embedded in three web-based Python digital textbook projects, attracting approximately 16,000 viewers per month and being used in at least 25 universities. This open-source software is freely available for download at pythontutor.com.

#### 2.1.3. ChatGPT

ChatGPT is an AI chatbot developed by OpenAI, designed for direct interaction with users. It was created by a team of researchers and technologists committed to developing AI safely and responsibly (Dempere et al., 2023) [19]. ChatGPT has demonstrated exceptional performance across various applications, including generating coherent and logical content, producing complete essays, providing rapid and accurate chatbot responses, performing proficient language translation, answering questions, and writing programming code, among others (Qadir, 2023) [20].

### 2.2. Research methodology

#### 2.2.1. Experimental procedure

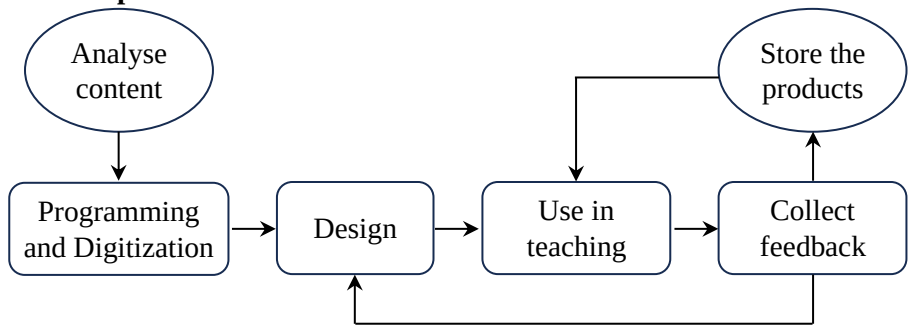



***Diagram 1. The process of constructing and using visual aids according to Bui Anh Tuan et al. (2022)***

*Step 1:* Analyze the lesson content to select a suitable visual aid (VA).
*Step 2:* Develop a lesson plan using VA.
*Step 3:* Implement the lesson plan based on teaching practice.
*Step 4:* Collect feedback to improve the lesson plan.
If the feedback is positive, proceed to *Step 5*.
*Step 5:* Store the lesson plan for future teaching.
If the feedback is not positive, refine and return to *Step 2*.

### 2.2.2. Some visual aids were created using Python and integrated with artificial intelligence tools

The outputs are generated in .jpg and .mp4 formats from the .py file, enabling the creation of visually engaging educational videos. Since these outputs originate from the .py file format, artificial intelligence can be applied to the visual aids through ChatGPT, utilizing data from the GPT model alongside the designed .py file data. This integration allows for the rapid production of visual aids, saving time while ensuring comprehensive and accurate content. However, limitations exist in the current implementation, as it is not yet fully optimized. Detailed and clear descriptions of the visual aids are essential to achieve the desired results. Figures 1, 2, 3, and 4 were designed using Python, while Figures 5 and 6 were created through a combination of ChatGPT and Python for output.

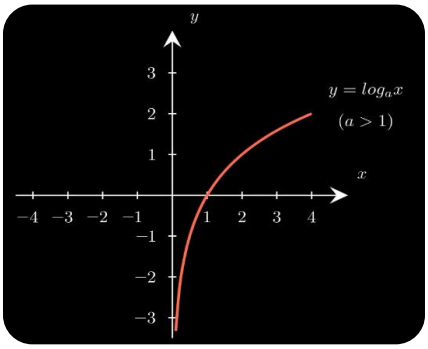



***Figure 1. Illustration of the graph of the function*** $y = \log_a x (a > 1)$ ***using Python***

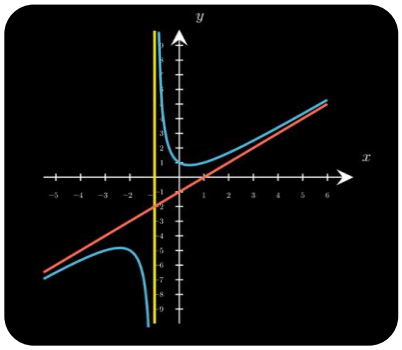



***Figure 2. Description of the oblique asymptote of the function using Python***

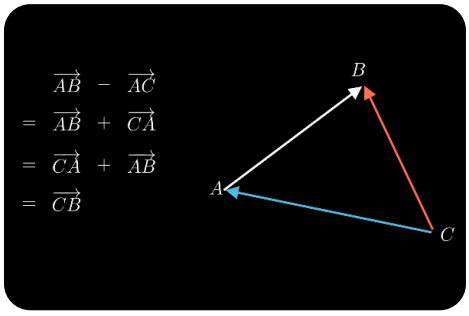



***Figure 3. Description of the difference of two vectors using Python***

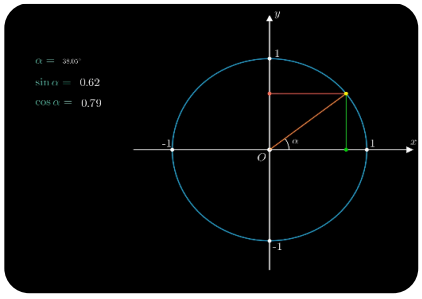
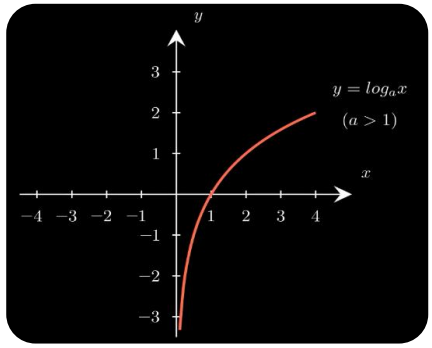
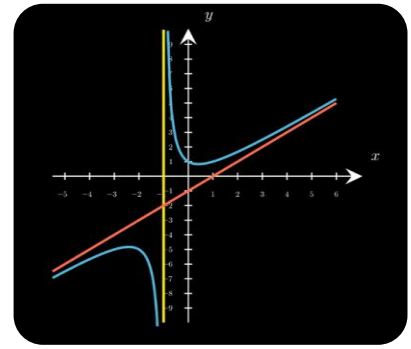
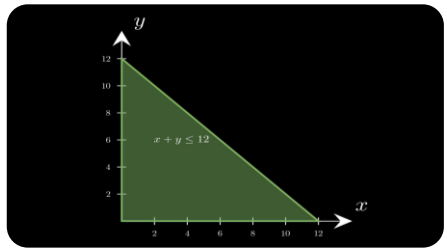



***Figure 4. Description of the unit circle using Python***



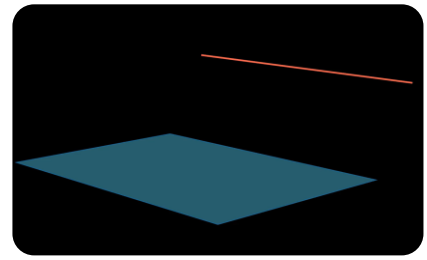



***Figure 5. Description of the solution region of the inequality*** $x + y \leq 12$ ***using ChatGPT with Python***

***Figure 6. Description of a line parallel to a plane using ChatGPT with Python***

## 2.3. Research results

### 2.3.1. Experiments

The experimental content involves assessing the suitability of two lesson plans and three teaching plans within the Mathematics project under the teaching conditions at high schools in the Mekong Delta. Specifically:

- *Lesson Plan 1:* Lesson content on “Trigonometric angle values from 0 to 180 degrees”.

- *Lesson Plan 2:* Lesson content on “Permutation - Combination - Arrangement”.

- *Teaching Plan for Project 1:* Introduction to mathematical animation tools. Open-source Manim programming in Python and Chat GPT support during programming.

- *Teaching Plan for Project 2:* Designing applied mathematical art and supporting design software.

- *Teaching Plan for Project 3:* Experience using GeoGebra software through graphing functions.

### 2.3.2. Experimental survey questionnaire

Table 1 contains the questions to survey students' opinions on learning mathematics through digital visual aids. For questions Q1, Q2, Q3, and Q4, a 5-point Likert scale is used for quantitative evaluation: Completely Disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Completely Agree = 5. Question Q5 uses a scale from 1 to 10 to quantitatively evaluate the responses.

***Table 1. Survey questions***

| Code | Observation variable |
|---|---|
| **Q1** | *Compared to traditional teaching, the benefits of learning Mathematics with digital visual aids are…* |
| Q1A | Easy accessibility |
| Q1B | Enhances learning interest |
| Q1C | Can learn anytime |
| Q1D | Can learn anywhere |
| Q1E | Saves time and costs |
| Q1F | Easy to use |
| **Q2** | *Characteristics of knowledge content when teaching with visual aids are…* |
| Q2A | Conveys information visually and clearly |
| Q2B | Increases interaction and curiosity |
| Q2C | Facilitates visualization and generalization of knowledge |
| Q2D | Promotes thinking and creativity |
| Q2E | Improves learning experience |
| **Q3** | *Organization of visual aid lectures are…* |
| Q3A | Uses logical structure |
| Q3B | Balances theory and practice |
| Q3C | Meets students' learning needs |
| **Q4** | *Compared to traditional teaching, I think…* |
| Q4A | It helps imagine and understand lessons better. |
| Q4B | Promotes interaction and enthusiasm |
| Q4C | Enhances problem-solving abilities |
| Q4D | Diversifies teaching methods |
| **Q5** | *On a scale from 1 to 10, please rate the visual teaching method.* |

For questions **Q1**, **Q2**, **Q3**, and **Q4**, a Likert 5-point scale is used for quantitative evaluation: *Completely Disagree* = 1, *Disagree* = 2, *Neutral* = 3, *Agree* = 4, *Completely Agree* = 5. Question **Q5** has a scale from 1 to 10 to quantitatively evaluate responses.

The study conducted a survey of 225 students at two high schools. General information about the observations in the study is divided and summarized in Table 2 based on criteria such as gender, grade level, and school.

***Table 2. General information about the survey sample***

| Information | Number of respondents (Individuals) | Percentage (%) |
|---|---|---|
| **Gender** | **225** | **100** |
| 1. Male | 107 | 47.56 |
| 2. Female | 118 | 52.44 |
| **Grade Level** | **225** | **100** |
| 1. Grade 10 | 86 | 38.22 |
| 2. Grade 11 | 139 | 61.78 |
| **School** | **225** | **100** |
| Long Xuyen High School | 121 | 53.78 |
| Huynh Thi Huong high school | 114 | 46.22 |

**2.3.3. Reliability analysis**

The results of students' opinions on the Cronbach's Alpha reliability of question groups **Q1**, **Q2**, **Q3**, and **Q4** were analyzed using IBM SPSS 26 software and are presented in Tables 3, 4, 5, and 6.

***Table 3. Analysis results of students' opinions for question group Q1***

| **Reliability statistics** | | | | |
|---|---|---|---|---|
| *Cronbach's alpha* | | | *N of items* | |
| 0.767 | | | 6 | |
| **Item-total statistics** | | | | |
| | *Scale mean if the item is deleted.* | *Scale variance if item deleted* | *Corrected item-total correlation* | *Cronbach's alpha if the item deleted* |
| **Q1A** | 16.16 | 10.459 | 0.519 | 0.731 |
| **Q1B** | 16.21 | 10.285 | 0.599 | 0.712 |
| **Q1C** | 16.30 | 9.560 | 0.503 | 0.741 |
| **Q1D** | 16.07 | 10.272 | 0.614 | 0.709 |
| **Q1E** | 16.28 | 10.808 | 0.482 | 0.740 |
| **Q1F** | 16.31 | 11.142 | 0.385 | 0.764 |

***Table 4. Analysis results of students' opinions for question group Q2***

| **Reliability statistics** | | | | |
|---|---|---|---|---|
| *Cronbach's Alpha* | | | *N of Items* | |
| 0.689 | | | 5 | |
| **Item-total statistics** | | | | |
| | *Scale mean if the item is deleted.* | *Scale variance if item deleted* | *Corrected item-total correlation* | *Cronbach's alpha if the item deleted* |
| **Q2A** | 14.92 | 5.427 | 0.479 | 0.625 |
| **Q2B** | 15.26 | 5.487 | 0.437 | 0.642 |
| **Q2C** | 14.89 | 5.733 | 0.384 | 0.664 |
| **Q2D** | 15.66 | 4.923 | 0.513 | 0.607 |
| **Q2E** | 15.20 | 5.402 | 0.409 | 0.655 |

***Table 5. Analysis results of students' opinions for question group Q3***

| **Reliability Statistics** | | | | |
|---|---|---|---|---|
| *Cronbach's alpha* | | | *N of items* | |
| 0.641 | | | 3 | |
| **Item-total statistics** | | | | |
| | *Scale mean if the item is deleted.* | *Scale variance if item deleted* | *Corrected item-total correlation* | *Cronbach's alpha if the item deleted* |
| **Q3A** | 6.68 | 2.208 | 0.549 | 0.408 |
| **Q3B** | 7.06 | 2.023 | 0.448 | 0.564 |
| **Q3C** | 6.44 | 2.810 | 0.378 | 0.636 |

***Table 6. Analysis results of students' opinions for question group Q4***

| **Reliability statistics** | | | | |
|---|---|---|---|---|
| *Cronbach's alpha* | | | *N of items* | |
| 0.841 | | | 4 | |
| **Item-total statistics** | | | | |
| | *Scale mean if the item is deleted.* | *Scale variance if item deleted* | *Corrected item-total correlation* | *Cronbach's alpha if the item deleted* |
| **Q4A** | 9.75 | 5.752 | 0.683 | 0.794 |
| **Q4B** | 9.55 | 5.570 | 0.736 | 0.770 |
| **Q4C** | 9.49 | 6.153 | 0.672 | 0.800 |
| **Q4D** | 9.75 | 6.002 | 0.612 | 0.826 |

Tables 5 and 6 show that the observed variables have appropriate total correlation coefficients, with all values exceeding 0.3. The Cronbach's alpha coefficients for question groups Q1, Q2, Q3, and Q4 are 0.767, 0.689, 0.641, and 0.841, respectively. All coefficients exceed 0.6, meeting the reliability requirements. This indicates that the questions are suitable for the opinion survey.

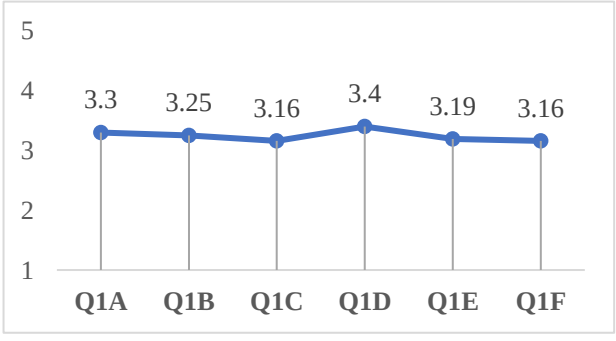



***Chart 1. Mean values of questions in group Q1***

Based on Chart 1, the total percentage of students selecting Agree and Completely Agree, though not high, corresponds to an average score of 3.16 and above, which falls within the Neutral and Agree range. This suggests that most students recognize the benefits of using visual teaching tools in Mathematics compared to traditional teaching methods.

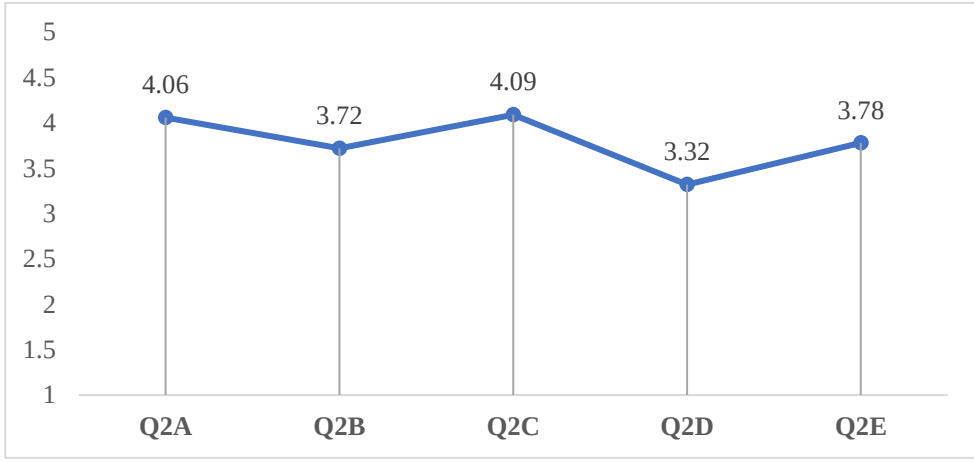



***Chart 2. Mean values of questions in group Q2***

From Chart 2, the Agree and Completely Agree rates for Q2A, Q2B, Q2C, and Q2E are all above 50%, while Q2D has Agree and Completely Agree rates below 50%. However, these rates are still higher than the Totally Disagree and Disagree rates. This is evident from the selection and agreement rates, with the selection rate being the highest. This indicates that students mostly agree with the content.

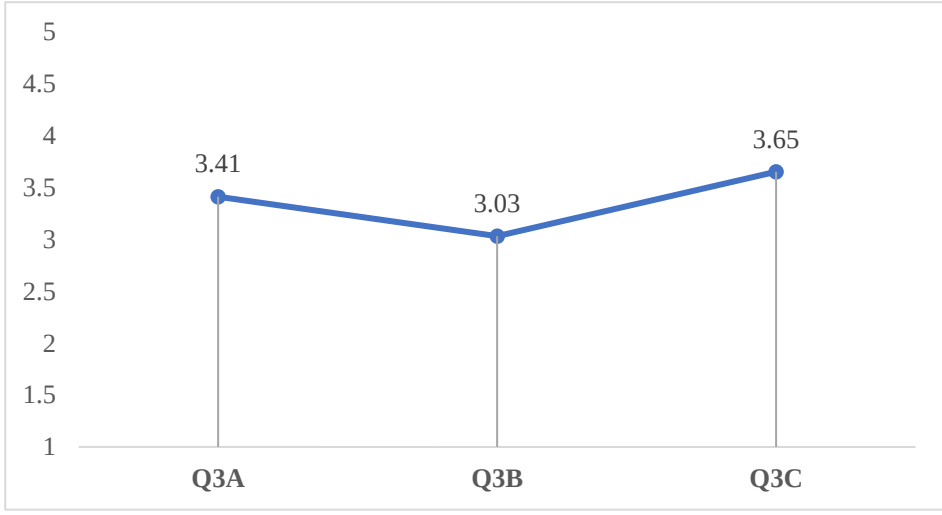



***Chart 3. Mean values of questions in group Q3***

In Chart 3, the Agree and Completely Agree rates for Q3A and Q3B are not high, but it is evident that students tend to agree with these items. Q3C, however, has a rate of 63.2%, indicating that the majority of students agree with the content. This demonstrates that the arrangement of visual teaching content aligns with the learning needs of students.

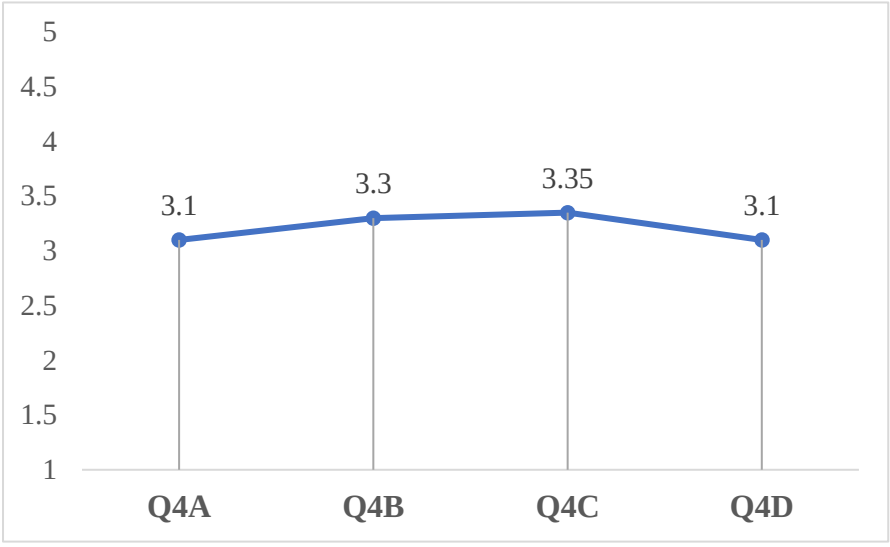



***Chart 4. Mean values of questions in group Q4***

The Agree and Completely Agree rates for the four questions Q4A, Q4B, Q4C, and Q4D are all below 50%. However, as shown in Chart 4, the Neutral and Agree rates are the highest. This indicates that most students believe that teaching with visual aids offers more benefits than traditional teaching, such as enhancing interaction between teachers and students, promoting problem-solving skills, and improving understanding of the lesson.

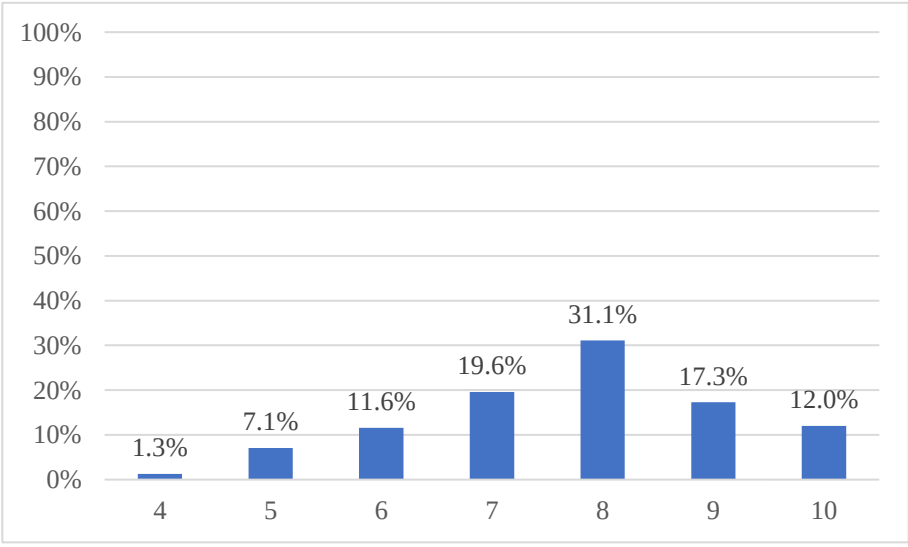



***Chart 5. Rating on visual teaching method***

Question Q5 asks about the rating scale of the learning experience. From Chart 5, the average score analyzed is 7.72, indicating that students rate the visual teaching method quite highly. Scores are generally distributed evenly from 4 to 10 points, with the highest frequency being 70 students selecting the 8-point level, accounting for 31.1%. There are three feedback responses for a score of 4, and no feedback for scores of 1, 2, or 3.

## 3. Conclusions

During the research on the theoretical foundation of visual tools and methods in teaching mathematics, particularly at the high school level, this study successfully proposed and implemented effective lesson plans and teaching projects. Notably, the application of the Python programming language demonstrated remarkable flexibility and power in designing visual aids. By synthesizing visual data from the "mathfagonze.com" website, Python's diverse capabilities were utilized to create a visual organizational sequence aligned with lesson content, optimizing the learning process.

This research aims to enhance the quality of mathematics education in high schools by sharing experiences and providing reference materials. Python is not merely a valuable tool but also a cornerstone of educational innovation, especially as technology continues to play an increasingly significant role in the learning and teaching process.

To further develop this research comprehensively, future directions may include expanding the scope of the study to various regions nationwide, encompassing both rural and urban areas, to obtain more representative results reflecting the effectiveness of this method. Additionally, long-term studies are necessary to evaluate the sustainable impact of using Python in mathematics teaching. The integration of emerging technologies, such as artificial intelligence and virtual reality, could further enhance the learning experience and improve teaching effectiveness. Lastly, developing training programs for teachers on technology integration and advanced teaching tools is essential to ensure the effective and sustainable application of this method in the future.

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