Article

Analysing Student Performance in Mathematics of Pre-primary students through the application of Engino Toy Blocks

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Abstract: The objective of this study is to examine the student performance for students of pre-primary studying mathematics, which involve the use of employing Engino toy blocks in their lessons. This inclusion aims to promote student engagement and optimise their learning experience in this particular field. Encouraging the utilisation of Engino activities among students during their classes also enhances their comprehension of intricate concepts. The statistical results show the students using Engino toy blocks performed better than those who didn't while learning the two modules, counting and addition. A sample of 50 students are considered with 25 each in the Experimental Group and the Control Group for this study. By incorporating creative initiatives, such as interactive games and team-based exercises, into lesson plans for mathematics, teachers may effectively engage young learners to improve team work and communication. Furthermore, the advancement of mathematical techniques for prospective educators can accelerate the implementation of comprehensive instructional methodologies and practical application of problem-solving skills. Consequently, this promotes the understanding and skills of both teachers and students within this field.

Keywords: Mathematics; Engino; student performance; statistics

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1. Introduction

Engino is a Cypriot company established in 2004 that manufactures a range of toy sets known as Engino toy sets. These sets include several construction blocks that students may combine to create complex play models. The firm has created several models that can be constructed using the blocks included in a specific toy set, depending on its contents [1]. Engino toy models are constructed by combining small blocks, enabling students to imaginatively and effortlessly construct technological models, therefore facilitating experimentation and enjoyable learning in the fields of science and technology. Each toy set manufactured by Engino contains a predetermined quantity of bricks that can be arranged into several distinct models [2]. The following figures show examples on how the Engino toy blocks work to enhance the students' learning experience.

engino.png

Figure 1. Engino- Please provide photo of blocks so readers can understand the notion of the blocks

Empirical evidence suggests that the creative capacity of every toy set grows exponentially with the number of blocks included in the set. The reason for this is the exclusive design of the Engino bricks, which enable simultaneous connectedness in several directions inside three-dimensional space [3].

The challenges encountered in teaching mathematics to pre-primary students encompass a decline in student motivation, insufficient teaching tactics employed in the subject, and poor problem-solving approaches and strategies [4]. It is crucial to tailor teaching methods to accommodate the variations among students, including academic intelligence, cognitive abilities, and readiness to learn [5]. This study is particularly vital when working with students who learning mathematics for the first time . It is important to investigate and cultivate novel curriculum to actively involve students in their learning experience.

Studies suggest that the use of tools, such as Engino Toy Blocks, can greatly improve students' mathematical abilities, particularly in pre-primary educational environments. Research highlights the significance of practical experiences in acquiring mathematical concepts, as students transition from tangible to theoretical comprehension [6]. Furthermore, analysing children's drawings, specifically those depicting Lego bricks, can offer useful insights into their numerical-spatial abilities and early mathematical skills, which can be helpful in diagnostic examinations [7]. Moreover, engaging in structured building block play has been found to have a favourable impact on the mathematical success and logical reasoning abilities of young children. This emphasises the advantages of hands-on activities in the process of learning mathematics [8,9]. Programmable robots, such as educational robotics, have proven to be beneficial in strengthening logical-mathematical skills in primary school kids. This demonstrates the success of novel tools in improving mathematics performance [10]. By integrating interactive tools such as Engino Toy Blocks, educators may design captivating learning experiences that foster mathematical comprehension and enhance skill acquisition in pre-primary kids.

Utilising blocks as a teaching tool for elementary school children is a highly effective educational method for fostering a strong interest in maths. Using block-based programming can assist pre-service instructors in establishing links between computational thinking and mathematics, hence promoting conceptual comprehension [11]. Moreover, research has demonstrated that employing concrete tools, whether they are actual objects or digitally enhanced, can improve children's arithmetic skills and foster a more profound comprehension of fundamental mathematical principles [12]. Granting young children, the opportunity to utilise blocks as cognitive instruments can facilitate the cultivation, demonstration, examination, and expression of mathematical notions, hence promoting significant mathematical concepts and reasoning methodologies [13,14]. Moreover, it is essential to highlight the significance of cultivating fundamental mathematical principles during early education in order to establish a solid groundwork for future mathematical achievements [15].

Analysing students' performance in mathematics using these techniques is crucial for enhancing their critical thinking skills. This study examines the student performance using both qualitative and quantitative analysis. A questionnaire is administered to both students and teachers to identify the component that impacts satisfaction, and statistical methods are employed to analyse the outcomes of introducing Engino blocks to pre-primary students.

2. Literature Review

Teaching mathematics to pre-primary students might provide difficulties, particularly in regards to training elementary pre-service teachers to introduce pre-symbolic algebra concepts [16]. Evidence indicates that a significant number of future teachers encounter difficulties when it comes to adapting to changes in the artefacts, objects, and their role in algebra. This underscores the necessity for improved assistance in this domain [17]. Moreover, teachers often exhibit a hesitancy to incorporate demanding assignments into their mathematics lessons, primarily because of preexisting assumptions about the skills of their students [18]. Nevertheless, by performing a series of demanding challenges, it is possible to shatter these inflexible attitudes and demonstrate unexpected achievements among students who were previously considered less proficient in mathematics [19]. Moreover, the exploration of focused mathematical treatments for students facing difficulties in mathematics within a virtual setting is still limited, particularly considering the difficulties brought about by the worldwide pandemic [20,21].

Studies investigating the utilisation of blocks in early childhood mathematics teaching have demonstrated encouraging outcomes. Research has shown a clear link between the capacity to design toy models and positive outcomes in mathematics [22,23]. This connection may have a direct influence on spatial skills and overall accomplishment in mathematics. Research has shown that providing children with access to block play, specifically similar toy blocks, can enhance their mathematics learning [24]. This, in turn, leads to increased arithmetic abilities in early childhood environments. Furthermore, the examination of children's illustrations of blocks has been proposed as a good diagnostic instrument for evaluating spatial, numerical, and proto-mathematical abilities. This can offer valuable insights for educators and researchers in the field of mathematics education [25]. The results emphasise the possibility of integrating interactive activities into early education to improve spatial abilities, mathematics comprehension, and overall academic achievements.

In the field of early education mathematics, there is a strong connection between block construction skills and children's performance in mathematics, particularly among those from low socio-economic backgrounds [26,27]. This correlation is comparable to the relationship between toy blocks and mathematics. Moreover, the use of toy robot models as educational instruments has demonstrated potential in improving mathematical acquisition and proficiency among elementary school students, promoting aptitude in robotics, computer science, collaboration, and leadership [28,29]. Moreover, the use of hands-on activities involving simple machines and mechanisms has been demonstrated to cultivate problem-solving skills, teamwork, communication, and time management in young learners. This lays a solid groundwork for computer programming and scientific inquiry at the elementary level [30]. These findings emphasise the need of integrating hands-on, interactive mathematical tools such as block construction, robots, and engineering kits into early mathematics instruction. This approach enhances the development of a wide range of skills in young children.

Research also highlights the significance of employing new teaching tools, conducting project experiments, and facilitating interactive sessions to enhance the joyfulness and effectiveness of learning [31]. These exercises facilitate the acquisition of advanced knowledge, abilities, and competences in mathematical concepts such as "length" and its corresponding measuring units [32]. Furthermore, textbooks and manuals have the objective of providing future educators with the necessary methodological knowledge and abilities to efficiently structure mathematics instruction in elementary schools [33]. Moreover, incorporating hands-on activities into mathematics instruction is crucial for creating exceptional sessions that emphasise problem-solving strategies, offer detailed instructions, materials, and suggestions for adapting instruction to diverse student needs [34]. Teachers' choices to integrate hands-on activities are shaped by multiple elements, such as their personal life encounters, understanding of students' backgrounds, and their moral compass, emphasising the necessity for a sophisticated approach to teaching mathematics [35].

Furthermore, study has shown that the utilisation of models as educational resources has a beneficial effect on students' academic performance in mathematics, emphasising the need of integrating visual aids into teaching methodologies [36]. Bayesian models have also been incorporated within enhancing students' learning experience [37]. Moreover, the application of model-based problem-solving via web-based tutors has demonstrated efficacy in enhancing the word problem-solving performance of students who are facing difficulties, highlighting the significance of technology in dynamic learning settings [38]. The results of these studies highlight the significance of including blocks and models into mathematics teaching in order to improve students' comprehension, analytical abilities, and overall academic performance.

3. Materials and Method

3.1. Research Approach

This paper begins with a comprehensive literature review highlighting the significance of analysing satisfaction in order to enhance student education. This research has been carried out at the Engino Summer Academy. The Experimental Group is the students that used Engino toy blocks and the Control Group is the students that did not use Engino toy blocks. The data from each item of the questionnaire is compiled using Excel software. The responses of the students, who are learning the two modules, "Counting" and "Addition" using Engino toy blocks, are initially represented using graphs. The bar charts and tables in Excel illustrate the relationship between the questions. These clearly demonstrate the correlation between each question and the understanding of the topics with Engino activities.

Qualitative Analysis

The questionnaires provided for the students (Refer Appendix A) and teachers (Refer Appendix B) will be analysed to provide qualitative aspect of the research. The questionnaire provided for the students had eight questions in total and the questionnaire given to the teachers had 13 questions in total. Data about each question of the questionnaire will be collated using excel software and the responses by the teachers after using Engino models, are depicted initially using graphs. Using excel software the relationship between the questions relative to that of Questions 12 (I am strongly satisfied with the quality of the lessons plan incorporating Engino.) and 13 (The incorporation of Engino models in lessons enhanced student learning experience.) is presented in bar charts and tables.

Quantitative Analysis

Each student will be given a challenge card with questions and the results from this will provide the quantitative results in this study. The statistical analysis examined the outcomes of the challenge cards for both Engino users (Experimental Group) and those who did not use Engino (Control Group). This provides strong evidence to show the impact of

Engino toy blocks within teaching the modules for the students. Furthermore, hypothesis testing is performed to analyse whether there incorporating Engino has a significant effect on the enhancement of the students.

The subsequent procedure was executed to do the analysis.

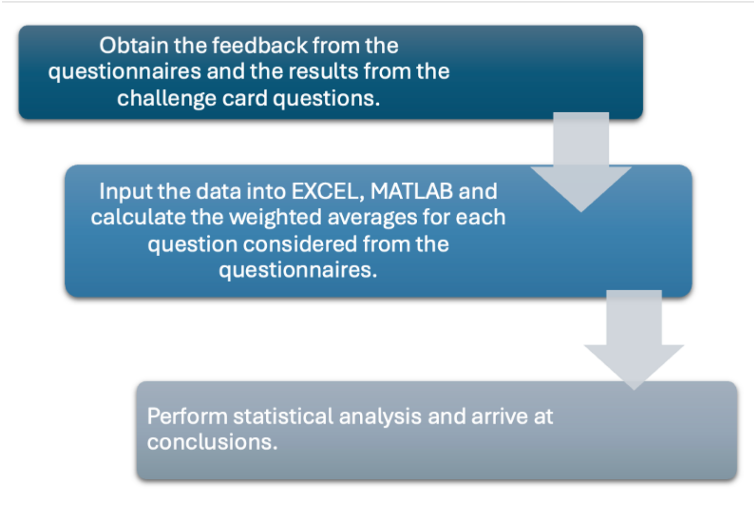

Figure 2. Chart: Process used for this study at a glance.

3.2. Modules Under investigation

The courses under consideration are:

1. Counting
2. Addition

It is acknowledged that there are many branches for Mathematics concepts, but again only the above catalytic modules are considered so as to find evidence of the impact of Engino blocks on student performance. The same method however, can be used and extended to other modules in different age groups, not only Mathematics related but also to any other field.

3.3. Software and Results processing

The study sample consisted of 50 students, which was divided equally and randomly into the experimental and control groups, 25 students in each.

The students' questionnaire results were entered into Matlab to generate graphs for each question in relation to Question 08, for the purpose of ensuring validity and comparability reasons to Excel findings. Facilitating a robust conclusion about the analysis of the data and determining the impact of Engino toy blocks on student learning. The feedback from the teachers questionnaire is also studied relative to that of Questions 12 and Question 13 .

The results from the challenge cards were analysed using Excel to determine measures of central tendency and dispersion, including mean, median, standard deviation, and other relevant computations. These calculations were necessary to establish the relationship between the group of Engino toy block users and the group who did not use Engino toy blocks.

The graphs were plotted by each software and subsequently compared. Additionally, the graphs provided information that allowed for the calculation of mean and the standard deviation between the responses from the questionnaires.

Software applications employ various graphical representations, such as bar charts, histograms, and tables, to analyse the correlation between the variables under consideration.

Effect size in statistics is the quantitative measure of the magnitude of an event [39,40]. This topic is typically associated with the application of hypothesis testing in the field of statistics. As indicated by the aforementioned writers, effect magnitude provides reliable scientific evidence for analysis. In this investigation, the calculation is performed using the following equation:

$$effect\ size = \frac{Diffenence\ between\ the\ means\ of\ the\ Experimental\ Group\ and\ Control\ Group}{Pooled\ Standard\ deviation}$$

This is also utilised by Hedge's and Olkin's equation, and it may be computed using Excel [41,42].

Typically, the absolute effect size is taken into account when assessing the statistical characteristics of the variables [43,44]. This study also highlights the significance of effect magnitude. It is primarily utilised in any conversations pertaining to statistics.

4. Results

4.1. Graphical Representation

Figures 2 and 3 show the results of each question considered from the students' and teachers' questionnaires respectively. They portray the questions affecting the use of Engino blocks for the modules considered.

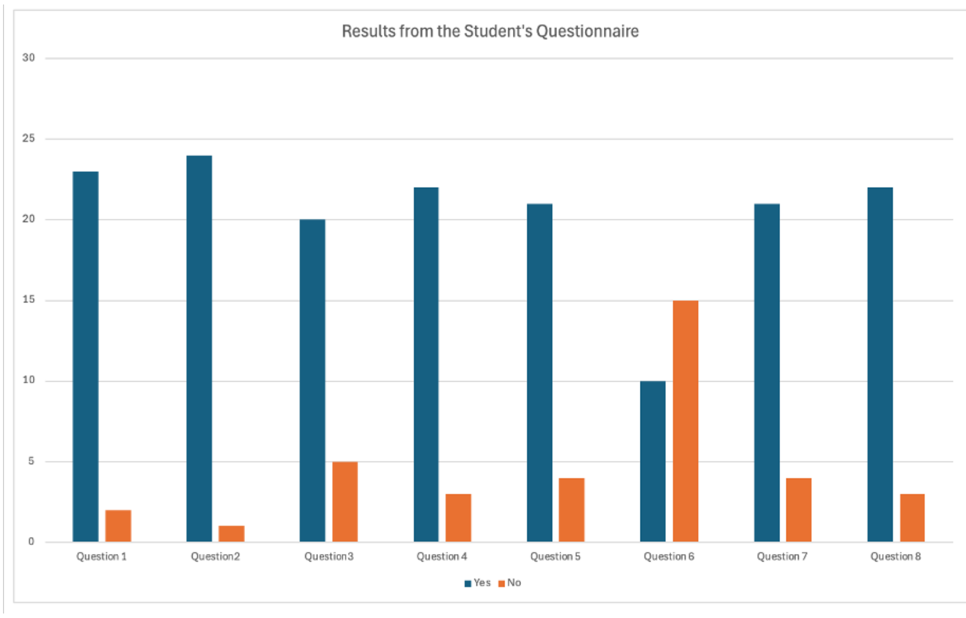

Figure 3. Results from the Student's Questionnaire.

Figure 2 shows the feedback from the students' questionnaire after they have used Engino toy blocks for their activities. Questions 1 (Did you enjoy using Engino blocks in class?) and Question 2 (Did you have fun building things using Engino blocks?) have the highest number of "Yes" responses, indicating they were likely the most positively received.

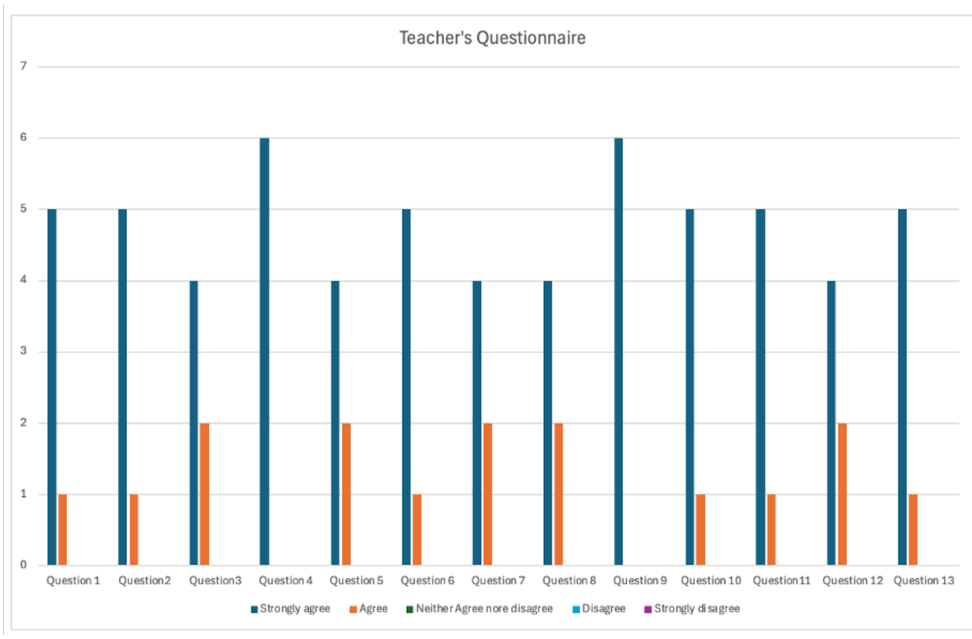

Figure 4. Results from the Teacher's Questionnaire.

Figure 3 illustrates the data collected from the questionnaire administered to the teachers. The vast majority of replies to most questions fell into the "Strongly agree" and "Agree" categories, indicating a remarkable level of agreement. The observed pattern indicates a robust and consistently positive agreement among the participants for all the questions. Items such as 4 and 9 garnered only "Strongly agree" replies, indicating a high level of agreement and suggesting that these questions tackled subjects that enjoy widespread support or approval.

Question	Proportion of Yes	Absolute Difference
Question 1	0.92	0.04
Question 2	0.96	0.08
Question 3	0.8	0.08
Question 4	0.88	0
Question 5	0.84	0.04
Question 6	0.4	0.48
Question 7	0.84	0.04
Question 8	0.88	0

Table 1. Proportion of Yes and Absolute Difference for each Question.

Table 1 above shows the Proportions of yes and the absolute values from the questionnaire results conducted for the students. Questions 1, 4, 5, and 7 have proportions close to Question 8, showing that students responded similarly to these questions compared to Question 8. Question 2 has a slightly higher proportion of "Yes" responses, while Question 3 has a slightly lower proportion. However, the most significant difference is with Question 6, where the proportion of "Yes" responses is much lower than in Question 8.

The Table 2 below shows the mean and standard deviations obtained from the number of questionnaire responses from the students who used Engino toy blocks. Question 1 and 2 have high mean values than the others and they also have very low standard deviation values. Low standard deviation values show that the responses were consistent for these two questions compared to the other questions.

4.2. Quantitative Results

The aim of this study was to investigate the effectiveness of using on Engino toy blocks for pre-primary students' mathematics education. The arithmetic means and standard

Question	Mean	Standard Deviation
Question 1	0.92	0.2713
Question 2	0.96	0.196
Question 3	0.8	0.4
Question 4	0.88	0.325
Question 5	0.84	0.3666
Question 6	0.4	0.4899
Question 7	0.84	0.3666
Question 8	0.88	0.325

Table 2. Mean and Standard Deviation for each Question.

deviations of the experimental and control groups were extracted for each based on the level of students' performance, as shown in Table 3.

Group	Mean	Standard Deviation
Experimental (Using Engino)	11.875	1.583
Control (Without Using Engino)	8.655	3.587

Table 3. Comparison of Mean and Standard Deviation between Experimental and Control Groups.

Analysis of Table 3 reveals that the average score of the students in the experimental group, 11.875, is 3.22 points higher than the average score of the control group, 8.655. The small standard deviation value, 1.583, seen in the Experimental group indicates the high level of consistency in student performance, as the findings are tightly concentrated around the mean value.

The control group has a higher standard deviation of 3.587, suggesting that the scores of the participants in this group range more from the group's mean of 8.655. Contrasting with the experimental group, the participants in the control group exhibited less consistency, seen from their heightened variability.

The following hypothesis testing was performed:

H_0: There is no difference in student performance between the Experimental Group and the Control Group.

H_1: There is a significant difference in student performance between the Experimental Group and the Control Group.

The p value found was 0.04421 which is less than the significance value of 0.05. Hence we reject the null hypothesis and conclude that there is a significant difference in student performance between the Experimental Group (those who used Engino toy blocks) and the Control Group (those who did not use Engino toy blocks).

The effect size was calculated to be 0.83, depicting a large effect. This underscores that the utilisation of Engino blocks positively influenced student performance in mathematics. The Pearson correlation coefficient was calculated, yielding an absolute value of 0.51. This indicates a robust linear connection between the two groups, hence corroborating the previously identified effect size. Consequently, students utilising Engino toy blocks achieved better outcomes on the challenge cards compared to those who did not employ Engino blocks to address the questions.

5. Discussion

The research findings indicate that the use of Engino blocks in teaching mathematics for pre-primary students has a notable and beneficial effect. The results demonstrate the enhancement in students' average performance when Engino toy blocks are integrated into their educational curriculum.

The advantages of Engino toy blocks predominantly arise from their interactive and tactile characteristics. The students appeared to derive pleasure from playing and acquiring knowledge with it, and, as teachers noted during the instruction, all students were far more involved in classroom activities. Increasing the student's motivation to learn mathematics, the Engino blocks facilitated qualitative and quantitative analysis conducted in this study. As a result, students have developed a strong capacity to retain knowledge and have integrated several studying habits such as independent exploration and problem-solving. The toy blocks foster creativity and analytical thinking across the acquisition of mathematical principles and facts.

Engino blocks are particularly valuable tools for facilitating collaborative work among students and enabling teachers to enhance students' essential abilities in communication, teamwork, problem-solving, and creativity. International pedagogical standards for teaching and learning mathematics highlight the need of incorporating technology in instruction and the significance of effective dissemination and retention of knowledge.

The teacher's questionnaires had some suggestions for improvements with the lessons plans using Engino. Some of them wanted to incorporate more 3D shapes within the lessons, to include some take away home kits to practice at home etc. These will be considered for further studies in the future and to enhance their teaching experience too.

The findings of this study align with prior research on this subject, including the work of Polianskaya (2018), which emphasises the significance of using tools like these in the instruction of mathematics. Furthermore, the research conducted by Mqawass (2018) identified several elements that impact the willingness to adopt contemporary technology, such as robotics in education. It was shown that young students exhibited a higher level of acceptance towards studying modern technology compared to adults, and males displayed a greater acceptance than females.

6. Conclusions

This study analysed the student performance in mathematics for pre-primary students through the application of Engino toy blocks at the Engino Summer Academy. The findings emphasised the importance of incorporating Engino toy blocks within the lessons for the students which enhanced their academic performance.

The data collected from the groups of students who used Engino toy blocks and those who did not were evaluated using Excel. The findings indicate that students utilising Engino toy blocks outperformed their peers who didn't use the Engino blocks. The mean, standard deviation, and hypothesis testing collectively affirm the study's dependability, as the results are consistent and the numerical precision of the test measures demonstrates relevance and validity. Consequently, the positive influence is significant for students utilising Engino toy blocks in their educational experience.

7. Suggestions for Future Research

Further investigation in the field of elementary mathematics education could centre on examining the efficacy of various forms of manipulatives, such as tangible Engino blocks, in relation to mathematical learning outcomes. Furthermore, doing research on the effects of incorporating block play into the educational programmes of economically disadvantaged nations could offer valuable knowledge on how to improve mathematical abilities in various educational environments. Moreover, further investigation could explore the utilisation of children's drawings as diagnostic instruments for evaluating mathematical comprehension and spatial aptitudes, specifically when depicting intricate items such as Engino models. This approach provides a distinct viewpoint on students' early mathematical abilities. Future studies can contribute to the development of novel and effective techniques for using Engino toy blocks in basic mathematics education to improve learning outcomes and assist children's mathematical growth.

8. Patents

This section is not mandatory, but may be added if there are patents resulting from the work reported in this manuscript.

Author Contributions: Conceptualization, X.X. and Y.Y.; methodology, X.X.; software, X.X.; validation, X.X., Y.Y. and Z.Z.; formal analysis, X.X.; investigation, X.X.; resources, X.X.; data curation, X.X.; writing—original draft preparation, X.X.; writing—review and editing, X.X.; visualization, X.X.; supervision, X.X.; project administration, X.X.; funding acquisition, Y.Y. All authors have read and agreed to the published version of the manuscript.", please turn to the CRediT taxonomy for the term explanation. Authorship must be limited to those who have contributed substantially to the work reported.

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Abbreviations

The following abbreviations are used in this manuscript:

DOAJ	Directory of open access journals
TLA	Three letter acronym
LD	Linear dichroism

Appendix A

Questionnaire for Students (Age Group 5-6)

The feedback from this students' questionnaire will be used to plot graphs and analyze the effects of all the questions in relation to Question 8 (Understanding the topic better with Engino). This will provide a strong foundation to show the enhancement in the learning experience when using Engino models.

1. Did you enjoy using Engino blocks in class?
   - Yes No
2. Did you have fun building things using Engino blocks?
   - Yes No
3. Would you like to use Engino blocks again to learn new things?

- Yes No

4. Was it easy to put together the Engino blocks?
    - Yes No
5. Did you like working with your friends when using Engino blocks?
    - Yes No
6. Did you need help from the teacher to build the models?
    - Yes No
7. Did you feel proud of what you built using Engino blocks?
    - Yes No
8. Did Engino blocks help you understand the topics better?
    - Yes No

Appendix B

Questionnaire for Teachers (Age Group 5-6)

Please evaluate the following statements according to your personal interaction with Engino blocks in your classroom. Utilize the following scale: Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree. Please tick the preference.

1. The students were more engaged when using Engino blocks in the classroom.
    - Strongly Agree
    - Agree
    - Neither Agree nor Disagree
    - Disagree
    - Strongly Disagree
2. Students showed more interest and enthusiasm when using Engino blocks.
    - Strongly Agree
    - Agree
    - Neither Agree nor Disagree
    - Disagree
    - Strongly Disagree
3. It was easy to incorporate Engino models into the lessons.
    - Strongly Agree
    - Agree
    - Neither Agree nor Disagree
    - Disagree
    - Strongly Disagree
4. The materials and instructions provided with the Engino blocks were sufficient.
    - Strongly Agree
    - Agree
    - Neither Agree nor Disagree
    - Disagree
    - Strongly Disagree
5. Students understood the topics better with Engino models.
    - Strongly Agree
    - Agree
    - Neither Agree nor Disagree
    - Disagree
    - Strongly Disagree
6. Students worked well as a team when building Engino models.
    - Strongly Agree

- Agree
- Neither Agree nor Disagree
- Disagree
- Strongly Disagree

7. Using Engino models encouraged students to improve collaboration.
    - Strongly Agree
    - Agree
    - Neither Agree nor Disagree
    - Disagree
    - Strongly Disagree
8. Students were able to communicate their ideas effectively in the classroom when using Engino models.
    - Strongly Agree
    - Agree
    - Neither Agree nor Disagree
    - Disagree
    - Strongly Disagree
9. The use of Engino was beneficial for the teaching objectives.
    - Strongly Agree
    - Agree
    - Neither Agree nor Disagree
    - Disagree
    - Strongly Disagree
10. I received positive feedback from the students after using Engino in class.
    - Strongly Agree
    - Agree
    - Neither Agree nor Disagree
    - Disagree
    - Strongly Disagree
11. I would like to use Engino in future lessons.
    - Strongly Agree
    - Agree
    - Neither Agree nor Disagree
    - Disagree
    - Strongly Disagree
12. I am strongly satisfied with the quality of the lessons plan incorporating Engino.
    - Strongly Agree
    - Agree
    - Neither Agree nor Disagree
    - Disagree
    - Strongly Disagree
13. The incorporation of Engino models in lessons enhanced student learning experience.
    - Strongly Agree
    - Agree
    - Neither Agree nor Disagree
    - Disagree
    - Strongly Disagree
14. Please specify any suggestions for improvements with the lesson plans using Engino:
    - ....
    - ....
    - ....

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