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Formulization of Using Technology in Teaching and Learning of Statistics

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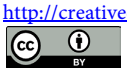

Abstract

A good teaching and learning session is much more dependent on the aspects of the teacher's subject content knowledge, pedagogical content knowledge and technological content knowledge. All these elements could be developed through the teacher's continuous effort and require the teacher's professional development in using digital technology. Integrating digital technology in teaching and learning plays a big role in effective instruction. It became essential in providing a meaningful learning experience for the students. This study is a conceptualization of the trends of using technology in the teaching of statistics and probability using digital technology. This study explored the learning environment for statistics and probability. Qualitative explorations were used to identify trends in how statistics and probability websites and online applications were used. The result demonstrates the emerging trends in teaching and learning statistics and probability by integrating digital technology which could enhance students' statical and probability thinking. Hence, it can be concluded that teachers should focus more on the ability to use digital technology as well as statistical knowledge and pedagogical knowledge. The implications are teachers' effective instruction and communication, students' learning motivation and could improve students' mathematics achievement. In conclusion, this study recommended that teachers should include using digital technology in their statistics and probability teaching and learning. The development of teaching and learning skills using digital technology could enhance students' abilities like critical thinking, data analysis, and mathematical reasoning. To maximize the advantages of using digital technology in the classroom teachers need to concentrate on improving students' learning skills in probability statistics and pay attention to the technical aspect of teaching statistics and probability using digital technology.

Keywords

Statistics and Probability Teaching and Learning, Digital Technology Pedagogy, Statistics and Probability Thinking, Statistics and Probability

Reasoning, Statistics and Probability Literacy

1. Introduction

Microsoft's market value exceeds the combined Gross Domestic Product (GDP) of the Netherlands, Luxembourg, and other countries, which makes people feel the charm of the knowledge economy and the challenges and opportunities it brings to countries around the world (Dong & Liu, 2022). The future of mankind and the prosperity of the country must depend on the innovation of knowledge and technology, as well as on the ability and efficiency of the creative use of knowledge, information, and technology. In today's digital age, digital capabilities have facilitated teaching and learning Mathematics to be more interesting. The traditional teaching and learning of Mathematics become less in-teresting because of uninteresting instructional content and it creates low confidence levels among students and teachers (Krishnasamy et al., 2020). Thus, this conceptualization paper tends to combine teaching and learning of statistics and probability with digital technol-ogy. Deeper digital technology used for statistics education will be cov-ered in this conceptualization.

Different perspectives in the education field have different ideas about the importance of combining digital technology in the curricu-lum. Literature shows that the international society has accepted the statement made by the National Education Technology Standard of the United States, which defines digital technology and curriculum integration as the process of using technology to support and strengthen learning and teaching in the daily learning process of academic knowledge (Simpson, 2018). This is because using digital technology has been identified as having many advantages in teaching and learning mathe-matics. For example, dynamic geometry software for graphics has many benefits in teaching of algebra and calculus (Heid, 2005). It can introduce algebra and integration in the form of symbolic equations and graphics so that students can express and operate directly (Koirala & Bowman, 2003); Furthermore, this situation has been demonstrated through the case studies conducted by middle school teachers that the usage of graphic calculators can effectively enhance students' grasp of variable relationships and experimental design. This is because some mathematical concepts are too complex to teach in a traditional way and multimedia content learning allows students to visualize the learning contents easily (Sharon, 2017).

However, the study of the integration of technology into mathematics courses is still in a state of flux. Issues such as the meaning of integration, the conditions of integration, the principles and standards of integration, and the methods and steps of integration, are still very vague. Thus, this paper tries to solve some related problems, deeply study the ways and methods of integrating probability and statistical teaching, reconceptualize some related problems, and provide

teachers with an operational teaching mode.

2. Background and Problem Statement

Since the past 20 years, the body of research on statistics education has grown quickly as its significance in the modern information age has come to be better understood. Statistics and probability, just like any other course, have had their own evolution. This millennium generation, especially students, faces the complexity and challenges of learning or implementing statistics and probability in their daily lives. In our everyday life environment, statistics plays an important element. It is a technique used to understand, examine, and make anecdotes to be trusted stories. It plays a very important tool in research for inquiry findings (Tchantchane et al., 2012). From elementary college education, for example, statistics and probability is a crucial topic that needs to be taken in mathematics. Since most statistical ideas are abstract in nature, and the teaching and learning technique used by the teacher is normally just introducing statistics and probability problems, or even researchers, face these problems with more challenging statistical and probability techniques of analysis. Therefore, there are many growing movements to include statistics and probability at all educational levels (Luy et al., 2019). Both mathematics education and statistics experts have the same consensus on these paradigms.

In this new era, using digital technology in the subject of statistics and probability has played a vital role (Chan & Ismail, 2012). The implementation of digital technology in statistics and probability teaching and learning for elementary school is still taking its own process. However, it has been a new norm to use digital technology when it comes to college and university students. The use of digital technology in statistics teaching is frequently associated with gadgets such as personal computers, tablets, and the statistical computing packages that go along with them, which have developed into a statistician's essential working tool. Some of the online mathematics instruction programs (OMIPs) come with video and other tools that can be utilized in probability and statistics teaching. However, the use of digital technology in teaching and learning still has big challenges, especially for the developing country that still struggles in equipping schools and teachers with technological equipment and skills. They are still using conventional methods of teaching statistics and probability due to expensive and complex equipment (Livingston, 2016) which is not provided by the government. There are various types of sub-categories on the digital technology used in statistics and probability instruction, there are computer software such as spreadsheets, digital calculators, standalone instructional applications, graphing calculators, multimedia assets, instructional software, statistical packages, and data repositories (Livingston, 2016), there also have OMIPs learning environment such as GeoGebra and Wolfram Alpha. In Malaysia, undergraduate students and postgraduate students are usually introduced to statistical software that is called Statistical Package for the Social Sciences (SPSS). Other than that,

in this new era when it comes to teaching statistics and probability, educators must play an essential role in making sure they master the application or type of technology tools used. The most crucial learning developments required in this modern generation of statistical and probability education are statistical and probability knowledge, technical statistical and probability knowledge, and technology-pedagogical statistical and probability knowledge (Batanero et al., 2016).

3. Objectives

The purpose of this study is to formalize development that can focus on using digital technologies in the teaching and learning of statistics and probability curriculum for secondary schools level. Furthermore, this study aims to identify teaching activities that can be arranged using digital technology

4. Methodology, Samples and Analysis

This is a qualitative study using the document literature reviewed. Samples of documents were collected based on the titles of "Mathematics Online Digital Sources for Teaching and Learning Statistics and Probability" and "Integrating Digital Technology in Statistics and Probability for Secondary Level Curriculum". The data was analyzed using thematic analyses to construct elements, categories, and themes. The themes were mapped with respected elements using logical ontological relationships by focusing to formulize on students developing cognitive, skills and affective domains.

5. Finding Themes

Based on the reviews and formulization, three main themes emerged. They are curriculum Enhancement, students' new skills development and teachers' professional development.

5.1. Themes 1: Curriculum Enhancement

The theme on curriculum enhancement using digital technology emerges by reviewing the standard curriculum outlined for teachers in their lesson plan which must be accomplished using the element of effective communication and instruction (Maba, 2017). Using digital technology in teaching and learning probability, students can be facilitated to grasp the statistics and probability knowledge by developing statistical and probability thinking through effective communication using digital technology. These could be done by engaging students using good interaction with digital tools, peers, and teachers. At the same time, teachers are encouraged to offer students to enable them to apply statistics and probability concepts and procedures using the daily life activity elements. Furthermore, these could be done in exams in better methods. Students' difficulties in comprehending the statical and probability concepts and procedures can be overcome efficiently using better communication since they can be given and

make necessary feedback while making logical statistical and probability connections (Park, 2018).

Meanwhile, the integration of digital technology was reported as an emerging trend as the development of new elements of learning using "online mathematics instruction programs" (OMIPs) as crucial tools (Bajuri et al., 2021). Experts agree that the rapid growth of information technology with embedded artificial intelligence elements has made these elements a crucial element to be integrated into the teaching and learning process (Nikolić et al., 2019). The interactive elements using digital technology techniques and strategy will make teaching and learning outcomes beyond the students' comprehension (Rodríguez-Muniz et al., 2019). Whether it has been taught in primary school, secondary school, or tertiary education, digital technology platforms such as Massive Open Online Courses (MOOC) have been found as very impactful platforms for the education industry. Research conducted by Jamal, Ghafar, Ismail, Awang, and Baharuddin (Jamal et al., 2020) discovered that MOOCs are interactive web-based digital tools that can also be used for remote learning to create new learning opportunities in higher education.

The use of online digital tools and software by educators to teach probability and statistics in the classroom was also reported as one of the elements that could strengthen and enhance teachers' creativity in their teaching and learning sessions. For example, to teach statistics and probability, Cai, Liu, Yang, and Liang (Cai et al., 2019) developed interactive tablet-based augmented reality (AR) technology in their teaching sessions. It is an alternative to the conventional method in which simulation teaching and learning tools like EXCEL, Tinker Plots, and animations can be included in augmented reality (AR) technology. Through a series of lessons incorporating AR technology, this creative teaching technique will facilitate students in junior high schools in understanding the fundamental ideas of statistics and probability. For example, according to research done by Cai, Liu, Yang and Liang (Cai et al., 2019), the participants could carry out a mathematics experiment about statistics and probability by integrating many digital technologies.

5.2. Themes 2: Students' New Skills Development

Data collected from articles can be inducted the theme of developing new skills among students. One of the most important skills when implementing digital technology into teaching and learning of statistics and probability is mathematical prerequisite skills, such as arithmetic and data analysis (Polhun et al., 2021) which need to blend with statistics and probability. This skills ability helps students to evaluate facts to gain insightful knowledge. These elements also will enhance the problem-solving skills which more efforts were hampered by a general lack of mathematical ability (Gupta, 2022). The second element is the ability to make decision-making based on data analyzed. Collected articles reported that many mathematical ideas and abilities are integrated into the elements of decision-making and problem-solving processes that students need to master.

Due to students lack of visual-spatial ability, these elements will be hard to possess in terms of determining distinctions, identifying connections, and arranging data in meaningful outcomes. Hence, the integration of digital technology into statistics and probability can cultivate skills such as critical thinking, data analytical skills, and cognitive competence, as well as develop probabilistic reasoning and statistical reasoning.

Findings show it has been reported that activities on developing students' critical thinking could be done when students observe a particular piece of information before looking back for any relevant details about the problem faced. They then draw conclusions from those specifics and carefully consider if they make sense in the larger context of the investigation (Kus & Çakiroglu, 2020). The mathematical problem-solving creativity elements entail students' ability to articulate mathematical information and uncover their underlying connections. The element of critical thinking is needed to analyze the information coming from relevant sources of data such as from specific bodies of reports and research. Hence, learning statistics and probability using digital technology can develop students' critical thinking especially when analyzing the information coming from research (Aizikovitsh-Udi, 2019).

Due to their mathematical background, students often have anxiety while learning mathematics. Primi et al. (Primi et al., 2018) highlight the "anxiety felt when taking any form of statistics" and "appears to involve a complicated diversity of emotional responses" associated with statistics-related test anxiety. For instance, while learning normal distribution using technology, the students adhere to conceptual knowledge of mathematics and place emphasis on exploration, problem-solving, higher-order abilities, and mathematical language (Aizikovitsh-Udi & Amit, 2011; Hadi et al., 2018). They actively construct their knowledge and understanding and hence evoke the related mathematical concern (Bajuri et al, 2023).

Understanding spatial visualization is exceptionally hard when learning statistics and probability. Cai et al. (Cai et al., 2020) emphasized the implementation of virtual objects using technology will enhance the learner experience in learning statistics and probability. The learners utilize a mobile or tablet to create and modify augmented reality 3-dimensional (3D) objects. Ergo, they are capable of experimenting with spatially related mathematical topics by engaging in augmented reality, everything from elementary geometry to work with figures to manipulations of Euclidean vectors (Martin-Gonzalez et al., 2016).

Chance, certainty, and likelihood are only a few of the ideas that the students will learn to recognize in the probability field. They will also draw parallels to other disciplines, such as science and social studies, as they examine several real-world examples of probability. In order to improve data analysis abilities and self-efficacy, it is beneficial to study probability and statistics using technology (Zetriuslita et al., 2020). While learning statistical analysis, students learn to analyze the raw data in order to draw valid conclusions from the data they have obtained. As stated by Zakariya et al. (Zetriuslita et al., 2020), students who are

confident in their mathematical abilities take a more comprehensive approach to learning first-year mathematics compared to those who are less confident. Thus, self-efficacy is improved by learning probability and statistics using technology. The learners are competent to make a judgment of one's belief in or their own competence to solve a certain mathematical issue or assignment in each context.

The cognitive capacities of students in problem-solving activities are mostly lacking, despite the fact that it is highlighted that the new Bloom's taxonomy is more relevant to current educational demands (Purnomo et al., 2022). Both mathematical competence and mathematical ability are applied synonymously when learning technological statistics and probability. Although there are few cognitive factors to be considered, scientists in learning and cognition have recently become interested in studying mathematics learning. The learners can solve mathematical problems and have the mathematical aptitude, which is to make use of mathematical information and hence instilling cognitive competence (Lin et al., 2018).

Statistics and probability are complex concepts that encompass several functional elements. Donati et al. (Donati et al., 2014), Primi et al. (Primi et al., 2017) and Maros et al. (Maros et al., 2020) highlighted that there is a growing interest has been recently posed on probabilistic reasoning abilities. In relation to this, the necessity of giving students the skills to reason about probability and statistics should not be neglected, as the learners have to deal with uncertainty and make decisions based on probabilistic and statistical data. From primary school through high school and beyond, these subject areas, including the study of graphs, statistics, and probability, are crucial to a well-rounded education. In order to engage students and maintain their interest, students must have more time to mature and develop their probabilistic and statistical reasoning using technology. It encompasses the ability to master probabilistic information and risk estimates (Reyna et al., 2009; Fundel et al., 2019).

Math is becoming increasingly invisible as digital technology takes over the globe (Bajuri et al., 2022). There are new requirements for numerical literacy, albeit this is not yet a widespread phrase in many nations (Denovan et al., 2017). Understanding that chance plays a role in everyone's lives is a prerequisite for mathematical literacy, but students often struggle to make that connection. The students go from an intuitive grasp of chance to a more logical framework for making calculated judgments under uncertain conditions. Questions like the availability of water, temperatures over a certain threshold, food, healthcare, etc., all incorporate elements of chance that may be learned and practiced through quantitative literacy. Thus, students will acquire the information and skills necessary to independently or sequentially implement mathematical operations utilizing numbers encoded in printed documents (OECD, 2011; Thorpe, 2018).

Probability and statistics using technology are covered in a wide variety of other subjects as well. Probability gives information on the possibility of an

event occurring. For instance, meteorologists utilize weather patterns to estimate the likelihood of rain (Jehanzaib et al., 2020). Due to the intertwined nature of the processes involved, students have a hard time disentangling determinism from the concept of chance in probability. Hence, there is a need to demonstrate the necessity to reject deterministic thinking and acknowledge that there is a basic change in nature, especially in the novel paradigm of the technological probability field. There is a wide range of pupils who can benefit from the combination of probability and statistics. Students can research any topic they're passionate about and then present their findings to the rest of the class (Lanuza et al., 2020).

Statistical instructors work to instill a sense of statistical literacy and statistical reasoning in their students, despite a lack of agreement on the nature of the relationship between these objectives and the degree to which they overlap (Sabbag et al., 2018). Due to its vast use, probability theory should be taught in mathematics schools. In mathematics, graphing, statistics, and probability are essential concepts. Besides that, taking part in probability and statistics courses can boost students' interest in and aptitude for the sciences and language acquisition. All these subject areas are integral to a student's education from kindergarten through all the upper years (Resnik & Schallmoser, 2019).

In a nutshell, the goal of the mathematics curriculum is to give students meaningful opportunities to use their knowledge of probability and statistics using technology. The curriculum should include more than simply the principles of basic probability, conditional probability, and conjunctive probability, together with numerical data by implementing technology. While learning statistics and probability using technology, students can acquire mathematical abilities, which include arithmetic skills and language skills. In addition, they can have a better understanding of the connection between data-driven and theoretical modeling when they consider the mathematical, probabilistic, and statistical relationships among these disciplines. Hence, there is no harm in learning probability and statistics using technology.

5.3. Themes 3: Teachers Professional Development

Teacher professional development especially in the aspect of teaching and learning statistics and probability should be emphasized on the elements of using technologies, which is helpful for their pedagogical and content professional improvement. Teacher professional development has been reported to be discussed in four elements: the first element is teaching and task planning. It brings great convenience for teachers to prepare lessons. A statistical and probability class can be prepared using many approaches using materials in different fields using technologies. This search is not limited by time and space. Meanwhile. It can greatly improve the teaching quality of teachers; secondly, promote the improvement of teachers' professional skills expand their thinking, and increase their knowledge; thirdly, accelerate the process of curriculum reform and promote the development of teachers' profession; finally, Broaden the path of teachers' pro-

fessional development and provide a new strategy for teachers' professional growth.

When preparing lessons, teachers need to use technology to search for materials, download courseware, make teaching software and so on (MacIntyre et al., 2020). This is not only conducive to optimizing teaching design and improving lesson preparation efficiency but also conducive to improving teachers' ability to apply technology and professional quality (Hassan et al., 2022).

For instance, when teachers prepare a lesson on derivatives of composite functions, teachers can use the software of Wolfram Alpha which is a new generation of search engine developed by Wolfram Research Company, which develops computational mathematics application software. This software is actually a computational knowledge engine, not a search engine. Its real innovation lies in its ability to immediately understand problems and give answers (Dimiceli et al., 2010). If we input the derivative of $x^4 \sin x$, we can get a series of knowledge about this compound function derivative (**Figure 1**). First, we can get the answer directly through WolframAlpha, derivative of $x^4 \sin x = x^3 (4\sin(x) + x\cos(x))$. At the same time, we can also get plots about this derivative, so that students can understand the derivative of this composite function more vividly. Then we can get the alternate form, reduced trigonometric form, numerical roots, and properties as a real function. Also, we get the series expansion at x = 0 and indefinite integral. Finally, we can see related queries of this derivative. It lists in detail the application, plot, and expansion of this derivative. So, it brings great convenience for teachers to prepare lessons.

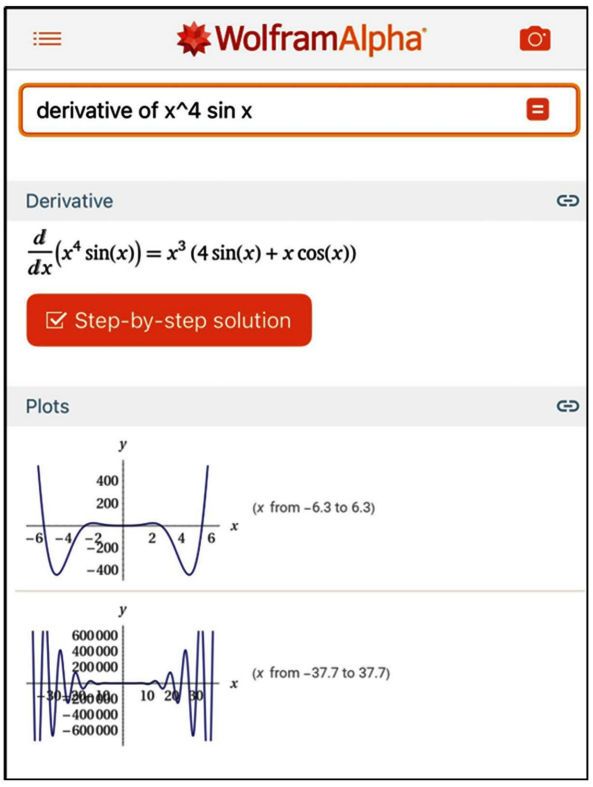

Figure 1. Derivative of $x^4 \sin x$.

The development of the progressive society of the times is, in the final analysis, marked by the renewal of knowledge. Inevitably, the use of cutting-edge technology in educational contexts will lead to a revitalization of educators' pedagogical acumen and an improvement in the organization of knowledge. Modern digital technology can also promote the cultivation and sublimation of teachers' professional attitudes.

As a mathematics educator, you should have some special professional skills, including computing ability, which is mainly reflected in the flexible use of some computing properties and operating laws, which makes complex operations simple, so that you can get results more quickly and accurately; The ability of logical thinking is mainly reflected in the ability of teachers to skillfully apply analysis、synthesis、comparison、abstraction、analogy and other methods to teaching; The ability of space imagination, based on the relationship between points, lines, surfaces and bodies, can draw and describe the object and model. When we use Wolfram Alpha, we can quickly and accurately get the calculation results, and clearly give the spatial graph for our reference, and give some critical values of the graph for us to explore. It gives a list of relevant knowledge to effectively improve teachers' logical thinking ability.

We have other tools to investigate and use, including Wolfram Alpha. The software can do scope and subject searches that encompass all facets of natural science, including natural science, food and health, engineering technology, and art (**Figure 2**).

Technology can accelerate the process of curriculum reform and promote the reform of teachers' professional development mode. The first is to advocate for better teacher preparation by promoting system building that considers educators' evolving professional needs. The second goal is to push for changes in the way educators work and how they instruct. Finally, using cutting-edge IT will undoubtedly encourage educators to push forward, actively adapt, and hone their craft.

As for the content of the curriculum reform, we need to improve the curriculum objectives; Secondly, optimize the curriculum; and finally, detail implementation requirements (Liu et al., 2022). In the technology integration class, we can apply technology to the second part of curriculum reform to optimize the curriculum. The use of technology makes it convenient for teachers to prepare lessons and improves teaching efficiency and quality. It makes the classroom more vivid, cultivates students' ability to active learning and exploration, and accelerates curriculum reform. The use of technology to integrate into the classroom has enabled us to constantly explore new knowledge and update the new objectives of the curriculum. Therefore, it also accelerates the first part of the curriculum reform to improve the curriculum objectives. Compared to normal progress, technology can accelerate the process of curriculum change.

The premise of using technology integration classroom is that teachers should first study and use technology and master the use method and purpose of this technology. Therefore, teachers can explore and learn more skills about their

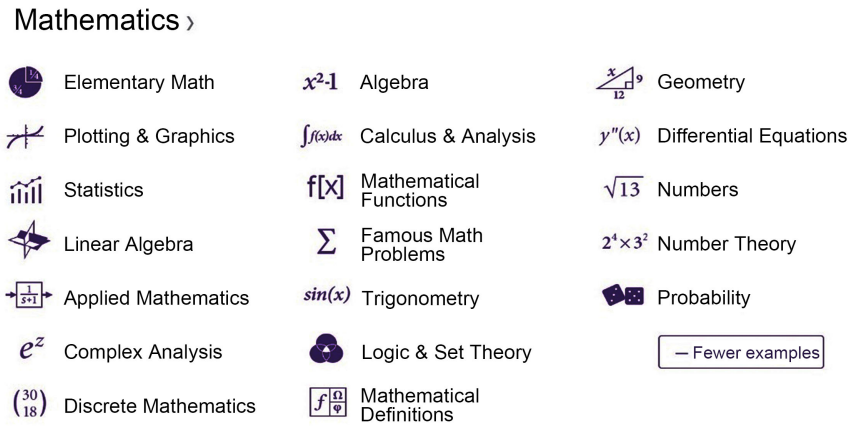

Figure 2. WolframAlpha of Mathematics.

profession and expand their knowledge. To some extent, it has promoted the development of teachers' professions.

In conclusion, the application of technology to promote teachers' professional growth and development is an important subject for realizing educational modernization and educational reform. It can not only bring great convenience to teachers' teaching but also promote the promotion of teachers' profession to a certain extent. On the other hand, technology integration teaching, not only creates new requirements for teachers but also is a big challenge for students. Students need to actively accept these technologies and skillfully apply them.

6. Conclusions

Many students have consistently believed over the years that statistics are tough and complex (Chan & Ismail, 2012). We need to find and explore new methods and technologies for the teaching of probability statistics. A teacher's experience with technology significantly influences his or her classroom technology integration (Liu et al., 2017). When combining IT and statistics, it is important to pay attention to the professional development of students and teachers. We need to focus on developing students' learning skills in probability statistics and pay attention to teachers teaching the technical teaching of probability statistics to maximize the benefits of IT in the classroom.

The integration of technology is a known and crucial issue in the field of mathematics education. Digital Technology plays the following role in integrating with the curriculum of probability statistics by cultivating the element of: 1) Foster critical thinking skills among teachers and students, 2) Elicit mathematics anxiety, 3) Cultivate Spatial Imagination, 4) Develop Data Analytical Skills and Self-Efficacy, 5) Instill Cognitive Competence, 6) Develop Probabilistic Reasoning and Statistical Reasoning, 7) Promote Quantitative Literacy, 8) Establish Non-Deterministic Thinking, 9) Foster Statistical Literacy and Statistical Reasoning. This can be done by stimulating interest in 1) learning and cultivating the spirit of exploration; 2) revealing essential laws and enhancing the awareness

of truth; 3) experiencing mathematical experiments to improve information literacy; 4) organizing dynamic classrooms and enhancing practical ability; 5) save classroom time and improve classroom effectiveness.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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