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New Technologies and the Gender Factor in the Comprehension of Probabilities: Evidence from the Perceptions of Students

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ABSTRACT Mathematical education in Greece is constantly evolving in the pursuit of optimal learning outcomes for students despite their cognitive differences. This study seeks to gain insight into the use of new technologies in teaching probability theory and the gender differences in the comprehension of probability theory. To this end, a survey was conducted involving 500 students of the Department of Statistics and Insurance Science at the University of Piraeus. The respective questionnaire involves questions of self-reported results and employs the Likert scale to obtain the students' perceptions. Our data demonstrate no difference among the genders regarding the use of new technologies or their performance (i.e., the test scores) in the relevant courses.

KEYWORDS *Probabilities, gender, new technologies, pedagogy*

Introduction

Female-identifying individuals have been reported to be heavily underrepresented in most mathematically intensive areas (Holman et al., 2018; Thelwall et al., 2019), which has stirred the discussion on gender stereotypes in education and the corresponding implications in the occupational realm. Furthermore, modern education methods are embracing electronic means (e.g., electronic platforms, educational software, digital games, etc.), which have strengthened the efforts to transmit knowledge in these fields. However, the following questions have arisen: "Are the new teaching approaches that employ mathematics educational technologies achieving their purpose of improving the level of understanding and helping students pursue their professional goals?" and "Does the ability to understand mathematics and its branches depend on gender?". We acknowledge that similar questions have been addressed before regarding various education systems. Nevertheless, such issues remain largely overlooked with regard to Greek education, and we aim to fill this gap.

The purpose of the present study is twofold. Firstly, we investigate whether electronic educational means contribute to a deeper and more effective comprehension of the notions traditionally included in Probabilities courses. Secondly, we assess whether gender affects the ability to understand and learn the relevant notions. To this end, a questionnaire consisting of thirty questions was developed and distributed to students at the Department of Statistics and Insurance Science at the University of Piraeus. The relevant questions addressed various aspects relating to the application of electronic educational means, the learning outcomes as perceived by the students, and their interest in the field of Probabilities and its potential for further study. Moreover, we employed statistical tests to assess whether gender relates to the answers given, thus serving both our purposes. We obtained a sample of 500 responses from students who have been taught the course in probability theory or courses involving substantial probabilistic contents. Finally, we acknowledge that both the research questions entail a vast range of important aspects and implications, which are unlikely to be covered in 30 questions. However, the present study, albeit not fully covering these topics, provides the foundation for a promising strand of research.

Theoretical Background

Probability theory provides a systematic approach to studying randomness and uncertainty (Ramachandran & Tsokos, 2021). Central notions in probability theory include random variables, distribution functions, stochastic processes, and events, which are the mathematical abstractions of non-deterministic events, either occurring once or evolving over time. These notions commonly exhibit increased complexity, thus posing various challenges on the learner's part and the teacher who is expected to guide them through the learning process.

Many students need help comprehending probability and statistical concepts in various educational contexts (Chiesi & Primi, 2010). Traditionally, education systems address the respective challenges via the mechanisms of probabilistic algebra. Pratt & Ainley (2014) argue that for secondary school students, probabilistic algebra is most often learned as a set of rules to be followed in order to get the correct answer, which leaves the notions themselves distant and meaningless. In this context, Biehler (1991) defines the "concept-tool" gap as the lack of integration between the meanings of uncertainty students hold and the performance demands made in curricula and examinations.

The notions of Probability theory offer a powerful foundation for many mathematical techniques, from statistical methods in science and social policy to technological risk analysis and economic decision theory (Fox, 2003). Thus, subjects in Probability theory have gained their place in modern curricula. Furthermore, Probability theory provides valuable tools for almost all sciences, and this is why the relevant introductory notions are included in secondary education as well.

Gender Diversity

The idea that males outnumber females in fields within science, technology, engineering, and mathematics (STEM) has become the conventional wisdom over the past few decades, both in education and in the occupational realm (Stewart-Williams & Halsey, 2021). The study by Stewart-Williams & Halsey (2021) emphasizes that the underlying claim that males outnumber females in quantitative subjects is commonly associated with the notion that males are more object-oriented (i.e., interested in things) and females are more socially oriented (i.e., interested in people). The same study attributes the STEM gender gap to workplace discrimination, gender preferences, within-gender variability, socialization, culture, and biology.

Similar traditional views have been supported in several studies focusing on the performance on standardized tests of mathematical reasoning, such as SAT-M and GRE. For example, Halpern et al. (2007) and Tsui et al. (2011) report that females score lower than males on the mathematics section of the standardized tests for admission to colleges and graduate schools. Furthermore, Gallagher and Kaufman (2005) report that males score higher than females on these tests. However, males and females attend equally demanding classes in high school-level mathematics, and females earn higher grades. In line with this research, several studies (e.g., OECD, 2018; Mostafa, 2019) highlight that the gap between male and female participants in STEM courses is still relevant. Hango (2013) attributes the STEM gaps to gender differences in mathematical ability and differences in values and preferences, such as labor market expectations, including family and work balance, differences in motivation and interest, and other influences. Moreover, Fryer and Levitt (2010) assess various factors potentially causing the gender gap. These factors involve time invested in preparation for mathematics courses, lower parental expectations for females, and biased tests, with the results, however, providing little support for the aforementioned hypotheses. Contrary to the previous beliefs, a significant body of literature suggests that very few cognitive measures support the notion of gender differences. For instance, the paper by Spelke (2005) reviews experimental studies finding no difference in the primary abilities for mathematics and, thus, concludes that mathematical and scientific reasoning relate to biological cognitive capacities, which are equally shared between males and females. This latter school of thought has existed since as early as the 1970s, with the seminal work of Maccoby & Jacklin (1974, p. 349) arguing that the notion of objected-oriented males as opposed to socially-oriented females is one of the "unfounded beliefs about sex differences." We note again the distinction between sex and gender, which, however, during the 1970s, was more of an academic discussion than a self-identifying matter.

In this context, the report by the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2019) advocates that gender bias is still prevalent and, in some settings, relevant to the entire education system. This bias is met in various forms, including the absence of women as leaders in textbooks, differential expectations of males and females by teachers, school policies that put pregnant girls at the door rather than respecting, protecting, and fulfilling their educational aspirations, etc. Furthermore, the same report claims that progress toward gender equality requires complementary and collective actions that promote female rights and empowerment, given the institutional, societal, political, and legal barriers that have historically restricted their participation in complete education, including their equal participation in higher education within STEM fields. The economic aspects of increasing female participation in STEM education are discussed in the report by the European Institute for Gender Equality report (EIGE, 2017), which forecasts the employment and economic benefits of closing the gender gap in STEM for the European Union (EU), and finds a considerable rise in employment, estimated between 850000 and 1200000 jobs and an increase between 2.2 and 3.0% in the GDP per capita, by 2050. This evidence substantiates the targets of gender equality with regard to STEM participation, which has become essential to the EU.

The use of New Technologies in Education

We increasingly observe the great influence that new technologies exert in the field of education. Online education platforms have been gaining momentum during the past two decades and, by now, have become an integral part of modern education systems. The Greek schools seem to be grasping this impetus and have intensified their efforts to engage electronic means in teaching conduct. Images, videos, and apps are arguably more appealing than conventional tools such as books and blackboards, especially for younger cohorts, and thus, such tools become highly useful during the lessons. Thus, technology-aided teaching seems to provide a very promising avenue for class conduct, capable of leading to more elaborate and comprehensive courses. Furthermore, substituting conventional with computer-based tools, which allow for course experiments, differentiates the perception of the students for the course and may be argued to lead to a more enjoyable and creative educational experience.

One important aspect of the education shift toward technology relates to bridging the concept-tool gap, discussed concerning probability courses in Batanero et al. (2005) and statistics in Biehler & Hoffman (2011). Such approaches design integrated learning programs utilizing digital simulations to overcome the stochastic misconceptions on the part of the students and create a more efficient learning environment.

The students' perceptions regarding technology-aided teaching provide another strand for empirical research. The study by Davidovitch and Yavich (2018) investigates the perceptions of Israeli students in Grades 9 and 10 on the use of tablets for education purposes. The specific study differentiates between STEM and non-STEM subjects and considers both the cognitive and the affective dimensions. The study finds no difference between STEM and non-STEM subjects both in the cognitive and the affective dimensions. Furthermore, the study finds no correlation between the age of the students and their tendency to weigh more, either the cognitive or the affective dimension. On the other hand, the study finds significant gender differences in the weighting of the cognitive and affective dimensions regarding the use of tablets for education. More precisely, this study finds that males attribute more weight to the cognitive dimension, which is consistent with the traditional school of thought, and to the affective dimension, which contrasts with the traditional views. Overall, these results suggest that males exhibit better affinity than females toward technology means.

Moreover, Mezhennaya & Pugachev (2018) assess the effects of using interactive computer-based methods with regard to the subject Probability theory and mathematical statistics offered to third-year engineering students at the Bauman Moscow State Technical University. The results of this study demonstrate that students achieve higher education outcomes when computer-based tasks are incorporated into the conventional lectures and seminars of the course regarding the first (i.e., Probability Theory) of the three teaching modules of the course. These findings reveal the positive effects of interactive computer-based education methods on the learning outcomes in probability theory.

The role of computer-assisted teaching was examined by Gürbüz & Birgin (2012) with regard to detecting and remedying probability misconceptions, such as the representativeness heuristic, the positive and negative recency, and the equiprobability bias. The specific study showcases that both the instructional approaches under consideration (i.e., traditional instruction and computer-assisted teaching) improve the students' understanding of probability contents and reduce their misconceptions. However, when the improvements in the groups are compared, the authors find that the intervention in the computer-assisted group was more effective in remedying the misconceptions. These findings demonstrate the effectiveness of computer-based technology against conventional teaching regarding elaborate notions in probability theory.

The purpose of the present study is to investigate (i) whether electronic means contribute to a better understanding of probability theory and its applications and (ii) whether gender plays a role in the learner's ability to understand and assimilate the relevant notions. This study contributes to the mathematics education literature regarding the Greek educational system, wherein relevant studies are scarce.

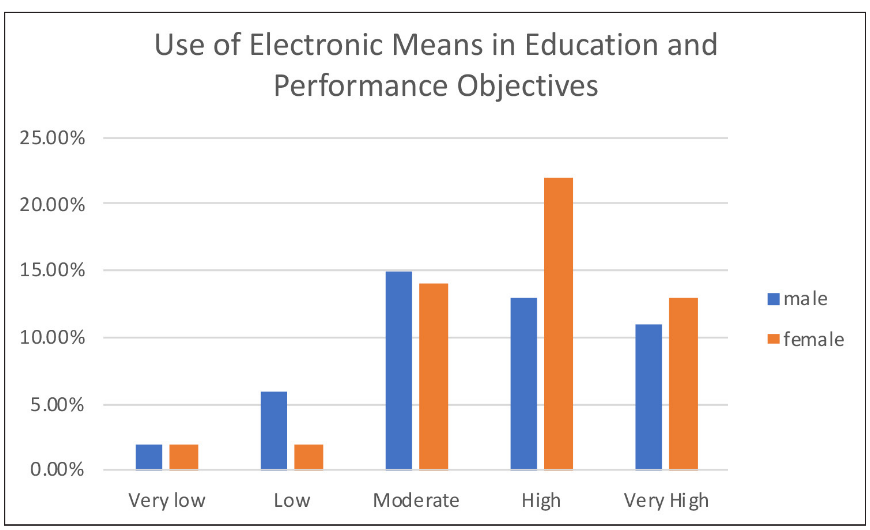
Statistical Analysis

In order to assess the effects of the application of new technologies in the teaching of probability theory and the gender-based differences in the comprehension of probability theory, we conducted a survey. The relevant questionnaire was developed by the teaching staff in the Department of Statistics and Insurance Science at the University of Piraeus and was administered to the students of the department through electronic communications. The target group involved students who, by that time, had attended the course Probability Theory I via MS-TEAMS and were currently attending the course Probability Theory II via conventional lectures. Therefore, these students possessed experience in attending relevant content both virtually and conventionally. The questionnaires were distributed between December 2021 and January 2022, and their responses were collected through the university's electronic platform. It comprised a total of 30 questions (i.e., demographic questions, multiple choice questions, questions of self-reported results, and Likert scale questions) assessing the students' perceptions. The questionnaire included choices for male, female, and non-binary respondents. We obtained responses from 500 participants, 47% (235) of whom were males and 53% (265) were females (no one identified as non-binary), all of whom were undergraduate students. Below, we present the statistical analysis of the questionnaire responses. We produce the frequency charts, discuss the results of the questions, and perform statistical tests to examine whether gender affects the students' perception regarding the application of new technologies for teaching purposes and the ability to understand and learn the notions of probabilities. Retaining the respondents' gender information enables us to test the various aspects of technology and education, taking into account the gender factor.

The first question considers the application of electronic means for educational purposes (e.g., electronic platforms, electronic educational material, e-books, e-exams, digital games, etc.) and their effectiveness regarding the learning objectives of the courses (i.e., the ability to comprehend and apply the basics of probability theory, set theory and combinatorics, and successfully address relevant real-life problems and applications), as perceived by the students. This is a 5-point Likert scale question, with the answers indicating the degree to which the respondent thinks that electronic means support the course performance objectives. Potential answers indicate the degree, which can be very low, low, moderate, high, or very high. We emphasize that this is a perception question that investigates the students' views on the effectiveness of the relevant means and directly relates to the first of our research questions. The respective answers are summarized in Figure 1.

Figure 1

Percentage by gender regarding the use of electronic means in education and performance objectives



Initial inspection of the specific results reveals a balanced picture regarding the use of electronic means for education purposes. Excluding the high degree where the females clearly surpass the males and the low degree where the males surpass the females, the rest of the answers indicate that there is no difference between males and females in their perception regarding the use of electronic means for

Table 1

Test results for the use of electronic means in education and performance objectives

	Test statistic	P-value	df
Pearson χ^2	4.170	0.383	0.383
Number of observations	500		

education purposes. Furthermore, a substantial part of the participants, both males (i.e., 24%) and females (i.e., 35%), seem to agree that the application of electronic means facilitates the learning objectives of the Probability courses.

In order to assess the students' views regarding the effectiveness of electronic means in education, we conducted a χ^2 test. This test groups the students into two groups (i.e., one including those answering "very low" and "low" who do not believe that the application of electronic means supports the course learning objectives, and one including those answering "moderate", "high", and "very high" who support the other view), and can be formally stated as follows:

> Ho: "Gender is independent of the opinion that attending a course using electronic means is more efficient in terms of the learning objectives of the course."
>
> H1: "Gender is not independent of the opinion that attending a course using electronic means is more efficient in terms of the learning objectives of the course."

At the 5% level of significance, we cannot reject the null hypothesis (χ^2 statistic = 4.170; df = 4; p-value = 0.383), and thus, we can conclude that gender is independent of the opinion that attending a course using electronic means is more efficient in terms of the course learning objectives.

The second question investigates whether the students believe that the new technologies adopted within the scope of the course enhanced their interest in probability notions. Here, we use the term new technologies as a term broader than electronic means, which includes software tools potentially requiring programming skills. Such tools have not always been particularly user-friendly and thus may have caused a level of anxiety in students. Nevertheless, the use of relevant tools has become the norm, especially regarding statistics education and practice, and therefore, their application is of particular interest. This is a 5-point Likert scale question assuming a similar structure to the previous one. We note that the specific question focuses on the interest aspect of technology, which is a vital element of the learning process. The corresponding results are summarized in Figure 2.

The students' answers show that using new technologies within the scope of the Probability course increased their interest in the relevant notions to a moderate to very high degree in a percentage that exceeds 80%. No major difference is observed between males and females, excluding the moderate degree to which females clearly surpass males.

In order to investigate the relationship between gender and the interest in the Probability contents caused by the use of the new technologies, we perform a χ^2 test, which groups the answers into two groups (i.e., one including the answers "very low" and "low" which involves the students who do not think that their interest was enhanced by the use of the relevant tools, and one including "moderate", "high" and "very high" which involves the students assuming a contrasting view), and can be formally stated as follows:

> Ho: "Gender is independent of the view that interest in the course is enhanced by the use of new technologies such as specialized software."
>
> H1: "Gender is not independent of the view that interest in the course is enhanced by the use of new technologies such as specialized software."

Figure 2

Percentage by gender regarding the use of new technologies and interest in probability

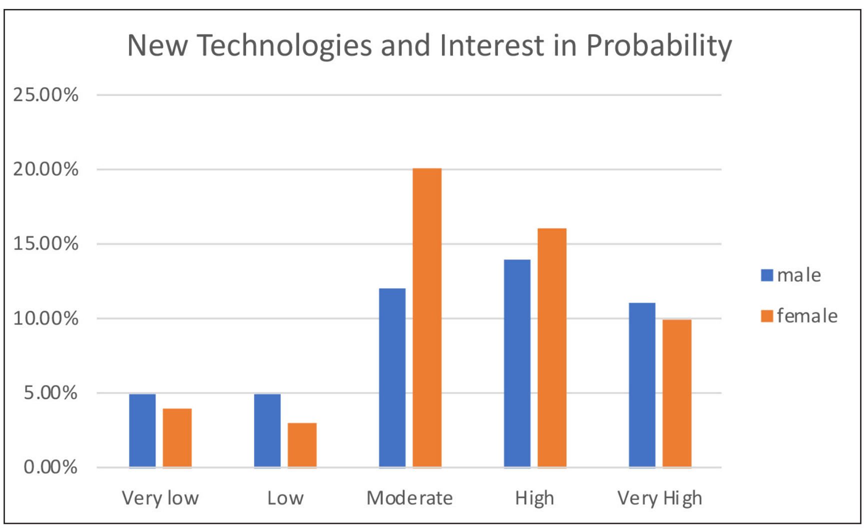


Table 2

Test results for the use of new technologies and interest in Probability

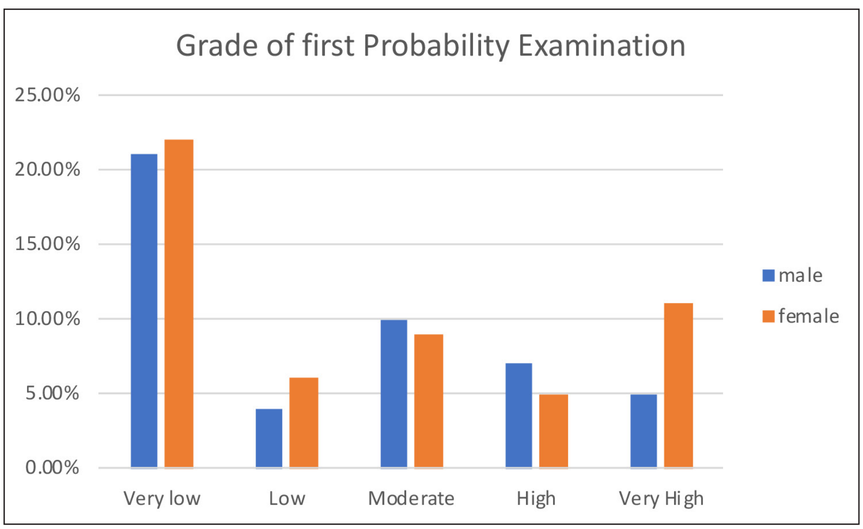
	Test statistic	P-value	df
Pearson χ^2	2.441	0.655	4
Number of observations	500		

At the 5% level of significance, we cannot reject the null hypothesis (χ^2 statistic = 2.441; df = 4; p-value = 0.655), and thus, we conclude that gender is independent of the view that using new technologies, such as specialized software increased their interest in the probability notions.

The next question focuses on the performance of the students in Probability, as indicated by their grades on the first examination. This is a self-reported results question utilizing the 10-grade scale adopted in Greek universities (i.e., grades 0-4 indicate insufficient performance, 5 indicates poor but sufficient performance, 6 indicates moderate performance, 7 indicates high performance, and 8-10 correspond to very high performance). This question is directly related to the learning outcomes of the course and is thus of utmost interest in the context of this study. The responses are summarized in Figure 3.

Figure 3

Percentage by gender regarding the grade in the first exam in Probability



The previous chart reveals that male students performed insufficiently and poorly but sufficiently in their first exam in Probabilities, about 25%, whereas female students performed about 28%. In other words, a total of 58% of the students performed poorly, receiving low and very low grades. Furthermore, there seems to be a slight differentiation regarding the very good performance, with 5% of males and 11% of females.

Subsequently, we seek to assess whether gender relates to performance in the first exam in Probability. To this end, we employ the χ^2 test formally stated:

Ho: "Gender is independent of the grade in the first exam in the Probability course."

H1: "Gender is not independent of the grade in the first exam in the Probability course."

At the 5% level of significance, we cannot reject the null hypothesis (χ^2 statistic = 2.709; df = 4; p-value = 0.608), and therefore, we conclude that gender is independent of the grade in the first exam in the Probability course.

The following question seeks to determine whether the survey participants possessed sufficient mathematics background prior to the commencement of their university studies. Sufficiency of their background is expected to have been reflected in their mathematics grades in the Greek State Exams. This is a question of self-reported results, using the grading scale of 20, which applies to Greek secondary education (i.e., grades under 10 indicate insufficient performance, 10-12.5 indicate poor but sufficient performance, 12.5-15 indicate moderate performance, 15-17.5 indicate good performance and 17.5-20 indicate very good performance). It is involved in the questionnaire to provide some insight into whether the results in the Probability exams relate to prior knowledge or to the class conduct of the course itself.

Table 3

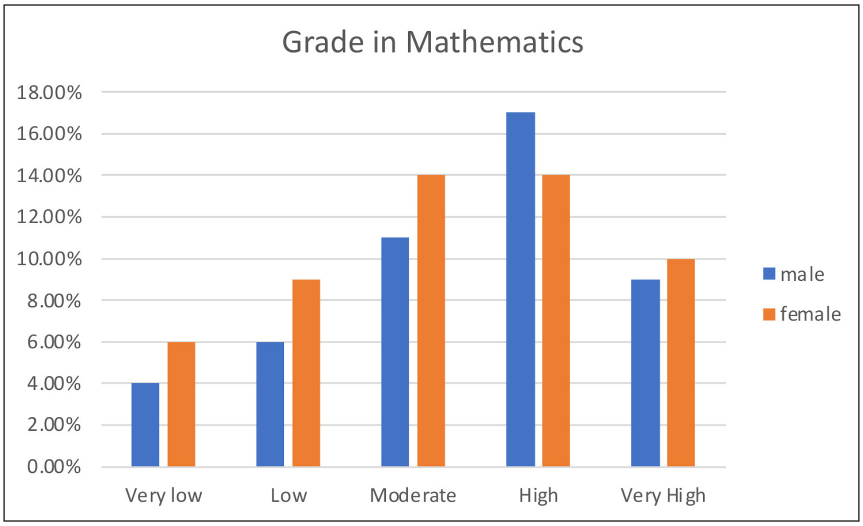
Test results for the grade in the first exam in Probability

	Test statistic	P-value	df
Pearson χ^2	2.709	0.608	4
Number of observations	500		

The chart in Figure 4 reveals that the vast majority of the students had moderate to very high grades in high school level mathematics, that is, grades ranging between 12.5 and 15, which are considered moderate, grades between 15 and 17.5, which are considered high,

Figure 4

Percentage by gender regarding the school mathematics grade



department. Neither gender seems to stand out in the school mathematics performance.

Subsequently, we perform a χ^2 test to investigate whether the mathematics grade achieved at school is affected by the gender of the student. This test is formally stated as:

Ho: "Gender is independent of grade."

H1: "Gender is not independent of grade."

At the 5% level of significance, we cannot reject the null hypothesis (χ^2 statistic = 1.348; df = 4; p-value = 0.853), and we thus provide evidence that gender is independent of the school-level mathematics grade.

Table 4

Test results for the school mathematics grade

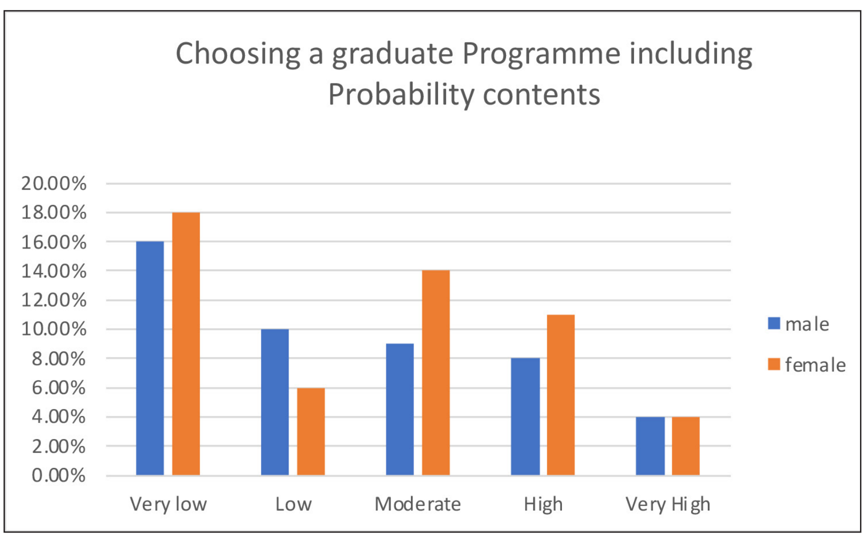
	Test statistic	P-value	df
Pearson χ^2	1.348	0.853	4
Number of observations	500		

and grades above 17.5, which are considered very high. Overall, these results suggest that the students have probably been sufficiently well-equipped with regard to mathematical contents prior to the commencement of their studies. This is to be expected, at least to some extent, given the quantitative nature of the specific

The final question we discuss is concerned with the intention of the students to pursue graduate-level studies that involve subjects entailing substantial probability content. This is again a 5-point Likert scale question with the answers indicating how likely the individual is to consider pursuing a relevant graduate program. The specific question seeks to identify whether the probability theory courses have enhanced the students' interest in the field and whether the relevant notions have been mastered enough for the individual to pursue advanced studies. The respective answers are summarized in Figure 5.

Figure 5

Percentage by gender regarding the choice of a graduate Program, including probability contents



This chart highlights that, in general, the students do not want to pursue graduate studies that include subjects with probability content. At first glance, male and female students are relatively close in their tendency to avoid such subjects at the graduate level.

In order to formally examine whether gender affects the choice of a graduate program that is relevant to Probabilities, we perform the following χ^2 test:

Ho: "Gender is independent of the choice of a graduate program, including Probability contents."

Table 5

Test results for the choice of a graduate programme which includes Probability contents

	Test statistic	P-value	df
Pearson χ^2	2.327	0.676	4
Number of observations	500		

H1: "Gender is not independent of the choice of a graduate program including Probability contents."

At the 5% level of significance, we cannot reject the specific null hypothesis (χ^2 statistic = 2.327; df = 4; p-value = 0.676), and thus, we provide statistical evidence that gender is independent of the choice of a graduate program, which includes substantial Probability contents.

Concluding Remarks

The purpose of this work is to assess whether the use of electronic means in education contributes to a deeper understanding of probability theory as well as whether gender affects the ability to learn the relevant content. Even though similar studies are not scarce in various contexts, we add to the corresponding body of literature with a survey addressed to the Greek academic community, bearing in mind the gender stereotypes still pertaining to Greek society and the dynamics of the rapid technological evolution, which tend to accelerate social change. To this end, we developed a questionnaire consisting of 30 questions, which was addressed to a sample of 500 students and provided the information necessary for the respective analysis.

Our results show that (i) students, regardless of their gender, believe that electronic means enhance the learning outcomes of the course, (ii) students exhibit a level of technology-driven interest for the Probability contents that is overwhelmingly moderate or above, and this is independent of their gender, (iii) students, irrespective of their gender, perform relatively poorly the first time they sit for the Probability exam, (iv) students possess a satisfactory level of prior knowledge regarding the Probability course, regardless of their gender, and (v) students, irrespective of their gender, are not very likely to include relevant courses in their graduate level studies. Overall, these findings are consistent with studies supporting the notion that affinity for quantitative studies is equally shared between males and females (e.g., Spelke, 2005).

The evidence provided in this study implies that efforts to intensify the utilization of electronic means for educational purposes are of vital interest to the educational community and should be strengthened. On the other hand, gender-based diversification of the teaching conduct, as well as the subsequent electronic means, do not seem to be of particular relevance here. However, further research is essential before it can be argued that such diversification efforts do not provide a substantial prospect. Finally, we note that the nature of quantitative courses such as Probability, which is intellectually demanding and may deviate from common experience, probably necessitates an appropriate combination between conventional lecturing and employing electronic means, which allow for effectively addressing problems of increased complexity. The boundaries between these two elements are subject to the course contents as well as the learners' background and potential. It is up to the teacher to assess and appropriately determine the exact setting for each course.

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Appendix

1=very little, 2=a little, 3=moderate, 4=a lot, 5=very much

1. Do you think that the application of electronic means in education has been more efficient in terms of the learning objectives of the course?

1	2	3	4	5
☐	☐	☐	☐	☐

2. Do you think the use of new technology increased your interest in the course?

1	2	3	4	5
☐	☐	☐	☐	☐

3. What was your grade in Mathematics in the Greek State Exams?

Under 10	10—12.5	12.5—15	15—17.5	17.5—20
☐	☐	☐	☐	☐

4. What grade did you get on your first exam in Probability theory?

Under 5	5	6	7	8—10
☐	☐	☐	☐	☐

5. How likely do you think you would choose a graduate program that includes substantial content in probability?

Under 5	5	6	7	8—10
☐	☐	☐	☐	☐