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Effectiveness of Technology-Integrated Instruction in Improving Mathematics Achievement

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Abstract

Mathematics is one of the fundamental subjects that form the basis of problem solving, scientific thinking and technological innovation, however, traditional teaching practices are not always conducive to students to engage and achieve. This study aimed to compare the effectiveness of ICT based instructional methods with traditional teaching methods on the mathematics achievement of students at the secondary level and to check if there existed any difference in gender in both instructional settings. A quantitative method of research was used in the form of quasi-experimental pre-test post-test non-equivalent control group design. 346 students from grade Nine were selected as sample from three secondary schools in Bhaktapur District and from them: the experimental group of the experimental class was taught with the ICT tools i.e. GeoGebra and the control group of the control class was taught by using the conventional teaching method. Data were collected using a validated 40 item objective achievement test based on Bloom's Taxonomy and the reliability of the test was checked using the split half method (r = 0.78). Statistical analyses, including descriptive statistics and independent samples t-tests were used to find group differences at 0.05 level of significance. Results showed no significant difference in the pre-test scores between the two groups while results of the post-test scores showed that the experimental group had a significant increase in scores compared with the control group. However, significant gender differences were also found in the post-test in both instructional conditions, and male students had better results than female students. The conclusion of the study is that the ICT integrated instruction is more effective than traditional method in improving mathematics achievement while there are persistent gender disparities which demonstrate a need for a targeted strategy to better support the female learners in technology-enhanced mathematics classrooms.

Keywords: Mathematics achievement, quasi-experimental design, experimental group, controlled group, geogebra

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Introduction

Mathematics occupies its central position in the curriculum because of the fact that this is directly related to the enhancement of logical reasoning, analytical capacity, and problem-solving ability which is very important not only for the achievement in studies but also in the functioning of a person in everyday life (Cunska & Savicka, 2012). The subject forms the foundation of scientific discoveries and technological innovations that are needed for national progress and competitiveness in the knowledge economy of the world. Countries which aspire to progress in certain areas, such as engineering, applied sciences and information technology, will need to invest in strengthening mathematical competencies from the primary level up to the higher education level (Kovács & Intsche, 2025). The importance of mathematics goes beyond the borders of mathematics, mathematical concept are behind other field of study like economics, population studies, engineering and technology. From making daily financial computations in homes, to the design of significant scientific experiments and data interpretations in innovation and research work, mathematical knowledge is still indispensable (Rimba &Tarmo, 2025).

In twenty-first century, there is a growing pressure imposed on education systems worldwide to develop innovative, creative and competent human resources that can meet the demands of the market economy and contribute to sustainable development (Rodríguez-Jimenez et al., 2023). However, mathematics education has been facing major challenges since the beginning when it comes to increase student engagement, conceptual understanding and the overall achievement. Traditional approaches to teaching (especially teacher-centered lecture approach) tend to limit the active involvement of students and promote passive learning. Research shows that students who receive only the traditional teaching methods often show a lack of motivation and relatively poor achievement in mathematics (Pokhrel & Poudel, 2024). These concerns have led researchers and educators to discover alternative pedagogical strategies to make mathematics more meaningful, interactive and accessible.

Within this context Information and Communication Technology (ICT) has become a promising instructional tool in the educational aspect of mathematics. ICT is a broad term for various digital technologies and resources that are used to gather, process, store, communicate and disseminate information (Ayeh et al., 2024). ICT integration in mathematics is specifically the integration of digital platforms, software, computer devices and multimedia applications to assist learning activities in mathematics such as instruction, visualisation of concepts, collaborative learning and independent exploration (Bhattarai, 2024; Kovacs & Wintsche, 2025). The integrated use of ICT in educational settings is increasingly being perceived a necessity as it promotes learner-centered pedagogy, it is more engaging by the learners and it helps to develop a deeper conceptual understanding. ICT-based learning environments have been proven to promote critical thinking, problem-solving, communication and digital literacy - all of which match demands of contemporary societies (De Witte and Rogge, 2014). As access to technology is becoming more prevalent, the integration of ICT into mathematics education is no longer experienced as an educational luxury, but rather as a necessary part of modern-day teaching and learning (Ikonomoska, 2024).

In recent years the availability and use of ICT tools has grown considerably. Teachers, school administrators and policymakers have begun to understand the role of digital tools in transforming the learning experience, teaching mathematical concepts using visual models and targeting different learning styles (Salami & Spangenberg, 2024). In Nepal, the use of ICT has been gradually spreading in various parts, backed by the government and non-governmental activities on the improvement of digital infrastructure and teacher training and ICT literacy of school. Although there are still some rural or remote areas where the access to ICTs is restricted, the dominating movement is that of increasing acceptance and use of ICT in the classroom settings. Teacher training programs, workshops and professional development opportunities have introduced educators to ICT-based instruction strategies which encourage them to move away from traditional text-based pedagogy to more interactive and exploratory approaches. Such efforts are indicative of a larger awareness of the need to transform mathematics from a perceived stiff and abstract subject to a dynamic and engaging subject of study enabled by digital technologies.

Despite this progress, there are still some challenges. Although previous studies that have been carried out in multiple contexts have shown that ICT improves student engagement, motivation, attitudes and mathematical achievement (Adu, 2025; Kamau & Njue, 2023; Mulenga & Marbana, 2020), the positive effects of ICT are not automatic. Effective integration also requires that the teacher should not have just a technical competence but also have appropriate pedagogical knowledge for the design of meaningful ICT-based mathematical activities. Teachers need to be knowledgeable about the functionalities and usage of ICT tools for visualization of abstract concepts, interactive simulation, scaffolding problem solving and differentiated instruction for different needs of learners (Muhammad Amjad Javaid & Dr. Muhammad Hameed Nawaz, 2022). Without the required skills training and pedagogical awareness ICT may be under-utilized, poorly deployed or relegated to surface level tasks which do not contribute to learning outcomes in any significant way. In addition, ICT perceptions of teachers influence teacher disposition towards ICT and its uptake and integration which may lead to teachers going back to the traditional approach even though ICT resources are available (Irakarama et al., 2024), in case the perceptions about ICT are negative or uncertain.

The other dimension is the student use. Although students are often involved in ICT for entertainment and communication and social networking purposes, they may not readily use ICT for academic purposes if they do not have structured instructional support (Bray & Tangney, 2017). This gap indicates the need to guide students to use ICT for mathematics learning in a purposeful manner for problem-solving, visualization and independent exploration.

In case of Nepal, the Government and other educational stakeholders have made an investment in digital infrastructure, expansion of internet and ICT related instructional initiatives. However, the achievement in mathematics is still quite low. National Examination Board (NEB) results continuously show that students do not perform in mathematics well as compared to other subjects and many of them get lower grades in Grade 10 and Grade 12 exams. This also raises some important questions regarding efficacy related to instructional practices that currently are in use in mathematics classrooms. Despite the exposure to ICT, the question still arises on whether the exposure of these tools has translated to improvements in the mathematical performance of students. Important questions then arise: Why do students continue to perform poorly in mathematics? Has the shift to ICT aided instruction been made any meaningful difference to achievement? Are teachers competent in the use of ICT in enhancing the mastery of concepts? Are there gender based differences in outcomes with the use of ICT based methods? These unanswered issues constitute the research problem.

Accordingly, the present study assesses the efficiency of ICT based instructional methods compared to the traditional teaching methods in enhancing mathematics achievement of the secondary level students. The study has also focused on the gender differences in mathematics achievement under both instructional conditions which can contribute to the development of evidence base to work on policy, curriculum design, teacher trainings and classroom practices in the context of Nepal.

Objectives of the Study

The objectives of this study were mentioned below:

To compare the effectiveness of traditional teaching methods and ICT based teaching methods in mathematics achievement of students at secondary level.

To determine gender difference in mathematical achievement in both groups of students.

Hypothesis of the Study

The null and alternative hypothesis of this study were mentioned below:

H_{01}: There is no significant difference between two groups of students in mathematics achievement teaching through traditional teaching methods and ICT-based teaching methods.

H_{10}: The mathematics achievement of students teaching through ICT-based teaching methods is better than the achievement of students teaching through traditional teaching methods.

H_{02}: There is no gender difference in mathematics achievement in both groups of students.

H_{20}: The mathematical achievement of female students is better than of the male students in both groups of students.

Methodology

In this research, only the quantitative techniques were used. The study was based on a quasi-experimental research design with pre-test, post-test, and non-equivalent control group design. The population of this study were all the secondary level students in Bhaktapur district. From the three municipalities of the district, one school was purposely chosen as a sample from the district. The sample was comprised of 346 students of Grade 9, of which 178 are boys and 168 are girls. In each school, two sections were selected, one was assigned as an experimental group and another as a control group. In the experimental and control groups, there were 183 students (97 boys and 86 girls) and 163 students (79 boys and 84 girls), respectively. An achievement test of 40 questions, of objective type from the chapter of Mensuration of Class 9 was prepared. In the framework of the questionnaire, questions were included from all the levels of cognitive domain of Bloom's Taxonomy (25% knowledge level, 50% understanding and problem-solving level and 25% higher ability level). The validity of the questionnaire was checked by two teachers of mathematics: one of them is a teacher at the secondary level and the other is a teacher at the university level.

In order to determine the reliability of the test items, a pilot test was administered in a school different from the sample schools in 40 students. The reliability was determined by means of the split-half (odd-even) method. The marks secured by odd questions was denoted as X and marks from even questions were denoted as Y. The correlation coefficient (r) was determined by the use of Karl Pearson's formula:

$$r = \frac{N\sum XY - \sum X \sum Y}{\sqrt{N\sum X^2 - (\sum X)^2}\sqrt{N\sum Y^2 - (\sum Y)^2}}$$

The correlation coefficients of test score was found 0.78. After calculating correlation coefficient, the probable error was calculated using the following formula for testing the significant of the test items.

$P.E\,(r) = \frac{(0.6745)(1-r^2)}{\sqrt{N}}$ and we got $P.E.(r) = 0.059$ and $6 \times P.E\,(r) = 6 \times 0.059 = 0.35$ which was less than correlation coefficient r (r = 0.78). Thus, the test items were significant and selected for this research.

After the validation of the tool, a pre-test was applied to both groups to determine how much the students already knew. Subsequently, the two groups were taught with different methods and differed in duration for three weeks. The experimental group was taught through GeoGebra software in the classroom and students were guided about using various ICT tools and AI resources for homework and self-study. On the other hand, the controlled group was taught in the traditional way, using only textbooks for class work and homework. Measures were taken to avoid the sharing of learning materials and methods between experimental and control group during the three week period. At the end of the intervention, a post-test was done for both groups. The data collected during pre-test and post-test were analyzed using Statistical package for Social Science (SPSS). Descriptive statistics (mean and standard deviation) was used to analyze the scores and inferential statistics (independent samples t-test) was used to test the significance of the difference between the two groups at 0.05 level of significance.

Results

For testing the effectiveness of ICT in mathematics achievement, the following tests were applied in this study.

Table 1: *Pre-test score of both groups of students*

Groups	N	Mean	SD	t-value (calculated)	t-value (table)
Experimental	183	31.74	4.17	1.56	1.96
Controlled	163	31.06	3.96		

Table (1) presents the pre-test scores of both the experimental and control groups of students before the intervention of ICT-based instructional methods in mathematics. This table shows that the experimental group obtained mean score of 31.74 with standard deviation SD of 4.17, while the control group obtained mean score of 31.06 with SD of 3.96. The calculated t-value was 1.56 which is less than the table t-value of 1.96 at 0.05 level of significance. Since, the calculated t-value is less than the critical t-value. This shows that the difference between the mean scores of the two groups is not significant. This implies that both the experimental and controlled groups were comparable in their mathematical achievement levels before the intervention.

Table 2:*Gender-wise pre-test score of students*

Groups	N	Mean	SD	t-value (calculated)	t-value (table)
Male	178	31.24	5.12	1.724	1.96
Female	168	30.79	4.37		

Table (2) shows that the mean and standard deviation of male students were 31.24 and 5.12 respectively, and the mean and standard deviation of female students were 30.79 and 4.37 respectively. The average marks of male students in pre-test examination was more than the average of female students by 0.45. Also, the calculated value of t was 1.724 and its corresponding table value was 1.96 at 0.05 level of significance. The calculated value of t is less than the corresponding table value. So, there is no significant difference in mathematics achievement between male and female students.

Table 3: *Gender-wise pre-test score of experimental group students*

Groups	N	Mean	SD	t-value (calculated)	t-value (table)
Male	97	33.72	5.76	3.39	1.96
Female	86	31.17	4.38		

Table (3) shows that the mean and standard deviation of male students were 33.72 and 5.76 respectively, and mean and standard deviation of female students were 31.17 and 4.38 respectively. The average marks of male students was greater than the average marks of female students by 2.55. Also, t-value of this experiment was 3.39 and the corresponding t-value from table was 1.96. The calculated t-value was greater than the corresponding table value. So, there was significant difference in mathematics achievement between male and female students in pre-test examination in Experimental group.

Table 4: *Gender-wise pre-test score of controlled group students*

Groups	N	Mean	SD	t-value (calculated)	t-value (table)
Male	79	32.19	4.67	0.876	1.96
Female	84	31.58	4.19		

Table (4) shows that the mean and standard deviation of male students were 32.19 and 4.67 respectively, and the mean and standard deviation of female students were 31.58 and 4.19 respectively. The average marks of male students was greater than the average marks of female students by 0.61. Also, the calculated value of t was 0.876 and its corresponding table value was 1.96. Here, the calculated value of t was less than the corresponding table value and this shows that there was no significant difference between male and female students of controlled group in mathematics achievements.

Table 5: *Post-test score of both groups of students*

Groups	N	Mean	SD	t-value (calculated)	t-value (table)
Experimental	183	32.74	4.89	4.04	1.96
Controlled	163	30.56	4.76		

Table (5) shows that the mean and standard deviation of experimental group were 32.74 and 4.89 respectively, and the mean and standard deviation of controlled group were 30.56 and 4.76 respectively. The average marks of controlled group was less than the average marks of experimental group in post-test by 2.18. Also, the calculated t-value of this experiments was 4.04 and the value of t from table was 1.96 at $\alpha = 0.05$ level of significance. Here, calculated value of t was more than the corresponding table value. Thus, there was significant difference in mathematics achievements between controlled group and experimental group of students in post-test. The analysis strongly supports the conclusion that the experimental group performed significantly better on the post- test than the controlled group.

Table 6: *Gender-wise post-test score of students*

Groups	N	Mean	SD	t-value (calculated)	t-value (table)
Male	178	31.24	4.97	5.506	1.96
Female	168	29.77	4.64		

Table (6) shows that the mean and standard deviation of male students were 31.24 and 4.97 respectively, and the mean and standard deviation of female students were 29.77 and 4.64 respectively. The average marks of male students in post-test examination was more than the average of female students by 1.47. Also, the calculated value of t was 5.506 and its corresponding table value was 1.96 at 0.05 level of significance. The calculated value of t is more than the corresponding table value. So, there is significant difference in mathematics achievement between male and female students.

Table 7: *Gender-wise post-test score of experimental group students*

Groups	N	Mean	SD	t-value (calculated)	t-value (table)
Male	97	34.68	4.65	4.605	1.96
Female	86	32.29	5.05		

Table (7) shows that the mean and standard deviation of male students were 34.68 and 4.65 respectively, and mean and standard deviation of female students were 32.29 and 5.05 respectively. The average marks of male students was greater than the average marks of female students by 2.39. Also, t-value of this experiment was 4.605 and the corresponding t-value from table was 1.96. The calculated t-value is greater than the corresponding table value. So, there was gender difference in mathematics achievement between male and female students in post-test examination in Experimental group.

Table 8: *Gender-wise post-test score of controlled group students*

Groups	N	Mean	SD	t-value (calculated)	t-value (table)
Male	79	32.13	4.07	2.248	1.96
Female	84	31.08	4.65		

Table (8) shows that the mean and standard deviation of male students were 32.13 and 4.07 respectively, and the mean and standard deviation of female students were 31.08 and 4.65 respectively. The average marks of male students was greater than the average marks of female students by 1.05. Also, the calculated value of t was 2.248 and its corresponding table value was 1.96. Here, the calculated value of t was more than the corresponding table value and this shows that there was gender difference in mathematics achievements between male and female students in controlled group.

Discussion

The main purpose of this study was to compare the effectiveness of ICT-based teaching methods and traditional teaching methods on the achievement of the students in the subject of mathematics at the secondary level in the district of Bhaktapur, as well as to find out the gender differences in the achievement of both groups of students. The findings of the quasi-experimental design offer significant information to learn about the integration of technology to support mathematics learning in the Nepali context.

Effectiveness of ICT-Based Instruction

The results of the pre-test revealed similar result between experimental and control group with respect to their original mathematics achievement. Mean scores of both the groups were very close and the calculated t-value was not more than the critical value of 0.05 level of significance. This baseline equivalence means that any differences between the two groups in post-test performance can reasonably be said to be the result of the intervention rather than pre-existing differences between the two groups.

After the intervention, the results in the post-test showed that the results of the experimental group that was taught using ICT-based teaching methods (GeoGebra and some other digital tools) had a significantly better result when compared to the results of the control group that was taught using traditional teaching methods. The mean score of experimental group was found to be higher in comparison to control group and the difference was found to be statistically significant at t-test level. This implies that the students who were exposed to ICT-integrated teaching method performed better in the topic of mensuration than their counterparts in the conventional class-based teaching method.

These results are consistent with previous research which has provided empirical evidence that integration of ICTs in mathematics teaching improves students understanding, engagement and achievement (e.g. Cunska & Savicka, 2012; De Witte & Rogge, 2014; Irakarama et al., 2024). The use of GeoGebra and other ICT tools probably supported the visual representation of abstract concepts, dynamic exploration and interactive problem solving and made mensuration concepts more concrete and accessible. Furthermore, providing pupils with guidelines pertaining to the use of ICT tools and AI in homework and self-study might have promoted independent learning and extended learning practice beyond the school time.

The findings also agree with the literature that identifies ICT as a catalyst of change from teacher centered pedagogy to learner centered pedagogy (Bhattarai, 2024; Mulenga and Marbana, 2020). In the experimental group of students, active participation in the manipulation of diagrams, exploring geometric relationships and immediate feedback were more heavily involved, all important components of learner-centered environments. By contrast, the control group used mostly textbooks and traditional explanations which can potentially limit exploration and individual pace.

Overall, the results provide empirical evidence for the first alternative hypothesis that ICT based teaching methods lead to a higher achievement in mathematics than traditional methods. They also contribute to the strengthening of policy recommendations to ensure the integration of ICT in the curriculum of mathematics as a way of improving the quality and relevance of education in the digital era.

Gender Differences in Mathematics Achievement

The study also examined gender differences in mathematics achievement at different stages and in both experimental and control groups. In the overall results of the pre -test, there was no statistically significant difference between the male and female students, which indicates that the male and female students had similar levels of prior knowledge in mensuration at the beginning of the study.

However, when the mean scores of the pre-test were analyzed separately among the experimental group, the male students showed a higher mean score than the female students, whereas among the control group, there was no significant difference between genders. This suggests that although overall baseline achievement was similar, there were some initial differences in certain parts which may have affected later outcomes.

In the post-test, there were significant gender differences in the overall performance and in each of the groups, with male students consistently making better gains than female students. The differences were statistically significant in the total sample, the experimental group and the control group. This means that male students either benefited more from the instructional methods used or were able to show greater levels of achievement by the end of the intervention period.

These findings partially contradict the second alternative hypothesis which stated that the result of female students would be better than the result of male students. Instead, the findings seem to indicate that current gender inequalities in achievement in mathematics were either perpetuated or slightly expanded, despite the integration of ICT in teaching. This pattern is audible to studies demonstrating that in some contexts female students may encounter further obstacles such as low self-confidence in mathematics, lack of access to technology or societal stereotypes that discourage them from fully interacting with ICT and STE(A)M subjects (Adu, 2025; Salami & Spangenberg, 2024).

One possible explanation is that male students may have also been more familiar or comfortable with digital tools and software and could therefore have taken better advantage of ICT-based instruction. Another possibility is that the classroom dynamics and cultural expectations may have influenced boys to engage more actively during ICT-based activities, ask more questions or experiment more with the software. Without specific support and encouragement, female students may not see the same benefit of being in environments rich with technology.

Implications for Practice and Policy

The findings have a number of important implications for teachers, school leaders and policymakers. First, the integration of ICT in mathematics teaching can have a major impact on student achievement when teachers are properly trained and supported in applying appropriate pedagogical strategies in mathematics teaching. Professional development programs should thus not only be focused on technical skills, but should also focus on how to design ICT-based learning activities to foster conceptual understanding, problem solving and active engagement.

Second, the persistence of the gender differences is an indication of the need for gender sensitive approaches in ICT integration. Teachers should be encouraged to understand how participation patterns are implemented, to ensure equal access to technology and to create supportive classroom environments where female students feel confident to experiment, to ask questions and to use ICT tools. Additional motivational programs, mentoring and role models in mathematics and technology may also help to alleviate gender gaps.

At a policy level, the findings provide a basis for the prioritization of ICT infrastructure, software and training in schools, especially in mathematics education (Dahal & G.C, 2025). However, investment in technology should come hand in hand with strategies to address equity and inclusion so as to ensure that the integration of ICT will be to the benefit of all learners, and not reinforcing existing disparities.

Limitations and Directions for Future Research

While the study is a good source of evidence, there are limitations. The sample was limited to three different schools of one district, and this may limit the generalizability of the findings for other parts of Nepal or for other educational settings. The period of intervention was relatively short (three weeks) and hence the long-term effects of ICT integration on achievement, motivation and attitudes were not measured. In addition, the study was based on one topic (Mensuration) and one type of assessment (objective test items) which may not reflect all the dimensions of mathematical understanding.

Future research might expand this work by having multiple districts, longer intervention times and more mathematical topics. Mixed-methods designs of classroom observation, interview and attitude scales could provide more in-depth information on the practices of students and teachers, as well as how gender differences play out in practice. Comparative studies of different ICT tools and platforms could also help to determine which technologies and pedagogy work best for different groups of learners.

Conclusion

The purpose of this study was to explore the effectiveness of ICT based instructional methods as compared to the traditional teaching methods in terms of the mathematics achievement of the secondary level students and to find out whether or not there were gender differences in these instructional contexts. The quasi-experimental pre-test post-test non-equivalent control group design, which have been implemented in three secondary schools in Bhaktapur District resulted empirical evidences in terms of the effectiveness of technology enhanced pedagogy in improving learning outcomes in mathematics.

The results showed that there were no differences between the experimental and the control groups before the intervention since the results in the pre-test were not significantly different. This baseline equivalence resulted in enhance in validity of post- tests comparisons. After the intervention of three weeks, the students, were taught using the ICT tools such as GeoGebra showed the post-test scores significantly higher as compared to the students who were taught through traditional way of using textbooks. These results support to conclude that ICT based instruction is more effective in improving mathematics achievement rather conventional pedagogy especially in topic as mensuration where the visualization, dynamic manipulation and interactive feedback are beneficial to student understanding.

Despite the fact that with overall impact of ICT based instruction was positive, gender based analyses showed that there were still persistent disparities. While there was no significant difference between the genders on performance of the students before the intervention, there was significant differences in the post-test in terms of both the experimental and the control groups with the male students doing better than the female students. This would appear to indicate that whilst ICT does improve achievement, it would not necessarily be useful in closing gender gaps, and could even work to reinforce the gender gaps that exist if adequate measures to support them are not in place in some situations. Factors like difference in level of confidence, previous exposure to technology, expectation and participation of the culture may have contributed to these differences.

In accordance to the previous studies conducted, the results of the research proves that the integration of ICT in mathematics teaching could improve and increase the performance, engagement and motivation of the students. However, the results are also an indication of the need for more than just technology to work. Instructional effectiveness has to do with the capacity of teachers to integrate ICT in pedagogy in a meaningful way and make all learners participate in an equitable manner. Thus, professional development efforts should be focused not only on their technical competences, but also their pedagogies of learner-centered, gender-responsive and equity-oriented mathematics teaching.

Given the growing digitalization of education, it is important for the stakeholders, such as the policymakers, school administrators and teacher education institution, to pay attention to the integration of ICT tools in the mathematics curriculum. Investment in digital infrastructure should be accompanied by teacher training, resource development and conducive school environments, in order to maximize the benefits of ICT.

In conclusion, it is evident from study that the ICT based instruction have high potential to improve mathematics achievement at secondary level but the implementation of ICT based instruction should be accompanied by deliberate strategies ensuring inclusiveness and equity. With the right support, ICT can not only contribute to better academic results, but to other educational objectives too, such as digital literacy, critical thinking and creating a competitive knowledge-based society. Future research and educational policy should therefore be aimed towards underpinning ICT integration, reducing gender related achievement gaps and extending the benefits of technology enhanced learning to all learners.

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