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Effectiveness of Excel-Assisted Instruction in Teaching Statistics for Learners' Acquisition of 21st Century Skills

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Abstract: *The integration of computer technologies in mathematics education can equip learners with the essential skills needed to succeed in the information and technology age. This study aimed to investigate the effectiveness of Excel Assisted Instruction (EAI) in teaching statistics for learners' acquisition of 21st century skills (21CS). The research was conducted with Grade 11 learners at Mwense Secondary School in Luapula Province, Zambia. An embedded quasi-experimental design was implemented. Both qualitative and quantitative data were collected. The experimental group received statistics lessons using EAI, while the control group was taught through conventional methods. Prior to the intervention, a diagnostic assessment on 21CS was administered to the two groups, followed by a focus group discussion interview. Qualitative data were analyzed thematically, while MS Excel was used to score and organize the quantitative data. Descriptive statistics, independent sample t-tests, and Mann-Whitney U tests were conducted using SPSS V27.0 for data analysis. The results indicated a statistically significant difference (sig < .001) in the scores of learners taught with EAI (Mean = 82.27%, SD = 3.38) compared to those taught via the conventional method (Mean = 39.23%, SD = 4.12). It found that learners in the experimental group demonstrated better 21CS compared to those in the control group. These findings were further supported by themes that emerged from the interview discussions. The study revealed that EAI is effective in teaching secondary school statistics and promoting the development of 21CS.*

Keywords: *Twenty-first Century Skills, Technology, Statistics, Excel, Excel-Assisted Instruction*

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1. Introduction

The 21st century is known as the era of information and technology (Rosdiana et al., 2020). This century is characterized by rapid technological advancements and easy access to information. Lawyer (2019) argues that to thrive in this information-driven society, individuals must possess critical skills such as critical thinking, problem-solving, communication, collaboration, efficient information retrieval, effective technology use, and statistical literacy. These skills, referred to as 21st century skills (21CS) (Mills, 2002; P21, 2010; Michaels et al., 2017), are very important today. Technology is integrated into nearly every aspect of society, it shapes how people think, learn, work, and live (Mtanga et al., 2012; Mulauzi et al., 2019). The prevalence of smartphones, social media, Google searches, e-learning, robotics, artificial intelligence and other electronic services exemplify this revolution. Learning to use technology is essential for literacy in the 21st century. Proficiency with technology is vital for success, this underpins the development of knowledge-based societies critical for social and economic progress (Masaiti et al., 2021; Policy Brief, 2010; MoTC, 2006). Acquiring 21CS equips individuals to participate effectively in today's economies. Therefore, citizens must possess these skills to drive social and economic growth, as emphasized by Alismail and McGuire (2015) and Barrett et al. (2019). This implies that achieving Zambia's Vision 2030 goal of becoming a prosperous middle-income country depends on the population's technological abilities (7NDP, 2017).

The educational system plays a critical role in developing 21CS (Policy Brief, 2015). Consequently, the curriculum establishes the path for adapting to 21st century society and emphasizes the incorporation of these skills (P21, 2010; UNESCO, 2005). However, the success of teaching and learning relies heavily on the pedagogy employed (Colin, 2017). Research shows that integrating computer technologies with subject knowledge is essential for implementing the 21st century curriculum and pedagogy. This facilitates progress toward SDG4, which aims to provide inclusive, equitable, quality, and lifelong education (Nyemba & Zulu, 2020). The ongoing global revision of education curricula, as seen in the works of Larvin & Larvin (2011), Gravemeijer et al. (2017), and Smit (2016), emphasizes the shift toward enhancing educational systems to meet current and future needs.

To integrate computer technologies into mathematics curriculum, STEM and STEAM curricula, along with Education 4.0, have been implemented. These curricula aim to equip learners with the necessary knowledge and skills for the modern world (Peters et al., 2023; Lawrence et al., 2020). To support mathematics teachers in effectively implementing these curricula frameworks such as TPACK, 2T2C, Bridge21, and 21st century ICT models have been developed. These frameworks guide mathematics teachers on how to integrate technology into their teaching and how learners should engage with technology in the 21st century classroom (Tangney et al., 2022; Bray, 2017; Ahmad et al., 2016; Warner, 2015; Zain & Balakrishnan, 2014; Mishra & Koehler, 2006). Despite the information available on teaching 21CS, our education system fails to impart these skills to secondary school graduates. As a result, they lack essential skills for success in the modern world and workforce (Plecher, 2020; World Bank, 2017; SEACMEQ, 2011; UNESCO, 2005). This educational deficiency has led to high unemployment rates, as learners are not equipped to engage in personal, professional, and business activities (Bvute, 2017; Policy Brief, 2010). This has been attributed to the ineffective teaching methods employed by secondary school teachers, particularly in mathematics. Teachers are still using conventional teaching methods which do not support skill development (Mwape & Musonda, 2014; Changwe & Mwanza, 2019). However, studies have shown that incorporating computer technologies into mathematics instruction can enhance understanding of the subject and develop 21CS.

While research in Zambia, Africa, and elsewhere has investigated the effects of using software such as Excel, R, and SPSS to teach statistics at various educational levels on academic performance and attitudes, none have focused on developing 21CS among secondary school learners. Theoretical literature suggests that to effectively use computer software in teaching secondary school statistics for 21CS, it should be integrated with constructivist methods that support experiential and cooperative learning. Unfortunately, no empirical studies have tested these suggestions in Zambia.

This study sought to investigate the effectiveness of Excel-assisted instruction (EAI) in teaching statistics in secondary schools for learners' acquisition of 21CS, specifically communication skills, information literacy, technology literacy, and statistical literacy (CITS). Therefore, the following research question guided this study:

How effective is EAI in teaching statistics for enhancing learners' acquisition of 21CS?

2. Literature Review

The integration of technology in education has gained significant momentum, particularly in mathematics and statistics instruction. Literature emphasizes the transformative potential of technology in enhancing learning outcomes, fostering engagement, and developing essential 21st century skills (21CS) such as communication, collaboration, problem-solving, and information, statistical, and technology literacy (Alismail & McGuire, 2015; P21, 2010). The growing demand for these skills highlights the need for instructional strategies that effectively incorporate technological tools into educational curricula.

Numerous studies have emphasized the importance of 21CS in modern education. According to the Partnership for 21st Century Learning (P21, 2010), skills such as critical thinking, creativity, communication, and collaboration are essential for success in the contemporary workforce. Scholars such as Barrett et al. (2019) and Fullan (2014) have highlighted the role of technology in fostering these competencies. However, much of the existing literature focuses on improving academic achievement rather than addressing how technology can contribute to the development of these critical skills.

In mathematics and statistics education, computer-assisted instruction (CAI) has been extensively explored for its impact on student performance and the development of higher-order thinking skills (Gavifekr & Rosdy, 2015). Basturk (2005) demonstrated that the use of statistical software such as SPSS significantly improved students' performance in inferential statistics compared to traditional teaching methods. However, these studies often neglect the role of technology in fostering 21CS. Moreover, there is limited research on technology integration in secondary school statistics education, particularly concerning the use of Microsoft Excel as a teaching tool.

Microsoft Excel has been identified as a versatile tool for teaching various mathematical concepts, including statistics. It provides learners with the ability to visualize data, apply statistical functions, and understand concepts beyond mere formulas (Georgieva, 2015). Giles (2002) demonstrated the effectiveness of Excel in teaching statistical problem-solving to Year 13 students in New Zealand. Despite these findings, most studies have emphasized cognitive gains and academic performance rather than the development of 21CS. Recent studies by Mulle (2023) and Cobcobo and Capua (2022) confirmed that Excel positively impacts students' understanding of statistics but still fails to adequately address its potential in developing broader competencies such as communication and problem-solving.

The integration of Excel in education can foster experiential and collaborative learning, this aligns with constructivist teaching approaches (Barell, 2020; Bray & Tangley, 2015). Rabi et al. (2021) argued that while Excel supports academic achievement, its role in 21CS development remains underexplored. In contrast, Borkulo et al. (2023) highlighted that computational thinking could be nurtured through the use of spreadsheets. Furthermore, Agyei (2013) and Bernard et al. (2019) demonstrated that technology-enhanced instruction improves problem-solving and statistical thinking, though the emphasis on broader skills remains insufficient.

One of the key advantages of Excel is its ability to enable learners to focus on conceptual understanding rather than manual computations. Gomez (2014) highlighted that Excel allows students to efficiently calculate figures, construct tables, and create graphs, thus freeing up time for deeper engagement with statistical concepts. Rahadyan et al. (2022) and Borkulo et al. (2023) echoed this sentiment, by emphasizing that Excel-supported learning provides hands-on experiences that foster engagement and understanding.

The interconnected nature of 21CS is another crucial aspect of Excel-assisted instruction. Suson (2019) noted that teaching one skill often reinforces others, which creates a synergistic learning environment. This interconnected approach is particularly effective when learners engage in solving real-life problems, a key component of constructivist learning (Kolb, 1984). Bvute (2017) found that Excel, combined with internet resources, transforms learning into a learner-centered experience, promotes information access and self-reliance.

Integrating technology into constructivist teaching approaches has been widely acknowledged as effective for fostering 21CS. Chalkiadaki (2011) and Rosdiana et al. (2020) argued that constructivism supports development of critical thinking, collaboration, and problem-solving skills. Suson (2019) emphasized that the effective application of statistical software requires integration into constructivist methods that encourage collaborative and experiential learning. Kolb and Boyatzis (1999) highlighted that learning through experience enables learners to retain knowledge and apply it in real-world contexts, which is a critical aspect of 21CS development.

Several studies have examined the effectiveness of Excel in teaching statistics. Chaamwe and Shumba (2016) identified Excel as a suitable e-learning tool for secondary school statistics education. Research by Lee et al. (2018), Cuadra (2021), Gasigwa et al. (2022), and Mulle (2023) demonstrated that Excel fosters active, hands-on, and cooperative learning experiences. Beyond enhancing understanding of statistical concepts, Excel supports the development of skills such as data management, critical thinking, and problem-solving.

Moreover, Mikre (2011) argued that technology enables discussions of real-life problems in classrooms, this promotes active learner engagement and knowledge construction. Stemock and Kerns (2019) supported this view, by showing that real-life problem-solving using Excel fosters the development of 21CS.

Despite the demonstrated benefits of technology-assisted instruction, many studies remain focused on academic achievement rather than skill development. Basturk (2005) and Voogt et al. (2013) confirmed that integrating statistical software improves learning outcomes but did not explore its impact on 21CS. Alismail and McGuire (2015) emphasized the need for instructional approaches that balance academic achievement with skill development.

2.1. Theoretical Framework

This study was guided by Experiential Learning Theory. This theory is based on the idea that knowledge and skills are acquired through experience or doing (Kolb, 1984). ELT is an offshoot of constructivism where learners construct knowledge based on their previous experiences (Singh, 2020). It has been argued that learning through experience allows learners to retain knowledge and apply it in the real world (Kolb & Boyatzis, 1999). With experiential learning, learners are given an opportunity to construct knowledge from their experiences. This can be promoted when learners explore and engage in mathematics with technology. Therefore, 21CS such as CITS can be developed through the process of doing and learning statistics with Excel.

3. Methodology

The study utilized an Embedded Quasi-experimental Design (EQD), both quantitative and qualitative data were collected, with an emphasis on quantitative data and qualitative data serving a supportive role (Johnson et al., 2007). Follow-up interviews were conducted to gain understanding of the quantitative results. The study took place at Mwense Secondary School in Luapula Province, Zambia, it involved 59 Grade 11 learners. Participants were divided into two classes, experimental and control group. Experimental group was taught statistics using EAI approach, while the control group received instruction through conventional teaching methods. To assess the learners' demonstration of (21CS before the intervention, both groups underwent a CITS diagnostic test as a pre-test. In the experimental group, the teacher employed chalk, a blackboard, Excel, and a projector to deliver lessons based on the Excel lessons outlined by Chaamwe and Shumba (2016). Learners focused on topics such as frequency tables, histograms, and descriptive statistics, they also used Excel to create visualizations (bar charts, pie charts, and histograms), calculate statistics (mode, median, mean, variance, and standard deviation), and determine quartiles. The features of Excel facilitated tasks such as creating class intervals and inserting formulas, this allowed learners to work both individually and in groups. In contrast, the control group relied solely on a scientific calculator for their instruction, here the teacher explained concepts and formulas using a blackboard and chalk, lessons were conducted based on a Grade 11 mathematics textbook by Chiyaka et al. (2016). No use of Excel occurred in this group. Instruction was provided by two different teachers. Following the learning period, both groups took a post-test to assess the acquisition of 21CS among learners, whereby a CITS 5-point Likert scale and observation checklist were used. Additionally, a follow-up Focused Group Discussion Interview was conducted with six participants from the experimental group.

The school was chosen for its accessibility, as the researcher was teaching there during the study. The grade level was selected based on where the study topic (statistics) is taught. Mwense Secondary School and grade 11 were chosen using convenience and purposive sampling techniques. Additionally, simple random sampling was used to select groups for the actual study and pilot study. The sampling frame included all four grade 11 classes. Instead of assigning learners to control, experimental, and pilot study groups, classes were randomly selected. Three of the four grade 11 classes were randomly drawn using a simple random draw with replacement method. A sub-group of six learners was selected from the experimental group for a Focus Group Discussion Interview, comprising learners with the highest (2), average (2), and lowest (2) scores on the acquisition of 21CS.

Results from the Likert-scale questionnaire were scored and summarized using MS Excel. Total scores were analyzed with IBM SPSS version 27.0 for Windows. The results were tested for normality to determine suitable tests for the study. Descriptive statistics assessed the differences in the demonstration of 21CS. Parametric and non-parametric tests, including a t-test and Mann-Whitney test, determined whether there was a significant difference between the control and experimental groups. The responses from the interviews were analyzed thematically.

The study ensured compliance with the ethical codes and guidelines for researchers at the University of Zambia. Ethical clearance was obtained from the university's Ethics Committee. Additionally, permission to conduct the study at the research site was sought from school authorities. Voluntary participation was emphasized, and participants were allowed to withdraw from the study at any stage. Furthermore, to maintain anonymity, participants were assigned code numbers, to ensure that their identities remained confidential throughout the study. The study also upheld the principles of honesty by avoiding any falsification, fabrication, or misrepresentation of research methods, data collection, data analysis, and the acknowledgment of other researchers' work.

Face validity and content validity were established by adapting a Likert-scale questionnaire from existing questionnaires by Kelly et al. (2019) and Martins-Pacheco et al. (2020). Internal consistency reliability was assessed using the Cronbach coefficient alpha with SPSS v27.0.

The Cronbach coefficient alpha values for the questionnaire were 0.781, which indicated reliability. To enhance credibility, the researcher employed multiple data collection methods, questionnaire, interview, and observations. This approach helped build a coherent justification for the research themes. Thick description was utilized to present the findings of the study. Quotes incorporated to provide a detailed account of the responses and make results more realistic and richer. Furthermore, the interview transcripts were validated by participants to ensure that their responses were accurately reported. The researcher ensured dependability by guaranteeing that the transcripts were free of errors and that the interviews were transcribed as reported by the participants.

4. Results and Discussion

4.1 Normality test

Normality tests were conducted to determine a reliable test for the scores. One of the assumptions for parametric tests to be reliable is that the data must be approximately normally distributed (Ghasemi & Zahediasl, 2012). Kolmogorov-Smirnov tests were used in this study. The findings are presented in table 1.

Table 1: Normality Test Results

	Statistic	df	Sig	Normally Distributed
Pre-test: Diagnostic Test	.075	62	.200	Yes
Post-test: 21st Century Skills	.253	59	<.001	No

The p-value of the results in table 1 were 0.200 for the diagnostic test, and less than 0.001 for 21CS. The p-value for the diagnostic test scores is greater than the alpha value (α=0.05). The results indicate that the results were not significant. On the other hand, the p-value for the other test was less than the alpha value, suggesting that the results were significant. Based on these findings, it was concluded that the scores for the diagnostic test were approximately normally distributed, while the scores for 21CS were not normally distributed. As the data set for the diagnostic test scores assumed normality, an appropriate parametric test, specifically an independent sample t-test, was used. In contrast, a non-parametric test, namely the Mann-Whitney U test, was used for the 21CS scores.

4.2 Pre-test results

A diagnostic test was used as a pre-test. An independent sample t-test was used to compare the scores of the two groups before learning began. The data set was tested for equality of variance to fulfil the requirement for performing t-test. The results of this test are presented in table 2.

Table 2: Homogeneity test of variance

	F	df	Sig
Levene’s test for equality of variance	.695	60	.408

The p-value (0.408) for the Levene test in table 2 indicates that there was no significant difference in variance between the experimental and control groups. As a result, it was assumed that the variance in pre-test scores was the same for both groups. The p-value for the independent sample t-test, assuming equal variances, is presented in table 3.

Table 3: Independent Sample t-test Results

	T	df	Sig (2-tailed)
Independent Samples test	-1.219	60	.228

Since the p-value of 0.228 in table 3 is greater than 0.05, the hypothesis that the groups are not significantly different cannot be rejected. Therefore, it can be concluded that at a significance level of $\alpha = 0.05$, there is no significant difference between the experimental and control group. Descriptive statistics were also used to compare the pre-test scores of the two groups, as shown in table 4.

Table 4: Descriptive statistics Results (N=62)

	Group	N	Mean	Standard Deviation
Pre-test	Experimental	30	49.41	8.546
	Control	32	48.53	9.441

Table 4 reveals that, on average, the learners in the control group scored 48.53%, while the learners in the experimental group scored 49.41%. Additionally, the distribution of scores around the mean for the control group and experimental group were 9.441 and 8.546 respectively. These descriptive statistics indicate that the groups were quite similar.

The pre-test scores between the control and experimental groups indicate that the learners' 21CS were the same before the learning process. The independent samples t-test showed that there was no significant difference between the two groups [t(60) = -1.219, p = .228]. The mean score for the experimental group was 49.41 (SD=8.55), while the control group had a mean score of 48.53 (SD=9.44). The results indicate that learners from both groups demonstrated low proficiency in 21CS. Therefore, it can be concluded that the two groups were at the same level in terms of 21CS and exhibited a lack of these skills. This confirms the findings by Plecher (2020); World Bank (2017); SEACMEQ (2011); UNESCO (2005), which also highlighted the deficiency of 21CS among secondary school learners in Zambia. The study by Masaiti et al. (2021) attributed this to limited access to technology facilities and low utilization of available technology resources by both learners and teachers, particularly in public secondary schools in Zambia.

4.3 Post-test results

Mann-whitney U-test, was performed on the scores to test the research hypothesis that there is no significant difference in the acquisition of 21CS between learners taught statistics with EAI and those taught with a conventional method. The results are presented in table 5.

Table 5: Man-whitney U test results

	test	Sig	Decision
The distribution of the post-test scores is the same across the two groups	Mann-whitney u test	<.001	Reject null hypothesis

Since P-value is less than 0.001 in table 5, which is less than 0.05, the null hypothesis is rejected and it can be concluded that at 0.05 level of significance there is a significant difference between the experimental and control group. This means that the two groups of learners were not at the same level in terms of 21CS after the learning process. The descriptive statistics were also used to further examine the difference in scores between the two groups. The mean scores are presented in table 6.

Table 6: Descriptive statistics Results (N=59)

	Group	N	Mean	Standard Deviation
Post-Test	Experimental	29	82.28	3.378
	Control	30	39.23	4.122

Table 6 presents the descriptive statistics results, and it reveals that, on average, the learners in control group scored 39.23% (with a standard deviation of 4.12), whereas the learners in the experimental group scored higher, at 82.27% (with a standard deviation of 3.38). Therefore, the results indicate that after the learning process, the average scores of the experimental group and the control group were different and learners in the experimental group had higher scores in terms of 21CS than learners in the control group.

Qualitative results were also collected whereby open-ended questions were posed during FGD interview. Responses demonstrating 21CS were identified from the transcript and analyzed thematically. The findings revealed that learners in the experimental group demonstrated acquisition of 21CS after learning statistics using Excel. Through analysis of the interview responses, four primary themes emerged: information literacy, technology literacy, statistical literacy, and communication skills. Participants highlighted their ability to summarize information and find reliable sources online, this reflected growth in information literacy. Similarly, responses such as "I learnt how to use a computer" and "I now know how to work with Excel" demonstrated advancements in technology literacy. Statistical literacy was evident as learners expressed an understanding of the meaning of statistical results, data presentation, and the importance of summarizing and interpreting statistical findings. Communication skills emerged as a key theme, with participants acknowledging their ability to seek clarification from teachers and interact with classmates this fostered collaborative learning. Responses also indicated that learners developed problem-solving and collaboration skills, this supports the findings of Suson (2019) that 21CS are interconnected, and that teaching one skill reinforces others. Additionally, observations indicated that learners in the experimental group were actively engaged in lessons, they worked on activities with computers both in groups and individually. Findings from the observation checklist showed that learners exhibited communication, collaboration, problem-solving, and technology literacy skills. These findings complement the quantitative results which show holistic skill development beyond statistical concepts. Based on both quantitative and qualitative results, learners in the experimental group acquired 21CS after learning statistics with MS Excel. This aligns with the work of Gravemeijer et al. (2017) and Suh and Seshaiyer (2013), who stated that 21CS can be taught through computer technologies in mathematics education. Integrating MS Excel into secondary school statistics provided learners with the opportunity to develop 21CS. These findings are supported by Changwe and Mwanza (2019), Cuadra (2021), Mulle (2023), Basturk (2005), Voogt et al. (2013), and Alismail and McGuire (2015), who emphasized the importance of technology in teaching mathematics and fostering the development of 21CS. EAI engaged learners through real-life statistical problems, supported active and cooperative learning, and improved their understanding of concepts and skills.

5. Conclusion and Recommendations

5.1 Conclusion

The study demonstrated that Excel-Assisted Instruction (EAI) effectively enhances the acquisition of 21CS among secondary school learners learning statistics. Quantitative analysis revealed a significant difference between learners taught with EAI and those taught using conventional methods, with the EAI group achieving higher 21CS scores. Additionally, interview discussions indicated that learners taught using EAI developed the skills, namely Information Literacy, Technology Literacy, Statistical Literacy, and Communication Skills. These qualitative findings complemented the quantitative results. Integrating MS Excel into statistics lessons provided learners with opportunities to develop 21CS. The study suggests that incorporating MS Excel in teaching statistics fosters learner-centered experiences, promotes active and collaborative learning, and connects education to real-life situations. This approach aligns with constructivist theory, which emphasizes the importance of experiential learning in skill development. Consequently, using MS Excel in teaching secondary statistics not only enhances understanding of statistical concepts but also facilitates the acquisition of 21CS. Therefore, the findings indicate a significant improvement in 21CS among learners taught with MS Excel compared to those taught through conventional methods. EAI proved effective in teaching secondary school statistics and fostering the acquisition of 21CS. However, future research could explore the influence of gender on 21CS acquisition with EAI, teachers' competencies in using Excel for instruction, and their perceptions of its use in teaching mathematics, particularly statistics.

5.2 Recommendations

Based on the findings of this study and previous research, it is recommended that educational institutions, specifically Teacher Training Colleges and Universities, prioritize training programs for teachers to effectively utilize technology such as Excel, in their teaching methodologies. These training efforts should focus on equipping teachers with the necessary skills to integrate computer software into Mathematics instruction. Additionally, secondary schools to be provided with adequate computer resources and internet connectivity. Lastly, our education system should prioritize assessing learners' acquisition of 21CS.

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