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Design and assessment of effective multimedia-based courseware for student quantitative data analysis

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ABSTRACT

The rapidly evolving technological trends are transforming higher education. This study focused on designing and evaluating the effectiveness of multimedia-based courseware in improving students' data analysis at Islamic University in Uganda. The objectives were: i) to create interactive multimedia courseware (IMC) to enhance students' quantitative data analysis skills; ii) to evaluate the suitability of IMC's content, interactivity, user interface, and design; and iii) to profile students' perceived benefits of using the IMC to learn quantitative data analysis. A descriptive survey involving 160 education undergraduate finalists, selected through random and consensus sampling, was conducted. Data was collected through a self-report survey instrument with high validity (content validity index=0.886) and reliability (Cronbach alpha=0.878). The IMC development followed the analysis, design, development, implementation, and evaluation (ADDIE) model and Gagne's learning events. Results indicated that the IMC content (mean=3.90, SD=0.94), interactivity (mean=4.10, SD=0.79), user interface (mean=4.04, SD=0.82), and screen design (mean=4.05, SD=0.87) were highly appropriate. Students perceived IMC as effective in enhancing their data analysis skills (mean=3.86, SD=0.92). The findings suggest that IMC can significantly improve students' quantitative analysis abilities. However, recommending further studies on the impact of IMC on students' quantitative data analysis skills comprehensively in a multidisciplinary manner, to potentially revolutionize learning.

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1. INTRODUCTION

The global community is currently experiencing rapidly evolving technological trends, leading to the integration of technology across various disciplines, including education. These advancements have addressed numerous challenges, ranging from administrative tasks to classroom teaching and learning. Notably, they have facilitated the creation of educational materials, such as multimedia-based courseware to enhance student engagement, comprehension, and retention of complex subjects [1]. Quantitative data analysis is a crucial skill in many academic fields, yet it poses unique challenges due to its abstract nature and reliance on mathematical and statistical concepts. The objectivist approach in research argues that

quantitative studies are the most suitable for producing broad, generalizable findings relevant to the population [2]. This method, not only, fosters a deeper understanding of the phenomena being studied, but also helps identify patterns and trends [3]. By effectively organizing and summarizing data, researchers can present objective results that enhance the clarity and impact of their findings [2], [4]. These are carried out through techniques such as descriptive, inferential, factor, cluster statistics, and classifiers [4], [5]. However, these techniques require sufficient knowledge, analytical skills, and judgment, which many students lack [6]. The lack of student knowledge results from the traditional teaching methods that often fall short in effectively conveying these concepts, leading to student frustration during research data analysis and poor performance. This is reflected in the continuous high plagiarism index observed in the data analysis section of research projects of undergraduate students at the Islamic University in Uganda (IUIU), informally reported by the Directorate of Research Publication and Innovation (RPI) at the IUIU. This redline demonstrates data fabrication referred to as "cooking data" among the students. Nevertheless, the potential of multimedia-based courseware to bridge this gap offers a promising avenue for educational innovation. In the context of this study, focuses on developing and evaluating the effectiveness of the interactive multimedia courseware (IMC) to improve undergraduate students at IUIU's proficiency in quantitative data analysis.

Technological support in the development of innovative learning methods such as flipped classrooms, blended and personalized learning, and IMC resources, have been addressing various learning needs [7], [8]. Previous research has highlighted the benefits of multimedia learning, particularly in subjects that require abstract thinking and the application of theoretical concepts to practical problems. Educational courseware, developed as learning environments to support students' mastery of specific subjects, has shown positive results in supporting teaching and learning. For instance, the interactive learning module (ILM) enhanced student achievement [9]. Integrated interactive multimedia curricula and the IMONEC program were developed to strengthen learners' personalities, proving feasible and effective [10]. Additionally, courseware designed for teaching problem-solving and other higher-order thinking skills has facilitated learning [11], recommending courseware approaches as a better way to support diverse learning contexts [12]. However, there is limited literature that specifically addresses the design and impact of multimedia-based courseware in the context of quantitative data analysis, which focuses on the context of the IUIU. The existing studies tend to focus on other fields like science, technology, engineering, and mathematics (STEM) internationally, designing courseware that is either too simplistic or overly complex, failing to strike a balance that caters to diverse learning styles and academic levels, leaving a gap in the specific area of data analysis in the context of IUIU. Therefore, this study focuses on developing and evaluating the effectiveness of multimedia-based educational courseware in improving students' proficiency in quantitative data analysis. The study focused on these three objectives to address gaps in the literature: i) examine how IMC can be effectively developed to enhance students' quantitative data analysis skills; ii) assess the suitability of the IMC regarding; the instructional content, interactive features, interface usability, and aesthetic appeal; and iii) to profile students' perceived benefits of using the IMC to learn quantitative data analysis.

This study is based on multimedia learning theories, incorporating Meyer's cognitive theory, Gagne's nine events of instruction, and the analysis, design, development, implementation, and evaluation (ADDIE) model. According to Mayer [13], combining verbal and visual presentation methods results in more effective learning than using verbal information alone. Multimedia learning, arises from the integration of both words and visuals in educational materials, with a focus on enhancing student engagement and understanding. Mayer's cognitive theory assumptions include dual processing-use of visual/auditory channels, cognitive load-emphasizing limited processing capacity in the brain, and active learning-learning which requires active cognitive engagement, rather than passive information absorption [13], [14]. This allows the content in courseware to be organized without overloading the working memory of the students.

The ADDIE framework is, a widely recognized instructional design model that outlines a systematic 5-stage process: i) Analysis: examining the instructional needs and target audience; ii) Design: developing the instructional plan and materials; iii) Development: creating the actual instructional content and resources; iv) Implementation: delivering and deploying the instructional program; and v) Evaluation: assessing the effectiveness and making refinements [15]. The model provides a structure for creating effective teaching and learning material, focused on student-centered learning [15]. The application of the model in this study was discussed in the study process in the method section. Further, Gagne's instructional model outlines a sequence of key steps to facilitate effective learning [16], [17]. Gagne's nine educational events include: capturing attention, communicating learning objectives, activating prior knowledge, presenting new content, guiding skill application, eliciting learner performance, providing meaningful feedback, assessing learner competencies, and enhancing retention and transfer: helping learners apply their knowledge to real-world situations [16]. The content in the courseware was suitably presented following Gagne's nine events of instruction. This led to the development of effective multimedia courseware for enhancing student learning.

Thus, this study offers a novel contribution to the field by developing and rigorously assessing multimedia-based courseware specifically for quantitative data analysis. This research provides valuable insights into the design of effective educational tools, potentially setting a new standard for multimedia-based instruction in quantitative statistics. For educational practice, this study offers an approach to enhance teaching strategies. Educators could adopt more interactive and engaging methods for teaching curriculum content, shifting from traditional lecture-based approaches to multimedia-rich environments. This can improve students' engagement and comprehension of complex analytical concepts. Further, the perceived value of the courseware by the students can guide the educational policy that emphasizes inclusive education which aims at creating inclusive educational tools that are accessible and beneficial for all students, regardless of their backgrounds or learning capabilities. Thus, ensuring equity in digital learning resources. Lastly, for educational reforms, the study will encourage policymakers to regularly assess the effectiveness of various educational technologies. Through setting up systems to continually evaluate new multimedia-based tools to ensure they align with student needs and educational goals.

2. METHOD

2.1. Study design

This study aims to develop and evaluate the effectiveness of IMC in improving students' quantitative data analysis skills. As a result, the study used descriptive research methodology with a survey design. The descriptive research allows for a description of the current event [18], such as developing IMC. Survey design assesses the needs and impact of the program, and informs evidence-based decisions that drive meaningful and effective development of a program [18].

2.2. Sample and population

In conducting this study, the researchers worked with a population of 233 final-year undergraduate students from the Faculty of Education from which 160 participants were selected during the 2023/2024 academic year. Researchers used an online random number generator to select participants from the list of undergraduate finalist students at the faculty of education, ensuring equal participation chances [18]. Census sampling was applied to select all Concurrent Diploma in Education students due to their small number [18]. The sample was diverse, including 122 students pursuing a Bachelor of Arts in Education, 30 Bachelor of Science in Education students, and 8 students from the Concurrent Diploma in Education program. Participation in the study was entirely voluntary, with each student given the option to decide whether or not to take part. The study participants were composed of 58.1% males and 41.9% females. In terms of information communication technology (ICT) skills, the majority of participants (69.4%) possessed moderate ICT skills. Additionally, 21.3% of the participants demonstrated high ICT proficiency, while 9.3% had low ICT skills. The researchers distributed 170 questionnaires and received 164 completed responses. However, three of these had missing value issues. To meet the target sample size of 160, four responses, including the three with missing values, were excluded, leaving 160 questionnaires for data analysis.

2.3. Questionnaire

To collect data, the researchers employed a self-administered, closed-ended questionnaire on a 5 point-Likert scale (1-strongly disagree to 5-strongly agree). Researchers carefully selected questionnaire items based on literature to measure the various constructs. The questionnaire consisted of 33 items, with 25 items measuring the appropriateness of the IMC and 8 items assessing the perceived value of using the developed IMC. Before use, this instrument was validated by two independent experts through a content validity approach, ensuring that the questions were appropriate and measured the intended constructs. The content validity index (CVI) for the questionnaire was calculated at .886, which, according to Pallant [19], is a strong indication that the content is valid and reliable for the study. To further ensure the reliability of the data collection tool, a pilot study was conducted, resulting in a Cronbach's alpha of .878. This high level of internal consistency reinforced the researchers' confidence in the robustness of the instrument for accurate measurement and analysis. The questionnaires were presented to the target interested participants to answer at the same time after learning quantitative data analysis with multimedia courseware developed, the participants answered willingly.

2.4. Courseware development procedure

This subsection describes the procedure used for the design and assessment of the multimedia courseware:

a. Resource collection: all necessary materials were collected in the form of course notes needed to build the tutorials such as images, texts, videos, content links, and audio. Information from the internet and the

choice of Microsoft PowerPoint 2013 for the design, was due to the knowledge of the researcher and participants.

b. Lesson arrangement, template building and actual use: lessons in the IMC were organized according to the objectives progressively and adequately. The researcher designed the curriculum creatively, through imaginative ideas that follow the structure of the ADDIE model and presentation guidelines of Gagne's nine events of instruction. This is enhanced by using Microsoft PowerPoint version 2013. Eventually, the application of the ADDIE framework in this study was:

- Analysis: during this stage, the designer identified learning needs, audience needs, goals, existing knowledge, and audience characteristics. Choosing the learning environment and delivery method (The instructional content was delivered via Microsoft PowerPoint presentations).
- Design: the instructional design process included setting learning goals, core skill objectives, and course structure. Selecting multimedia assets (images, videos, audio, and assessments). Identifying curriculum topics (e.g., descriptive statistics in Excel). Defining methods for generating descriptive statistics, creating frequency tables and graphs, and introducing inferential statistics. Teaching correlational analysis using Pearson's correlation coefficient, computational procedures, and interpretation of results.
- Development: the production stage involves implementing the IMC as per the instructional design plan, including these key steps: all contents outlined in the design phase were acquired, organized, and serialized. Relevant images, pictures, videos, and audio clips were sourced from YouTube and the Internet. Microsoft PowerPoint was used to compile these materials into tutorials. The content was presented in various formats, including images/pictures and text/words, to optimize learning. The content in the IMC was structured according to Gagne's nine teaching events of instruction: i) Attention-grabbing: learners' attention was captured at the beginning of the tutorial with a short, animated clip of greetings (peace be upon them), designed to engage and intrigue the audience; ii) Informing learners of learning outcomes: objectives were presented at the start of each topic, making learners aware of what they were expected to achieve by the end of the tutorial; iii) Stimulating recall of prior learning: the tutorial provided a brief review of quantitative data analysis, helping learners recall their prior knowledge and establish a foundation for new information; iv) Content presentation: the tutorial content was presented using a multimedia approach, incorporating text, images, and videos to keep learners interested and engaged; v) Providing learner instructions: clear user instructions and navigation keys were provided, allowing learners to easily navigate through the content. Links to relevant videos were included as needed to support understanding; vi) Eliciting performance: practice questions were included at the end of each learning section to test learners' knowledge. These activities allowed learners to apply what they had learned before progressing; vii) Providing feedback: formative feedback was given immediately after learners answered practice questions, informing them of the correctness of their responses and motivating them to continue learning; viii) Evaluating learner performance: at the end of the tutorial, learners' knowledge and skills were evaluated. A summary of results was presented, along with feedback based on their performance levels; and ix) Facilitating learner retention and transfer: to ensure retention and application of knowledge, learners were given more challenging problems that reflected real-world scenarios, helping them transfer their skills to practical situations. By incorporating Gagne's nine events, the study aims to create an engaging and effective learning experience that improves students' data analysis skills. The researcher also consulted lecturers and students for feedback on the course design, which was used for improvement. The program then underwent a supervisor review to verify the validity of the materials and media, ensuring its effectiveness in enhancing quantitative data analysis skills before implementation.
- Implementation: this process involves two stages: pilot testing and final implementation. During the pilot testing phase, an experimental study was conducted with 20 undergraduate finalist students from the faculty of management studies over one week. The purpose was to perform a formative evaluation of the instruments to ensure they accurately measured the intended variables before applying them to the broader target population. The final implementation stage involves integrating the educational programs into classroom learning. The interactive multimedia educational program was provided to the finalist undergraduate students at the Faculty of Education for self-learning over one week. Afterward, the program's effectiveness in enhancing quantitative data analysis skills and the associated benefits were evaluated using a questionnaire which is clearly described in the next evaluation phase.
- Evaluation: this phase involved testing the courseware for further improvements through the pilot data and actual use of the courseware for research data collection. In the first place of testing the courseware for further improvements, after the implementation of the courseware to a small group of participants from the target study population, for learning quantitative data analysis, a pilot study was conducted to collect data through a questionnaire regarding the courseware development. The feedback gathered from

this pilot study was instrumental in refining the courseware, leading to improvements across several key areas: instructional content, interactive features, interface usability, and aesthetic appeal. First, adjustments were made to the instructional content to enhance language appropriateness, ensuring that the material was easier for students to understand. Additionally, motivational elements were incorporated to further engage users. Second, based on the pilot feedback, the interactive features were enhanced. Navigation buttons were redesigned for better usability, and more relevant and engaging videos were added to increase the overall interactivity of the courseware. In terms of interface usability, the pilot results highlighted the need for clearer instructions and smoother transitions within the courseware tutorial. These issues were addressed to improve the overall user experience. Finally, to enhance the aesthetic appeal, the courseware's design was updated. More vibrant and visually appealing colors were incorporated, and the font size was adjusted for better readability. These changes made the courseware more engaging and visually accessible to students. The pilot study played a crucial role in refining the courseware, ensuring it was effective, user-friendly, and engaging for the intended audience. Through this, the courseware was well evaluated before being used for the primary study data collection.

The actual use of the courseware- In the actual implementation phase, the courseware was utilized to assess its effectiveness in enhancing students' proficiency with quantitative data analysis techniques. This phase was crucial for collecting the study's primary data. Following the improvements made after the pilot study, the finalized courseware was provided to a selected sample of participants, who used it for one week to develop their quantitative data analysis skills. During this time, students engaged with the interactive multimedia-based instructional content, which had been optimized to ensure it was both user-friendly and educationally effective. After one week, a questionnaire was administered to gather quantitative primary data. The questionnaire was designed to maintain the anonymity of participants and focused on evaluating the courseware's effectiveness in improving the student's ability to analyze quantitative data. The data collected from this phase was critical for addressing the study's objectives, providing insights into how well the IMC supported students in developing essential data analysis skills.

2.5. Data collection procedure

The hardcopy questionnaires were presented to the target interested participants to answer at the same time after learning quantitative data analysis with multimedia courseware developed, the participants answered willingly. After answering the questionnaires, the researcher collected them for the analysis process. The researchers distributed 170 questionnaires and received 164 completed responses. However, three of these had missing value issues. To meet the target sample size of 160, four responses, including the three with missing values, were excluded, leaving 160 questionnaires for data analysis. The questionnaire consisted of 33 items, with 25 items measuring the appropriateness of the IMC and 8 items assessing the perceived value of using the developed IMC.

2.6. Data analysis

Once data collection was complete, the researchers used descriptive statistical methods, specifically measures of central tendency such as means and standard deviations (SD), to analyze the results. This approach allowed them to evaluate key characteristics of the IMC developed for the study and identify patterns in how the IMC influenced students' proficiency in quantitative data analysis [19]. These statistical measures were crucial for assessing the effectiveness of the courseware in supporting student learning.

2.7. Ethical consideration

Ethical considerations were central to this research. Before the administration of the questionnaire, the researchers obtained permission from the university secretary IUIU to conduct this study. Later, informed consent from all participants was requested, ensuring they understood the purpose of the study and their role in it. This helped to establish a sense of transparency and trust while also adhering to ethical research standards. In addition, the researchers took significant measures to ensure the confidentiality of all participant responses, safeguarding their privacy throughout the research process. The courseware developed as part of this study represents an important educational resource, it will only be made available upon request to ensure proper usage and to protect the intellectual integrity of the research. Throughout this process, ethically sound findings could meaningfully contribute to the field of educational technology and quantitative analysis skills.

3. RESULTS AND DISCUSSION

This section reveals the significant findings of the major study questions of concern and discusses these findings with the relevant literature. From the tables for presenting the results, the short abbreviations are: 'N' is the constant sample size, 'Max' means maximum, 'Min' means minimum, and SD is the standard deviation.

3.1. Evaluating the suitability of interactive multimedia courseware

The study analyzed data on the effectiveness of multimedia educational programs, evaluating content, interactive features, and user interface design. Findings, including mean values, were discussed within the evaluation framework [20], as shown in Table 1.

Table 1. Means of interpreting mean values [20]

Min.	Max.	Explanation
4.00	5.00	Very suitable
3.00	3.99	Suitable
2.00	2.99	Fairly convenient
1.00	1.99	Unsuitable

3.2. Descriptive analysis of the suitability of instructional content

The statistical analysis provided descriptive measures (mean, SD) to assess educational suitability, interpreting insights on instructional content quality. Table 2 summarizes findings on instructional content suitability. The first criterion, readability and coherence, scored a mean of 3.47 and a SD of 1.06, indicating accessible content supporting skill enhancement. The second criterion, language appropriateness, averaged a mean of 3.91 and a SD of 0.85, facilitating comprehension and skill development. The third criterion evaluated the clarity of textual explanations in the multimedia program, with a mean response of 4.13 and a SD of 0.82, indicating generally effective clarity in enhancing students' understanding of quantitative data analysis skills. Visual imagery's appropriateness was assessed with a mean response of 4.35 and a SD of 0.79, indicating high suitability for supporting comprehension and improving data analysis capabilities. The study also examined the motivational impact of tutorial questions and activities, with a mean response of 3.61 and a SD of 1.00, showing reasonable engagement and facilitation of skill acquisition. Presentation format diversity and appropriateness were evaluated, with a mean response of 3.94 and a SD of 1.12, indicating effective use for diverse learner needs and skill development. Overall, the instructional content in the multimedia courseware averaged a response value of 3.90, with a SD of 0.94. The instructional content in the tutorial was appropriate given the need and kind of audience which enhanced students' quantitative data analysis skills.

This finding agrees with Samat and Aziz [21] that states that using clear and well-organized content in multimedia learning is more effective; previous studies [2], [14] urges that makes it favorable to learners. More importantly, the finding demonstrates the need to stimulate student learning, through effective multimedia content. This implication is supported by Verecio [8] and Kivuti [22] who found that effective instructional content arouses and maintains positive attitudes of students in learning, thus improving learning. Therefore, educators should use diverse multimedia content to cater to different student learning styles but must evaluate their effectiveness and consider student variables [23].

Nevertheless, the findings are contrary to the study by Uzun and Yildirim [24] who found that certain design features, like anthropomorphic elements (like faces on inanimate objects) and sound effects, were perceived as distracting by some students, suggesting that while these features can make learning more enjoyable, they may also risk diverting attention from core content, especially for students with lower prior knowledge, hence decreasing learning engagement in the learning content. Therefore, careful consideration of the cognitive and emotional components in IMC content is vital for engaging content.

Table 2. Descriptive statistics showing the suitability of instructional content in the IMC

Item	N	Min	Max	Means	SD
Readability and coherence	160	1.00	5.00	3.47	1.06
Language appropriateness	160	1.00	5.00	3.91	0.85
Explanatory adequacy	160	1.00	5.00	4.13	0.82
Multimedia integration	160	1.00	5.00	4.35	0.79
Motivational design	160	1.00	5.00	3.61	1.00
Multimodal presentation	160	1.00	5.00	3.94	1.12
Mean values and SD	160	1.00	5.00	3.90	0.94

3.3. Descriptive analysis of the suitability of interactive courseware

To assess interactivity in the courseware, descriptive statistics were used to interpret mean and SD values, extracting insights on feature suitability and effectiveness. Table 3 presents a comprehensive evaluation of interactivity features in multimedia educational courseware and their impact on enhancing quantitative data analysis skills. Navigation buttons' functionality and effectiveness averaged 3.89 (SD=0.71), facilitating smooth transitions between content. Embedded video elements' usefulness and

appropriateness averaged 4.34 (SD=0.81), enhancing interactive learning. User-friendliness of tutorial buttons averaged 4.14 (SD=0.82), contributing to program suitability. Integration and support of links averaged 4.04 (SD=0.82), enhancing skill development. Feedback's stimulating nature averaged 4.06 (SD=0.69), motivating engagement. Timeliness and frequency of corrective feedback averaged 4.13 (SD=0.89), aiding skill improvement. Overall, interactivity in the multimedia tutorials averaged 4.10 (SD=0.79), effectively enhancing data analysis skills among the students. Multimedia integration in education enhances student engagement and learning outcomes, with tools like interactive videos improving focus, interest, and retention, [25], [26]. The multimedia course material interactivity further eases the student use of the courseware [27]. However, challenges such as resource limitations, digital literacy gaps, and connectivity persist [28]. Thus, addressing these challenges in the interactivity of multimedia courseware is paramount for improved performance in learning among learners [22], [27].

On the other hand, the finding did not agree with Pedra *et al.* [29] who reported that high interactivity features increased interest but did not improve learning in engineering animations. Further, English for foreign learners perceived interactive videos as motivating and helpful for listening comprehension, but frequent interactive elements could be distracting [30]; thus, decreasing meaningful learner engagement in the content. Therefore, selectivity and purposeful inclusion of the interactivity elements may result in engaging learning outcomes.

Table 3. Descriptive statistics showing the suitability of the interactivity in the IMC

Item	N	Min	Max	Means	SD
Functional navigation	160	1.00	5.00	3.89	0.71
The benefit of the videos	160	1.00	5.00	4.34	0.82
Easy to use buttons	160	1.00	5.00	4.14	0.82
Links that work as intended	160	1.00	5.00	4.04	0.82
Correct feedback	160	1.00	5.00	4.06	0.69
Timely feedback	160	1.00	5.00	4.13	0.89
Mean values and SD	160	1.00	5.00	4.10	0.79

3.4. Descriptive analysis of user interface suitability for screen design

To evaluate the appropriateness and effectiveness of the user interface screen design, descriptive statistics were analyzed to derive insights into its suitability. The study assessed the user interface in an interactive multimedia tutorial for improving quantitative data analysis skills. Analysis from Table 4 shows that control commands were intuitive (mean=3.94, SD=0.64), enhancing navigation effectiveness. Navigation buttons were well-placed (mean=4.08, SD=0.74), ensuring easy content access. Users had full control over tutorial videos (mean=4.28, SD=0.78), aiding content comprehension. Learning at own pace was facilitated (mean=4.37, SD=0.85), enhancing convenience. Well-organized screen interface (mean=3.57, SD=0.95) supported skill enhancement. Clear navigation directions (mean=3.79, SD=0.95) contributed to interface effectiveness. Smooth slide transitions (mean=4.23, SD=0.83) improved usability. Overall, the user interface averaged 4.04 (SD=0.82), indicating high convenience and support for skill enhancement. Further, the high user interface rating (4.04) implies that the multimedia courseware is user-friendly, promoting ease of navigation, increased engagement, and skill enhancement. It supports diverse learning styles and minimizes technical barriers, providing a seamless learning experience. This result highlights the importance of thoughtful user interface design and usability standards for effective educational technology.

Previous studies [31], [32] found that user interface design is crucial for enhancing educational multimedia and e-learning software effectiveness by influencing motivation, interactivity, and cognitive load. Integrating learning principles with user interface design is vital, with usability testing, adaptive interfaces, and gamification enhancing engagement and outcomes [33]. This approach helps to create inclusive, engaging, and effective learning experiences tailored to diverse student needs. Significantly influences perceived learning in distance education [34].

Nonetheless, while 3D illustrations in multimedia may boost motivation, this effect does not necessarily extend to other types of learning environments [35]. Therefore, motivational and learner-specific factors are important for creating more effective and adaptive instructional experiences. Kim *et al.* [36] suggest that poorly designed user interfaces result in low learner engagement in instructional design. This implies that ineffective user interface design causes low learner motivation in interactive multimedia learning. Further, O'Connor and Larkin [37] urge that before updating and improving the Moodle virtual learning environment (VLE) it shows a negative impact on enhancing student engagement and satisfaction. These studies underscore that careful consideration of necessary factors in user interface design is crucial for effective learner engagement in interactive multimedia learning across different disciplines.

Table 4. Descriptive statistics showing the suitability of the user interface in the IMC

Item	N	Min	Max	Means	SD
Intuitive and accessible control commands	160	1.00	5.00	3.94	0.64
Properly placed buttons	160	1.00	5.00	4.08	0.74
Complete control over your videos	160	1.00	5.00	4.28	0.78
Take control of my learning	160	1.00	5.00	4.37	0.85
Organized screen	160	1.00	5.00	3.57	0.95
Clear directions to move	160	1.00	5.00	3.79	0.95
Ease of moving from one slide to another	160	1.00	5.00	4.23	0.83
Mean values and SD	160	1.00	5.00	4.04	0.82

3.5. Descriptive analysis of fit in screen design aesthetics

To evaluate the visual appeal and aesthetic qualities of the screen design, descriptive statistics were analyzed to derive insights into its effectiveness and suitability. Table 5 analyzes the aesthetic qualities of screen design in multimedia tutorials. Key findings include a visually appealing color scheme (mean=3.92, SD=0.72), and enhancing engagement. Positive evaluation of tutorial screen creativity (mean=4.16, SD=0.82), supporting skill enhancement. Well-received color consistency (mean=4.17, SD=0.94), enhancing program suitability. Appropriate colors for skill enhancement (mean=4.08, SD=1.02), aligning with user preferences. Suitable font sizes and line spacing for readability (mean=3.94, SD=0.84), supporting skill development. Overall, screen design aesthetics averaged 4.05 (SD=0.87), indicating relevance and support for enhancing data analysis skills. The high rating of screen design aesthetics (4.05) implies that visually appealing designs enhance student engagement, motivation, and cognitive focus, supporting the development of data analysis skills. It highlights the importance of balancing aesthetics with functionality in educational courseware to optimize learning outcomes.

Research shows that visual design and aesthetics significantly enhance student engagement and learning in online education. Resulting from the appealing designs which improve usability, credibility, and user experience [38]. Further, gestalt principles in screen design boost both appearance and learning value [39], and strategic positioning of all visual elements, with a particular emphasis on the placement of images [40]. Blending the features in multimedia format, thus making it beautiful and interesting [41], [42]. Theoretical frameworks highlight the importance of balancing aesthetics with functionality to optimize engagement and learning outcomes, hence aesthetic elements positively influence students' interactions with course materials [43]. These findings underscore the significance of balancing aesthetic appeal with functionality in educational courseware to optimize student engagement and learning outcomes.

However, it is found that poor design can hinder the effectiveness of learning management systems (LMS) in higher education [38]. Especially, poor-rated surface structure designs negatively affect learner engagement with multimedia interactive platforms [44]. Further, aesthetics or usability may not directly affect learners' emotional states, rather, it is the perceived aesthetics and usability that positively influence emotions [45]. Purposeful aesthetics design can facilitate interest for continued learner engagement with the multimedia platform, hence creating a chance for achieving positive learning outcomes.

Table 5. Descriptive statistics showing the suitability of the screen design aesthetic qualities in the IMC

Item	N	Min	Max	Means	SD
Attractive colors	160	1.00	5.00	3.92	0.72
Creativity in graphic design	160	1.00	5.00	4.16	0.82
Color matching	160	1.00	5.00	4.17	0.94
Good colors used	160	1.00	5.00	4.08	1.02
Fonts and spacing vary between readability	160	1.00	5.00	3.94	0.84
Mean values and SD	160	1.00	5.00	4.05	0.87

3.6. Descriptive analysis of students' perceived benefits of using instructional courseware

The effectiveness of the interactive multimedia approach was assessed using descriptive statistical analysis, examining mean and SD values to derive insights into its usefulness. The results shown in Table 6 indicate that the IMC had a positive impact on students' quantitative data analysis skills. Specifically, the courseware supported students' ability to process data, with a mean response of 3.48 and a SD of 0.95. The educational programs improved students' ability to create graphs from input data, with a mean of 3.69 and a SD of 0.85. The courseware significantly enhanced students' ability to generate frequency tables from input data, with a mean of 4.01 and a SD of 0.95. The tutorials were very effective in developing students' skills in generating descriptive statistics, such as mean and SD, with a mean of 4.02 and a SD of 1.00. The courseware significantly improved students' ability to interpret mean and SD values, with a mean of 4.07 and a SD of

0.90. The tutorials were effective in enhancing student's ability to relate two variables, with a mean of 3.92 and a SD of 0.84. The courseware was useful in improving students' interpretation skills for correlation values, with a mean of 3.86 and a SD of 0.97. Overall, the mean value for the benefits students derived from using the IMC was 3.86, with a SD of 0.92, indicating that the tutorials were highly beneficial in enhancing students' quantitative data analysis skills. The result shows that the IMC effectively enhances students' quantitative data analysis skills. It highlights the value of multimedia in improving engagement, retention, and data literacy. The findings support scaling such tools for broader educational use and refining courseware design to further enhance learning outcomes.

These results agree with the findings in the literature. The literature highlights the effectiveness of IMC in enhancing student learning across various disciplines. Research indicates that students who learn through the aid of multimedia materials show significant differences from those who learn through traditional means [22], [46]. Through increased student interest in learning and ability to innovate in multimedia teaching [47]. Further, studies show that such courseware improves engagement, retention, and achievement in subjects like programming [8] and data modelling [48]. Multimedia elements and interactive features contribute to positive learning attitudes and consistent improvement in educational goal attainment [27], [47], [49]. Research indicates significant improvements in post-test scores after using multimedia tutorials [48]. Conversely, although students perceived immersive virtual reality as interesting and motivational, it may not always lead to better learning outcomes compared to traditional methods but can supplement the traditional teaching methods [50]. As educational technology evolves, courseware development continues to adapt, incorporating diverse learning styles and game-based approaches across multiple fields, presenting both opportunities and challenges for educators in the digital age [51].

Table 6. Descriptive statistics of students' perceived benefits from IMC

Item	N	Min	Max	Means	SD
Data processing	160	1	5	3.48	0.95
Generate graphs	160	1	5	3.69	0.85
Frequency generation	160	1	5	4.01	0.95
Generate descriptive statistics	160	1	5	4.02	1.00
Interpretation of mean and SD values	160	1	5	4.07	0.90
Association between two variables	160	1	5	3.92	0.84
Interpretation of correlation values	160	1	5	3.86	0.97
Mean values and SD	160	1	5	3.86	0.92

The findings in this study communicate various vital implications to the stakeholders. In the first place, tailoring content to students' needs improves engagement and skill development. Educators should design multimedia content with clear learning outcomes aligned with student capabilities. Further, policies should support standards for audience-specific content, encourage multimedia use in curricula, and promote teacher training in instructional design. Finally, effective multimedia integration can enhance learning, therefore, institutions should consider scaling up its use to improve outcomes across broader student populations. Research on multimedia learning reveals mixed findings regarding its effectiveness and motivational impact on enhancing student engagement. Research on multimedia integration in education has shown promise for enhancing student engagement and learning outcomes [52]. While some studies found no significant improvement in learning performance, students reported positive perceptions of multimodal content, believing it aided comprehension and retention [40], [52]. Effective use of multimedia can create interactive, engaging learning environments that cater to diverse student needs [40].

On the contrary, immersive virtual reality may not always lead to better learning outcomes compared to traditional methods, due to several limitations in the implementation [50], and the effect on learning may not be long-lasting [53]. Therefore, combining audio and visual elements is key [40]. Kravchenko and Cass [25] demonstrated that transforming existing lecture content into interactive videos embedded in structured lesson designs can improve educational outcomes and student engagement. These findings suggest that while multimedia technology can be a valuable tool in education, its effectiveness for learner engagement, interaction and achievement of learning outcomes, depends on thoughtful integration with traditional teaching methods and active instructor involvement.

However, this study is limited to some extent. For instance, a self-report survey is the only primary data collection method used in this study. While self-report surveys are valuable for gathering personal insights, they are susceptible to several biases. Further, inaccurate self-assessment is another concern, as respondents may lack the necessary self-awareness to accurately report their skills assessed. Additionally, recall bias might have influenced responses, especially if participants struggled to accurately remember past exposure to the IMC. The study is limited to the specific discipline making it generalizable to similar situations except other disciplines. Thus, further research is needed to fully understand the impact of IMC on

learning, and consider variables such as student characteristics and learning environments to expand the scope [23], further using supplementary methods such as interviews, and observational data to mitigate the limitations in future research.

4. CONCLUSION

This study investigated the development and evaluation of the effectiveness of an IMC, designed to bolster students' quantitative data analysis competencies in a research context. The key objectives were to create an IMC program, to evaluate the suitability of the IMC in terms of instructional content, interactivity, user interface, and visual design, to profile students' perceived benefits of using the IMC to learn quantitative data analysis. The study offers an innovative, technology-enhanced learning tool that can be adapted for similar instructional contexts, hence supporting effective learning experiences. Further, offering valuable insights into how multimedia-based learning tools can improve student engagement, understanding, and performance in complex subjects. Finally contributing to the broader field of educational technology and instructional design, providing evidence for the potential benefits of multimedia interventions in quantitative research education. Therefore, the implication for the policy and practice, is that educators should design multimedia content with clear learning outcomes aligned with student capabilities. Further, policies should support standards for audience-specific content, encourage multimedia use in curricula, and promote teacher training in instructional design. Finally, institutions should consider scaling up its use to improve outcomes across broader student populations. Resulting of this study were limited to the faculty of education students and evaluated their quantitative data analysis skills. Future studies should focus on the impact of IMC on students' quantitative data analysis skills comprehensively in a multidisciplinary manner, more specifically considering variables such as student characteristics and learning environments to expand the scope, which could contribute greatly to the transformation of learning. Further supplementary data collection methods such as interviews and observations should be employed to mitigate the limitations in future research.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
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Va : **Va**lidation
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P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest, whether personal or financial.

DATA AVAILABILITY

The data supporting the findings of this study are available from corresponding author [ZA], upon reasonable request.

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