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Students' adoption and use of textbooks integrated with quick response codes for Geoscience animations in climatology at Mwenge Catholic University in Tanzania

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Research Article

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Abstract

Using a descriptive survey design and a questionnaire, this study examined undergraduate students' adoption and use of textbooks integrated with Quick Response codes for Geoscience animations in climatology at Mwenge Catholic University. The study was grounded on original Unified Theory of Acceptance and Use of Technology. Quantitative and qualitative data were collected, through online Google Form, from a population of 458 students who studied Climatology in 2025/2026 Academic Year. Quantitative data were analyzed through the Statistical Package for Social Sciences (version 22.0) and presented in contingency tables and histogram. Qualitative data were analysed thematically and presented in narrative form. Majority of students (60.9%) preferred textbooks integrated with Quick Response codes for animations, indicating strong performance expectancy. With respect to effort expectancy, majority of students perceived the technology as user friendly. Furthermore, majority of students (between 58% and 66%) had access to supporting conditions, including internet connectivity and electricity at the main campus. Few students faced barriers, including inadequate digital literacy skills, limited access to digital devices, and low English language proficiency. The study concludes that Quick Response codes have huge potential to enhance instruction in climatology in Tanzania. Lastly, stakeholders should develop policies to promote use of the technology.

Background to the Study

According to Law and So [1], Quick Response (QR) codes are digital encoding tools that store and deliver information rapidly through mobile scanning technologies. These pedagogical tools facilitate mobile learning (m-learning) through enhancement of accessibility, learner engagement and interactivity [2]. Pegged on experimental and system-development research design, Al-Khalifa [3]'s study revealed that students' acceptance of QR codes is shaped by technology's usefulness, accessibility, and simplicity of use.

Differences with respect to instructors' and students' adoption of QR codes in universities across the globe are explained by various factors including technological infrastructure, institutional support, economic systems and cultural practices as per the Technology Acceptance Model (TAM) and Diffusion of Innovations (DOI) [4, 5]. For instance, higher adoption rates in universities of North America, Europe, Asia and Middle East are largely explained by, inter alia, instructors' and students' perceived usefulness and ease of use of QR codes, post-pandemic (COVID-19) digital transformation, high smartphone penetration, systematic implementation of robust policy frameworks and institutional integration of QR codes into learning management systems and other administrative processes [6–8].

Rabu et al. [9] explored initial students' perceptions on the use of QR codes amongst 204 undergraduate students at Universiti Sains Malaysia during the 2017/2018 Academic Year. Among other things, the study largely revealed students' positive perceptions with respect to convenience, efficiency and speed in accessing relevant digital resources. In addition, the study revealed fewer negative perceptions with regard to unreliable internet connectivity, unfamiliarity with the technology and potential distractions.

Similarly, Albăstroiu and Felea [10] explored the use of QR codes in the Romanian higher education. Among other findings, the study revealed students' positive responses on the use of QR codes. Specifically, students appreciated the immediacy and convenience with respect to processes of accessing supplementary content including multimedia resources and additional readings.

Lower instructors' and students' adoption rates for QR codes in universities of Africa are largely explained by inadequate institutional support, poor internet connectivity, limited access to digital devices and low digital literacy [5, 11]. In the course of examining the role of innovative educational technologies in order to address digital divide in Africa,

Chasubuta et al. [12] and Tulinayo et al. [13] identified the following key barriers: 1) limited internet connectivity, 2) inadequate technological infrastructure, 3) insufficient access to digital devices, 4) high costs of data, 5) low educators' and students' digital literacy, 6) weak policy implementation, and 7) limited institutional support. However, increasing levels of internet accessibility and affordability in the continent are likely to significantly increase instructors' and students' adoption of CR codes in universities in the near future.

Considering the fact that teaching and learning of climatology in higher learning institutions of sub-Sharan Africa has largely been theoretical [14], several scholars recommended the use of QR codes in order to link classroom instruction with real-time climate-related information, including field-based case studies [15, 16]. Indeed, QR codes that are linked to up-to-date animations, geographic visualizations, interactive models, interactive laboratory exercises, datasets and videos are likely to enhance students' experiential learning encompassing, inter alia, hands-on activities, real-life problem-solving activities and virtual fieldwork. Drawing on France and Haigh [17], digital resources could support virtual fieldwork activities and experiential learning.

Pegged on the Multimedia Learning Theory [18], integration of textual and visual information (e.g. images and interactive elements), through QR codes, enhances students' understanding and retention. Moreover, QR codes can enhance students' cooperative learning and students' cognitive achievement as well as positive attitudes [19]. CR codes embedded in textbooks provide opportunities to enhance students' self-regulated learning [20] by connecting theoretical underpinnings of complex climatological concepts and processes with real-world settings.

Using a sample of 538 students from several universities the United States of America (USA), a study undertaken by Rockinson-Szapkiw et al. [21] revealed that university students who largely utilized e-textbooks had higher levels of self-regulated learning and engagement than ones who largely utilized print textbooks in a semester. In order to ensure successful use of CR codes by instructors and students in universities, stakeholders need to address technological, infrastructural and pedagogical challenges. With regard to the latter, for instance, instructors should use appropriate instructional designs, hence minimize redundant content and cognitive overload [22].

Climatology enables students to understand intricate environmental challenges including climate change and variability as well as increasing vulnerability in order to undertake robust mitigation and adaptation strategies for addressing risks and building societies' resilience. However, several challenges negatively affect teaching and learning of climatology in higher learning institutions of sub-Saharan Africa. These include: 1) inadequate financial resources for infrastructure (e.g. laboratories for Geographic Information Systems (GIS), climate models and data management systems with respect to digital infrastructure) and practical learning opportunities such as fieldwork [23], 2) inadequate well-trained and experienced instructors in the pedagogy of climate science [24], 3) complexity of nonlinear and intricate natural and human systems operating at different spatial-temporal scales [25], and 4) interdisciplinary nature of climatology spanning several disciplines, including chemistry, economics, geography, physics, and political science [25].

Other challenges that negatively influence teaching and learning of climatology in higher learning institutions of sub-Saharan Africa are: 4) over-reliance on lecture method and limited use of interactive strategies, including multimedia [26], 5) weak institutional support such as collaborations/partnerships [5], and 6) ideological, cultural and political constraints (including climate denial and vested interests) [27]. Such challenges contribute to, inter alia, students' cognitive overload, hence less engagement with climatological concepts/processes and limited development of critical-thinking and problem-solving competencies [22]. The use of QR codes in teaching and learning of climatology in universities of Africa would compensate for several challenges as presented above.

Specifically, textbooks integrated with QR codes for Geoscience animations support the Constructivist Learning Theory positing that students actively construct knowledge by integrating new information with prior experiences through meaningful engagement, social interaction, and reflection [28, 29]. In this regard, Geoscience animations enhance collaborative and experiential learning particularly in blended learning environment. Pegged on the Cognitive Load Theory, Geoscience animations can decrease extraneous cognitive load [22].

Statement of the Problem

Few empirical studies on the continent of Africa concentrated on general m-learning/ICT adoption and use rather than QR codes as an education tool [30]. For ones that examined QR codes as an education tool, they largely focused on adoption and use of administrative systems pertaining to payment, library, examinations and attendance as part of course management [31–34]. Fewer empirical studies focused on textbooks integrated with QR codes worldwide. For instance, AlNajdi [20] focused on designated technology with regard to the education system in Saudi Arabia.

Majority of undergraduate students who study climatology in universities of Africa rely on static printed textbooks. Textbooks that are integrated with QR codes for Geoscience animations in climatology are likely to enhance students' self-directed learning and engagement as well as blended learning settings. There is, however, scant information on students' levels of adopting and using QR codes for Geoscience

animations. To the best knowledge of the researcher, no studies have been undertaken on students' adoption and use of textbooks integrated with QR codes for Geoscience animations in universities globally.

Since internet penetration in Tanzania was recently approximated by the Tanzania Communications Regulatory Authority (TCRA) to be 85% and 5G coverage reached 30% of human population [35, 36], there is huge potential for universities in the country to enhance students' adoption and use of textbooks integrated with QR codes for Geoscience animations. In order to contribute to efforts of addressing this research gap, this empirical study was undertaken among first-year undergraduate students who studied climatology at Mwenge Catholic University (MWECAU) during the first semester for the 2025/2026 Academic Year.

Research Questions

1. How does performance expectancy influence undergraduate students' intention to adopt and use QR codes for Geoscience animations in climatology?
2. How does effort expectancy influence undergraduate students' intention to adopt and use QR codes for Geoscience animations in climatology?
3. How do facilitating conditions influence undergraduate students' intention to adopt and use QR codes for Geoscience animations in climatology?
4. What is the effect of social support on undergraduate students' intention to adopt and use QR codes for Geoscience animations in climatology?

Theoretical Framework

The theoretical framework for understanding university students' adoption and use of QR codes for Geoscience animations in climatology is pegged on the original Unified Theory of Acceptance and Use of Technology (UTAUT). Venkatesh et al. [37] developed UTAUT by integrating other eight theories on technology acceptance, including 1) TAM that explains how perceived usefulness and perceived ease of use influence students' adoption of new technologies [4], 2) Theory of Planned Behavior (TPB), developed by Ajzen [38], explaining students' intention to use technology as shaped by attitude, perceived social pressure and perceived control over access to and use of devices, and 3) Diffusion of Innovations Theory, developed by Rogers [39], explaining students' adoption and use of designated technology is shaped by constructs of relative advantage, compatibility, complexity, trialability and observability.

The original UTAUT posits that users' intention to adopt and their actual use of designated technology are shaped by the following constructs: 1) performance expectancy, 2) effort expectancy, 3) facilitating conditions, and 4) social influence. Specifically, performance expectancy refers to the extent to which students believe the use of QR codes for Geoscience animations would improve their learning outcomes while effort expectancy refers to the extent to which students perceive the use of a technology is simple and without challenges. Furthermore, facilitating conditions encompass, inter alia, internet connectivity,

access to appropriate devices, scanning applications for QR codes, support from institutional ICT, instructor's guidance and adequate digital literacy skills) while social influence is about the extent to which instructors and peers encourage the use of QR codes for Geoscience animations in climatology. Several studies in higher education revealed UTAUT's constructs significantly predicted students' adoption of interactive m-learning technologies [1, 40]. Though it was specified that this study is pegged on the original UTAUT [37], it is worth understanding that variables of habit, price value and hedonic motivation were added by Venkatesh et al. [41] in UTAUT2 in order to enhance the predictive power of the model on users' behavioural intention and use of digital and m-technologies.

Methodology

The descriptive survey design was deployed in order to investigate university students' adoption and use of QR codes for Geoscience animations in climatology through an interactive digital platform of Pearson's Mastering Meteorology. During the last decade, Pearson has been replacing traditional printed textbooks with adaptive online learning platforms, including MyLab, Revel, eText, and Mastering. This initiative is justified by the need for instructors and students to access resources that support professional development, instruction, and student engagement [42]. It is worth noting that Pearson is considered one of the largest academic publishers for university textbooks globally.

With regard to this study, Mastering Meteorology encompassed six (6) textbooks [15, 16, 43–46] with topics for teaching climatology/meteorology. Those resources form part of textbooks and reference books in the course outline for GEO 112 (Climatology). Throughout the first semester, the course instructor frequently demonstrated how to access and use QR codes in digital textbooks and stressed the need for students to do the same in order to, inter alia, easily enhance their critical-thinking and problem-solving skills.

The platform of Mastering Meteorology teach students to visualize complex climatological concepts and processes through simulations and animations, hands-on practice and real-world examples [47, 48]. Among other things, the platform provides video case studies from different sources including the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA), map-based tools (through GIS) for analyzing patterns of weather and climate as well as critical-thinking and problem-solving exercises with feedback.

Generally, each textbook contains about 100 QR code-linked animations from Geoscience Animation Library that enable students to visualize complex and dynamic climate-related Earth system processes such as atmospheric energy balance, cloud formation, Earth–Sun relationships, global circulation systems, moisture processes, temperature regulation, hydrologic cycling, ocean–atmosphere interactions, climate classification, landscape evolution, climate change mechanisms and climate variability mechanisms. For instance, one of Geoscience animations enable students to visualize Earth's energy imbalance due to uneven solar heating, being strongest at the Equator and weakest at the poles.

Among other drivers, the atmospheric circulation redistribute energy leading to creation of Hadley cells (as well as the Ferrel and Polar cells) and climate zones.

Before the commencement of data collection in the lecture hall on March 03, 2026, ethical clearance and permission to undertake the study were obtained from MWECAU's Directorate of Postgraduate Studies Research Innovations and Consultancy Committee. Within a fortnight before the administration of a pilot-tested survey questionnaire through Google Form and students' WhatsApp platforms, an announcement demanded each student to have a functioning smartphone and data bundle (about 100 MB) for the exercise in case of failure to access MWECAU's internet, currently at a speed of 200 mps. Few students who did not have designated devices and ones who could not open the link containing the instrument were allowed to borrow functioning gadgets from their colleagues.

Students were asked to indicate their registration numbers for purposes of identification and record-matching. The researcher treated all data collected during the study with highest level of confidentiality and strictly used them for research. Two (2) students, indicated as 'missing' in Table 1, did not accomplish the task due to sickness. Timestamp in Google Form reveals that 450 students (98.25%) filled out the instrument on March 03, 2026 and eight (8) students (1.75%) did the same on March 13, 2026, after the last remainder. According to Dillman et al. [49] as well as Evans and Mathur [50], online questionnaires are extensively used in higher learning institutions as they provide opportunities for efficient distribution, decrease data-entry errors and increase participants' response rates.

The International Business Machines Statistical Package for the Social Sciences (IBM SPSS Statistics) Version 22.0 was utilized during analysis of quantitative data from closed-ended questions. With respect to selected characteristics of students who filled out designated survey questionnaire, slightly more than one-half (53.7%) are females, one-half (50.4%) are pursuing Bachelor of Arts with Education (BAEd) and slightly less than one-third (29.6%) are pursuing Bachelor of Science with Education (BSEd) while one-fifth (19.6%) are pursuing Bachelor of Arts in Geography and Environmental Studies (BAGEN) (Table 1). With regard to 232 BAEd students who filled out the questionnaire, 105, 52, 45, 15, 12, 03, 01 are specializing in teaching subjects of Geography and Kiswahili (GK), Geography and History (GH), Geography and English (GE), Geography and French (GF), Geography and Economics (GECO), Geography and Literature (GL), and Geography and Divinity (GD), respectively. With respect to 136 BSEd who filled out the instrument, 100, 19, 12, 05 are specializing in Biology and Geography (BG), Chemistry and Geography (CG), Geography and Information Communication Technology (GEO ICT), and Geography and Mathematics (GM), respectively.

According to statistics issued by the Tanzania Commission for Universities (TCU) [51], female students dominate/closely match male students in clusters of education, humanities and social sciences for undergraduate programmes. These clusters are commonly viewed as socially focused fields that are socially and culturally considered appropriate for women [52]. To the contrary, male students dominate clusters of science, technology, engineering, and mathematics (STEM). This state-of-affairs is attributed to persistent gender stereotypes, unequal access to quality science education during earlier stages of

schooling, and socio-cultural norms that link technical and scientific professions more strongly with men than women. In this regard, Chen et al. [53] investigated how gender-role stereotypes impacted academic performance of Chinese high school girls in STEM. The study revealed that the relationship between stereotypes and academic achievement was mediated by educational aspirations.

Furthermore, slightly more than one-half (55.68%) of students had undertaken A-level/Diploma/Qualifying Test (QT) studies in a cluster of three regions, namely Manyara, Arusha and Kilimanjaro, in Northern Tanzania. This state-of-affairs is largely explained by close proximity. With respect to 156 students who had undertaken A-level/Diploma studies in Manyara Region, it is worth noting significant differences between its districts: Mbulu (85), Babati (55), Hanang' (13), Simanjiro (02) and Kiteto (01). Similarly, 68 students had undertaken A-level/Diploma studies in Arusha Region and the distribution in its districts is as follows: Arusha (61), Monduli (05), Karatu (01), Ngorongoro (01), and Longido (00). Basing on a distance-decay effect as explained by the Spatial Interaction Theory [54], few students had undertaken A-level/Diploma/QT studies in distant regions of western (Iringa, Katavi, Rukwa & Songwe) and southern (Lindi and Mtwara) Tanzania as well as regions in the islands of Zanzibar (Pemba South, Mjini Magharibi, Pemba North, & Unguja North).

With regard to measures of central tendency for ages of 457 students, the mean, median, and mode were 22.34, 22.00, and 21 years, respectively. With respect to measures of dispersion, the minimum age, maximum age, and standard deviation were, 19 years, 42 years, and 2.68, respectively.

Table 1
Selected characteristics of students who filled out GEO 112 survey questionnaire

Variables (Levels)	Frequency	Valid Percent
Students' sexes		
Female	247	53.7
Male	211	45.9
Missing	2	.4
Total	460	100.0
Programmes being pursued by students		
BAEd	232	50.4
BSEd	136	29.6
BAGEN	90	19.6
Missing	2	.4
Total	460	100.0
Regions where students pursued A-level or Diploma		
Manyara	156	33.9
Arusha	68	14.8
Kilimanjaro	31	6.7
Dodoma	22	4.8
Mwanza	22	4.8
Morogoro	19	4.1
Kagera	17	3.7
Pwani	16	3.5
Singida	11	2.4
Kigoma	10	2.2
Other 19 regions*	86	18.7
Missing	2	0.4
Total	460	100.0
Nota Bene: * Mbeya (9), Geita (9), Simiyu (9), Tabora (9), Tanga (9), Mara (6), Shinyanga (6),		

Iringa (5), Pemba South (4), Ruvuma (4), Katavi (4), Dar-es-Salaam (2), Lindi (2), Mjini

Magharibi (2), Mtwara (2), Pemba North (1), Rukwa (1), Songwe (1), and Unguja North

(1)

Source

Fieldwork (2026)

Based on a survey questionnaire, quantitative data were collected through closed-ended items (including Likert-scale and multiple-choice questions). Specifically, closed-ended items on frequency of using QR codes for accessing Geoscience animations in climatology are based on a four-point scale: 1 = daily, 2 = weekly, 3 = fortnightly, and 4 = monthly. Furthermore, quantitative data on levels of students' agreement to experiencing challenges of: 1) lacking time to search for relevant, high quality QR codes for Geoscience animations, 2) lacking technical skills to integrate animations smoothly into lessons, 3) poor internet connectivity/power supply disrupting the use of QR codes for Geoscience animations, 4) struggling to interpret abstract concepts shown in QR codes for Geoscience, and 5) preferring traditional teaching methods (for instance, maps and textbooks) over QR codes for Geoscience are based on a five-point Likert scale: 1 = strongly disagree 2 = disagree, 3 = neither disagree nor agree, 4 = agree, and 5 = strongly agree. Cronbach's alpha reliability analysis was undertaken, in IBM SPSS, for five (5) negatively worded Likert-scale items that measured students' levels of agreement. The analysis produced a Cronbach's alpha coefficient of .863, indicating a high level of internal consistency [55].

Apart from univariate analysis pertaining to measures of central tendency and dispersion in order to describe the population of students as summarized above, bivariate analysis was done in order to show interactions between two categorical (nominal/ordinal) variables as revealed in contingency tables (cross tabulation) with valid percentages. For instance, Tables 1, 2 & 3, on the first research question, show variations with respect to students' use of Geoscience animations in climatology by academic programmes, sexes, and age groups. Chi-square tests of independence were conducted in order to examine relationships between categorical variables. Incase significant associations were found, Cramér's V was computed in order to assess the strength of the relationship [55, 56]. However, results for Chi-square tests of independence were ignored when more than 20% of cells in contingency tables had expected counts of zero as per the commonly accepted rule of thumb [55].

With respect to statistically significant Chi-square results, Cramér's V was computed in IBM SPSS in order to establish the effect size, hence the strength of the relationship between categorical (nominal/ordinal) variables. Cramér's V values are interpreted as: 1) negligible when values are below 0.10, 2) weak when values are above 0.10 and below 0.20, 3) moderate when values above 0.20 and less than 0.40, and 4) strong when the value is 0.40 or higher [56].

Pegged on UTAUT [37], this study examined relationship between students' perceptions on adoption and use of QR codes for Geoscience animations (Tables 1, 2, 3, 4, 5, 6, 7, 8, 9 & 10) and their scores in a 40-item multiple-choice test that was administered during 40 minutes on February 26, 2026. The test, that included graph- and diagram-based items, was consistent with expected learning outcomes for GEO 112 (Climatology). The researcher utilized a test blueprint, based on Bloom's Taxonomy, in order to ensure balanced coverage of cognitive levels from basic knowledge to higher-order thinking skills [57].

Test items were accessed from credible sources including validated test-banks accompanying quality textbooks on climatology and meteorology and ones derived from peer-reviewed journal articles in order to enhance content validity. Specifically, test items covered the following areas in climatology/meteorology: 1) atmospheric composition and greenhouse effect, 2) atmospheric circulation and weather systems, 3) ocean–atmosphere interactions (ENSO, currents), 4) radiation, energy balance, and heat transfer, 5) ozone layer and atmospheric chemistry, 6) climate classification systems, 7) paleoclimatology and Earth history, 8) synoptic meteorology and weather analysis, and 9) climate change.

Each test item has a clear stem and plausible distractors as per established item-writing guidelines that ensure relevancy, clarity and measurement of meaningful expected learning outcomes [58]. The researcher ensured test items are free from bias and unnecessary technical jargon as recommended by Ebel and Frisbie [59]. Careful seating arrangement, spacing of candidates, active invigilation and use of multiple versions of the same test with different arrangement of items curtailed opportunities for students to engage in academic misconduct [60].

Students' scores, measured on a ratio scale, were summarized by computing measures of central tendency (mean, median & mode) and dispersion (range and standard deviation). The distribution of students' scores is presented in a histogram and a 3 x 3 contingency table that tabulated three programmes of BAGEN, BAEd, and BSEd constituting a nominal variable with three categories of test scores: 1) Below 16, 2) 17–25, and 3) Above 25 constituting an ordinal variable. Results for a Chi-square test were ignored since 37.5% of the six cells had expected counts less than 5 (minimum expected count = .19), hence a failure to satisfy one of key assumptions for the test [55, 61].

Findings and Discussion

Influence of performance expectancy on undergraduate students' intention to adopt and use QR codes for Geoscience animations in climatology

With regard to Research Question 1, the response pattern was predominantly skewed toward disagreement (60.9%) for 'strongly disagree' and 'disagree') on students' preference of traditional teaching methods (for instance, maps and textbooks) over QR codes for Geoscience animations (Table 2). A higher proportion of BAEd students (68.6%) disagreed compared to BAGEN students (53.3%) and BSEd students (52.9%). A Chi-square test of independence showed a statistically significant association between students' preference of traditional teaching methods (for instance, maps and

textbooks) over QR codes for Geoscience animations and academic programmes being pursued by students, $\chi^2(8, N = 458) = 18.22$, $p = .020$. With respect to the effect size, Cramer's V = .14 suggests a weak practical strength of the relationship. It is very likely that a large student population (458) increased test sensitivity.

Table 2: Students' preference of traditional teaching methods (for instance, maps and textbooks) over QR codes for Geoscience animations by academic programmes

Programmes		Scale					Total
		Strongly disagree	Disagree	ND/NA*	Agree	Strongly agree	
BAGEN	Count	21	27	11	20	11	90
	%	23.3%	30.0%	12.2%	22.2%	12.2%	100.0%
BAEd	Count	80	79	18	35	20	232
	%	34.5%	34.1%	7.8%	15.1%	8.6%	100.0%
BSEd	Count	37	35	7	35	22	136
	%	27.2%	25.7%	5.1%	25.7%	16.2%	100.0%
Total	Count	138	141	36	90	53	458
	%	30.1%	30.8%	7.9%	19.7%	11.6%	100.0%
Note: ND/NA* = Neither Disagree Nor Agree							

The findings suggest that majority of students consider QR codes for Geoscience animations to be more effective when studying climatological concepts and processes. According to Dajani and Abu Hegleh [40], several studies, pegged on UTAUT [37], revealed that performance expectancy significantly predicted individuals' behavioral intention to use digital technologies. Utilizing a sample of 495 respondents from Chinese universities, Teng et al. [62] revealed that performance expectancy significantly predicted students' sustained intention to use metaverse learning platforms in Chinese universities. Basing on a sample of 215 respondents, Gao et al. [63]'s empirical study revealed that performance expectancy significantly predicted individuals' sustained intention to use QR codes for mobile payment systems in China. Davis [4] explained that students are more likely to use QR codes when they believe that they would enhance learning efficiency. Additionally, use of QR codes is likely to enhance self-regulated learning amongst university students.

Furthermore, the findings revealed that disciplinary orientation shaped students' perceptions on the usefulness of QR codes for Geoscience animations in climatology. Compared to BSEd and BAGEN students, BAEd students revealed a greater tendency to reject traditional approaches of teaching, suggesting a stronger preference for technology-enhanced pedagogies. Such differences could be attributed to variations in digital literacy, pedagogical exposure, and curriculum focus across programmes. Using a sample of 1,032 undergraduate students in Turkey and the United Kingdom, an empirical study conducted by Kurt and Tingöy [64] revealed that pedagogical and disciplinary settings shaped behavioral intention and use of technology.

With respect to an open-ended question in a survey questionnaire on challenges experienced when adopting and using designated technology, several responses were typified by positive statements including *"animation is good for learning", "clear understanding,"* and *"no challenge"*. Such responses suggest that QR codes for Geoscience animations enhanced students' positive cognitive skills and visualization of climatological concepts and processes. It should be noted, however, that few respondents expressed difficulties in interpreting some abstract climatological concepts such as the Köppen system and diagrams. In this regard, responses included negative statements such as *"difficulty interpreting diagrams", "abstract concepts are hard to visualize"* and *"I don't understand animations"*. These findings suggest that academic readiness, prior knowledge and spatial reasoning skills influenced the extent to which students gained from QR codes for Geoscience animations.

Pertaining to students' learning outcomes when studying GEO 112 (Climatology) through textbooks integrated with QR codes for Geoscience animations, Fig. 1 reveals almost a standard normal distribution of scores for 450 students who did GEO 112 test on Thursday February 26, 2026 with a mean of 20.6, median of 20.0, and a mode of 20 as well as coefficients of .297 for skewness and .028 for kurtosis. Analysis of designated scores in a contingency table (Table 3) shows a higher proportion of BSEd students (16.2%) who scored above 25 compared to 15.6% for BAGEN students and 8.6% for BAEd students.

Additionally, a lower proportion of BSEd students (11.8%) scored below 16 compared to 12.2% for BAGEN students and 25.9% for BAEd students. It is very likely that increased students' engagement with QR codes, implying favourable performance expectancy in UTAUT, is associated with better performance in the designated test, while controlling for potential confounding variables such as study habits and prior academic ability. Similarly, Karia et al. [65] explained that the application of QR codes in healthcare strengthened students' engagement. However, results for a Chi-square test with respect to the current study were ignored since 25.0% of the three cells had expected counts less than 5 (minimum expected count = 1.57). According to the chi-square tests of independence, the assumption regarding expected cell frequencies was not satisfied, as more than 20% of the cells in the contingency tables had expected counts below the acceptable threshold [55].

on February 26, 2026

Table 3
Distribution of students' test scores for GEO 112 (Climatology) by academic programmes

Programmes		Categories of Test scores			Missing*	Total
		Below 16	17–25	Above 25		
BAGEN	Count	11	65	14	0	90
	%	12.2%	72.2%	15.6%	0.0%	100.0%
BAEd	Count	60	146	20	6	232
	%	25.9%	62.9%	8.6%	2.6%	100.0%
BSEd	Count	16	96	22	2	136
	%	11.8%	70.6%	16.2%	1.5%	100.0%
Total	Count	87	307	56	8	458
	%	19.0%	67.0%	12.2%	1.7%	100.0%

Note: Missing* Eight (8) students did not do the test on Thursday February 26, 2026 for different reasons, including sickness

Influence of effort expectancy on undergraduate students' intention to adopt and use QR codes for Geoscience animations in climatology

In response to Research Question 2, about three-fifths (58.1%) of students used QR codes for Geoscience animations in climatology, during the first semester for the 2025/2026 Academic Year, on daily basis. Differences in use of CR codes were observed across academic programmes. BSEd students reported highest level of use (72.8%), followed by BAGEN students (61.1%) while BAEd students reported lowest level of use (48.3%) on daily basis (Table 4). A Chi-square test of independence was conducted to examine the association between students' reported frequencies of using QR codes in climatology and academic programmes being pursued by students. The analysis revealed a statistically significant relationship, $\chi^2(6, N = 458) = 23.35$, $p = .001$. These findings suggest that there is a significant association between the variables. Though 16.7% of the cells had expected counts less than 5 (minimum expected count = 2.16), it is within acceptable thresholds, hence the findings are considered reliable. With regard to the effect size, Cramer's V = .16 suggests a weak practical strength of the relationship. It is very likely that a large student population enhanced the sensitivity of the statistical test.

Table 4
Students' frequencies and percentages of using QR codes for Geoscience animations in climatology by academic programmes

Programmes		Daily	Weekly	Fortnightly*	Monthly	Total
BAGEN	Count	55	22	1	12	90
	%	61.1%	24.4%	1.1%	13.3%	100.0%
BAEd	Count	112	82	8	30	232
	%	48.3%	35.3%	3.4%	12.9%	100.0%
BSEd	Count	99	26	2	9	136
	%	72.8%	19.1%	1.5%	6.6%	100.0%
Total	Count	266	130	11	51	458
	%	58.1%	28.4%	2.4%	11.1%	100.0%

Note: * Apparently, some students may not have understood the term "fortnightly," as the counts and percentages

reported for "Fortnightly" are consistently lower than those for "Monthly."

In terms of sexes, male students reported higher level of use (61.6%) and female students reported lower level of use (55.1%) on daily basis (Table 5). A Chi-square test of independence indicated no statistically significant association between students' reported frequencies of using QR codes in climatology and students' sexes, $\chi^2(3, N = 458) = 3.16$, $p = .368$.

Table 5
Students' frequencies and percentages of using QR codes for Geoscience animations in climatology by sexes

Students' sexes		Daily	Weekly	Fortnightly*	Monthly	Total
Female	Count	136	73	8	30	247
	%	55.1%	29.6%	3.2%	12.1%	100.0%
Male	Count	130	57	3	21	211
	%	61.6%	27.0%	1.4%	10.0%	100.0%
Total	Count	266	130	11	51	458
	%	58.1%	28.4%	2.4%	11.1%	100.0%

Note: * Apparently, some students may not have understood the term "fortnightly," as the counts and percentages

reported for "Fortnightly" are consistently lower than those for "Monthly."

Furthermore, students in the age-group of 24–42 years reported highest level of use (63.1%), followed by ones in the age-group of 19–21 years (58.4%) while ones in the age-group of 22–23 years reported lowest level of use (55.9%) (Table 6). Results for a Chi-square test were ignored since 43.8% of the seven cells had expected counts less than 5 (minimum expected count = .02).

Table 6
Students' frequency of using QR codes for Geoscience animations in climatology by age groups

Age Groups		Daily	Weekly	Fortnightly*	Monthly	Total
19–21	Count	115	60	3	19	197
	%	58.4%	30.5%	1.5%	9.6%	100.0%
22–23	Count	109	53	7	26	195
	%	55.9%	27.2%	3.6%	13.3%	100.0%
24–42	Count	41	17	1	6	65
	%	63.1%	26.2%	1.5%	9.2%	100.0%
Missing	Count	1	0	0	0	1
	%	100.0%	0.0%	0.0%	0.0%	100.0%
Total	Count	266	130	11	51	458
	%	58.1%	28.4%	2.4%	11.1%	100.0%

Note: * Apparently, some students may not have understood the term "fortnightly," as the counts and percentages

reported for "Fortnightly" are consistently lower than those for "Monthly."

Majority of responses (55.5% for 'strongly disagree' and 'disagree') indicated a concentration toward disagreement on students struggling to interpret abstract concepts shown in Geoscience animations (Table 7). A higher proportion of BAEd students (60.4%) disagreed compared to BAGEN students (51.1%) and BSEd students (50.0%). A Chi-square test of independence revealed no statistically significant association between students struggling to interpret abstract concepts shown in Geoscience animations and academic programmes being pursued by students, $\chi^2(8, N = 458) = 5.81$, $p = .669$.

Table 7
Students struggled to interpret abstract concepts shown in Geoscience animations by academic programmes

Programmes		Scale					Total
		Strongly disagree	Disagree	ND/NA*	Agree	Strongly agree	
BAGEN	Count	21	25	10	23	11	90
	%	23.3%	27.8%	11.1%	25.6%	12.2%	100.0%
BAEd	Count	60	80	22	48	22	232
	%	25.9%	34.5%	9.5%	20.7%	9.5%	100.0%
BSEd	Count	31	37	12	39	17	136
	%	22.8%	27.2%	8.8%	28.7%	12.5%	100.0%
Total	Count	112	142	44	110	50	458
	%	24.5%	31.0%	9.6%	24.0%	10.9%	100.0%

Note: ND/NA* = Neither Disagree Nor Agree

Furthermore, the response pattern was predominantly skewed toward disagreement (71.0% for 'strongly disagree' and 'disagree') on students' lack of time to search for relevant, high quality QR codes for Geoscience animations (Table 8). A higher proportion of BAEd students (74.6%) disagreed compared to BAGEN students (66.7%) and BSEd students (67.6%). The Chi-square test of independence was undertaken in order to assess differences between designated groups of students. In this regard, the test revealed a statistically significant association between students' lack of time to search for relevant, high quality QR codes for Geoscience animations and academic programmes being pursued by students, $\chi^2(8, N = 458) = 19.23$, $p = .014$. All expected cell counts exceeded 5, implying that the assumptions of the Chi-square test were met. However, Cramer's V = .14 suggests a small practical effect of the relationship. Probably, a large student population made the statistical test more sensitive.

Table 8
Students' lack of time to search for relevant, high quality QR codes for Geoscience animations by academic programmes

Programmes		Scale					Total
		Strongly disagree	Disagree	ND/NA*	Agree	Strongly agree	
BAGEN	Count	25	35	8	16	6	90
	%	27.8%	38.9%	8.9%	17.8%	6.7%	100.0%
BAEd	Count	61	112	22	21	16	232
	%	26.3%	48.3%	9.5%	9.1%	6.9%	100.0%
BSEd	Count	49	43	7	27	10	136
	%	36.0%	31.6%	5.1%	19.9%	7.4%	100.0%
Total	Count	135	190	37	64	32	458
	%	29.5%	41.5%	8.1%	14.0%	7.0%	100.0%

Note: ND/NA* = Neither Disagree Nor Agree

With regard to effort expectancy, the findings presented in Tables 4, 5, 6, 7, and 8 revealed that undergraduate students generally perceived QR codes for Geoscience animations as user-friendly when studying climatology. It is very likely that visual and engaging features of animations may have decreased students' cognitive demands, hence improved students' comprehension of complex climatological concepts and processes. In this respect, gender did not substantially shape effort expectancy. Studies that were undertaken by Abubakari et al. [66] and Ayite et al. [67] revealed a narrowing digital gender divide among university students with regard to adoption and use of educational technologies. Correspondingly, Dajani and Abu Hegleh [40] established effort expectancy as a significant predictor of university students' behavioural intentions to use animations.

Considering findings emanating from an open-ended question on challenges faced when adopting and using the designated technology, some respondents indicated difficulties in understanding scientific terminologies, English terminologies and fast narrations as used in animations. Also, some respondents admitted that they lacked technical skills to operate digital devices thus negatively affecting effort expectancy under UTAUT. It is worth noting that most of the students in Tanzania study English as the second language (after a vernacular) or third language (after a vernacular and Kiswahili language).

These observations correspond with studies conducted in Tanzanian universities which identified limited ICT competence and language proficiency as barriers to effective engagement with digital learning technologies [68, 69]. Specifically, 32 students, about 7% of 458 students who filled out the questionnaire, indicated that they had undertaken QT studies before pursuing university studies.

According to Magembe [68] and Nalaila et al. [69], most of the university students in Tanzania who had undertaken QT studies face a myriad of challenges including: 1) difficulties in social adjustment within universities, 2) financial constraints, 3) inadequate academic preparedness, 4) inadequate institutional/academic support systems, 5) insufficient information and communication technology (ICT) competence, and 6) limited English language proficiency. By extension, limited proficiency in English language within universities of Tanzania significantly decrease students' abilities to communicate and engage in classroom activities, including ones pertaining to the use of digital technologies.

Influence of facilitating conditions on undergraduate students' intention to adopt and use QR codes for Geoscience animations in climatology

Responses were largely concentrated in the disagreement categories (66.2% for 'strongly disagree' and 'disagree') on students' lack of technical skills to integrate QR codes for Geoscience animations smoothly into lessons (Table 9). A higher proportion of BAEd students (71.1%) disagreed compared to BAGEN students (55.6%) and BSEd students (64.7%). Based on the construct of facilitating conditions under UTAUT, majority of respondents have adequate digital skills to adopt and use QR codes for Geoscience animations. A Chi-square test of independence revealed no statistically significant association between students' lack of technical skills to integrate QR codes for Geoscience animations smoothly into lessons and academic programmes being pursued by students, $\chi^2(8, N = 458) = 10.64$, $p = .223$.

Table 9
Students' lack of technical skills to integrate QR codes for Geoscience animations smoothly into lessons by academic programmes

Programmes		Scale					Total
		Strongly disagree	Disagree	ND/NA*	Agree	Strongly agree	
BAGEN	Count	18	32	12	19	9	90
	%	20.0%	35.6%	13.3%	21.1%	10.0%	100.0%
BAEd	Count	71	94	14	33	20	232
	%	30.6%	40.5%	6.0%	14.2%	8.6%	100.0%
BSEd	Count	40	48	15	23	10	136
	%	29.4%	35.3%	11.0%	16.9%	7.4%	100.0%
Total	Count	129	174	41	75	39	458
	%	28.2%	38.0%	9.0%	16.4%	8.5%	100.0%

Note: ND/NA* = Neither Disagree Nor Agree

The response pattern was predominantly skewed toward disagreement (58.0%) for 'strongly disagree' and 'disagree') on poor internet connectivity/power supply disrupting the use of QR codes for Geoscience animations (Table 10). A higher proportion of BAEd students (59.9%) disagreed compared to BAGEN students (53.3%) and BSEd students (58.1%). A Chi-square test of independence revealed no statistically significant association between poor internet connectivity/power supply disrupting the use of QR codes for Geoscience animations and academic programmes being pursued by students, $\chi^2(8, N = 458) = 3.17$, $p = .924$. Considering the construct to facilitating condition under UTAUT, majority of respondents did not experience poor internet connectivity/power supply as barriers to adopting and using QR codes for Geoscience animations in climatology.

Table 10
Poor internet connectivity/power supply disrupted the use of QR codes for Geoscience animations by academic programmes

Programmes		Scale					Total
		Strongly disagree	Disagree	ND/NA*	Agree	Strongly agree	
BAGEN	Count	22	26	12	19	11	90
	%	24.4%	28.9%	13.3%	21.1%	12.2%	100.0%
BAEd	Count	54	85	21	44	28	232
	%	23.3%	36.6%	9.1%	19.0%	12.1%	100.0%
BSEd	Count	35	44	16	24	17	136
	%	25.7%	32.4%	11.8%	17.6%	12.5%	100.0%
Total	Count	111	155	49	87	56	458
	%	24.2%	33.8%	10.7%	19.0%	12.2%	100.0%

Note: ND/NA* = Neither Disagree Nor Agree

Pegged on UTAUT, majority of students were positive to MWECAU's conditions with regard to enhancement of technical skills, internet connectivity and power supply. Several empirical studies revealed that facilitating conditions (for instance, access to learning management systems, availability of smartphones, digital literacy training, institutional technical support, and reliable internet connectivity) explained significant proportion of variance in university students' behavioural intention to integrate m-learning technologies into their studies [8, 70]. However, thematic findings emanating from an open-ended question on challenges faced when adopting and using QR codes for Geoscience animations in climatology at MWECAU revealed technological barriers to some students. Students' responses include lack of digital devices (such as smartphones, laptops and computers), network failure, poor or unstable internet connectivity, lack of data bundles due to financial constraints, and unreliable electricity supply.

With respect to enhancement of digital literacy, students and instructors at the main campus have access to ICT infrastructure, including Computer Centre in ICT laboratories and the main library containing, inter alia, e-resources. Furthermore, first-year undergraduate students, pursuing different academic programmes, are taught GST 102 (Basic Computer Application), which equips them with foundational computer knowledge and practical skills. Since MWECAU's main campus is connected to Tanzania's fibre-optic and fixed broadband internet network at a speed of 200 mps as rendered by Tanzania Telecommunications Corporation (TTCL), instructors and students freely access online learning resources at selected locations within the main campus and can actively participate in e-learning activities through the eCampus platform. Also, there is a high-capacity standby generator to ensure sustained electricity supply at the main campus during power outages from the national electricity provider, Tanzania Electric Supply Company Limited (TANESCO).

Nevertheless, majority of students at MWECAU reside off campus, hence more likely to experience limited internet connectivity and unreliable power supply.

Influence of effort social support on undergraduate students' intention to adopt and use QR codes for Geoscience animations in climatology

Considering thematic findings emanating from an open-ended question on challenges faced when adopting and using QR codes for Geoscience animations in climatology, few respondents wrote phrases on the need to enhance students' group work/group discussions during GEO 112 (Climatology) lessons. This state-of-affairs suggests that many students did not face serious challenges pertaining to social support when studying the designated course and, by extension, when adopting and using textbooks integrated with QR codes in climatology.

It is worth noting that MWECAU provides support services to students in order to foster conducive learning environment in accordance with designated standards and guidelines issued by TCU [71], the regulator. Within a period of five (5) years, MWECAU prepare and submit an institutional self-assessment report to TCU on implementation of various academic and non-academic activities including ones related to social support. Besides, the Higher Education Students' Loans Board (HESLB) works closely with TCU and universities in Tanzania to ensure appropriate allocation of loans to bona fide students, including ones from underprivileged communities. According to Mosenda [72], 252,773 university students were expected to access, through HESLB, loans amounting TSh 916.7 billion (approximately US$353 million) during the 2025/2026 Academic Year.

Through implementation of an open-door policy, MWECAU offer, inter alia, guidance and counselling services, academic advisors' services and career development services to students. In order to enhance students' welfare, several social support services are rendered to students through the Dean of Students' Office and the students' Government named Mwenge Catholic University Students' Organization (MWECAUSO). Several health-related challenges of students are addressed at MWECAU's Health Centre. Furthermore, students access sport-related facilities including football pitches and basketball courts within the university. With regard to spiritual wellbeing, there is a Roman Catholic Church within the main

campus as well as churches for other denominations and mosques in vicinities of MWECAU. However, it should be understood that majority of students at MWECAU reside off campus, hence more likely to experience inadequate social support including limited access to university welfare services, inadequate academic group discussions, and insecurity.

Conclusion

The findings based on a survey questionnaire revealed that majority of university students had positive perceptions on performance expectancy, effort expectancy, facilitating conditions, and social support with regard to actual usage of textbooks integrated with QR codes for Geoscience animations in climatology. Compared to static printed textbooks, majority of students found textbooks integrated with QR codes for Geoscience animations to be useful, easy to use, and were adequately supported. The agreement between quantitative and qualitative findings validate the applicability of original UTAUT in explaining university students' acceptance of m-learning technologies.

Recommendations

Pegged on findings and conclusions, this study recommends stakeholders of higher education, including administrators of regulatory bodies (e.g. TCU), administrators of universities, curriculum developers and policymakers, to develop policies, standards and guidelines that promote instructors' and students' adoption and use of high-quality climate-related textbooks containing QR codes that combine print content and interactive multimedia resources. Additionally, designated policies should provide opportunities to enhance collaborations between universities and other stakeholders in order to ensure availability of reliable digital learning infrastructure (including internet connectivity and mobile-device accessibility) to instructors, students and other stakeholders in higher education. Specifically, designated policies should provide opportunities for universities to collaborate with internet service providers in order to ensure off-campus students access academic resources linked to QR-codes either freely or at cheaper prices.

At practice level, universities should regularly train instructors and students on pedagogical use of

QR-supported textbooks and encourage them to effectively utilize designated digital resources during teaching and learning activities in order improve, inter alia, classroom instruction and fieldwork activities in climatology. Such capacity-building initiatives will enhance instructors' and students' performance expectancy and effort expectancy on usage of textbooks integrated with QR codes in climatology, and by extension, other science-related courses. Besides, universities should address technical barriers some students face and ensure they access internet connectivity and compatible digital devices and peer collaboration for social support.

Declarations

Declaration of Participant Consent Students who studied GEO 112 (Climatology) were informed about the objectives, methods/processes as well as potential risks and benefits pertaining to the study before their participation. All participants signed designated consent forms and were assured that their responses would be handled with strict confidentiality and complete anonymity. Additionally, the study was undertaken in accordance with MWECAU's ethical research standards as overseen by MWECAU's Directorate of Postgraduate Studies Research Innovations and Consultancy Committee.

Competing interests

The author declares no competing interests.

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Author contributions

F.B. conceptualized the study, conducted the literature review, collected and analyzed the data, presented the findings, interpreted and discussed the findings, and prepared and revised the manuscript.

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Figures

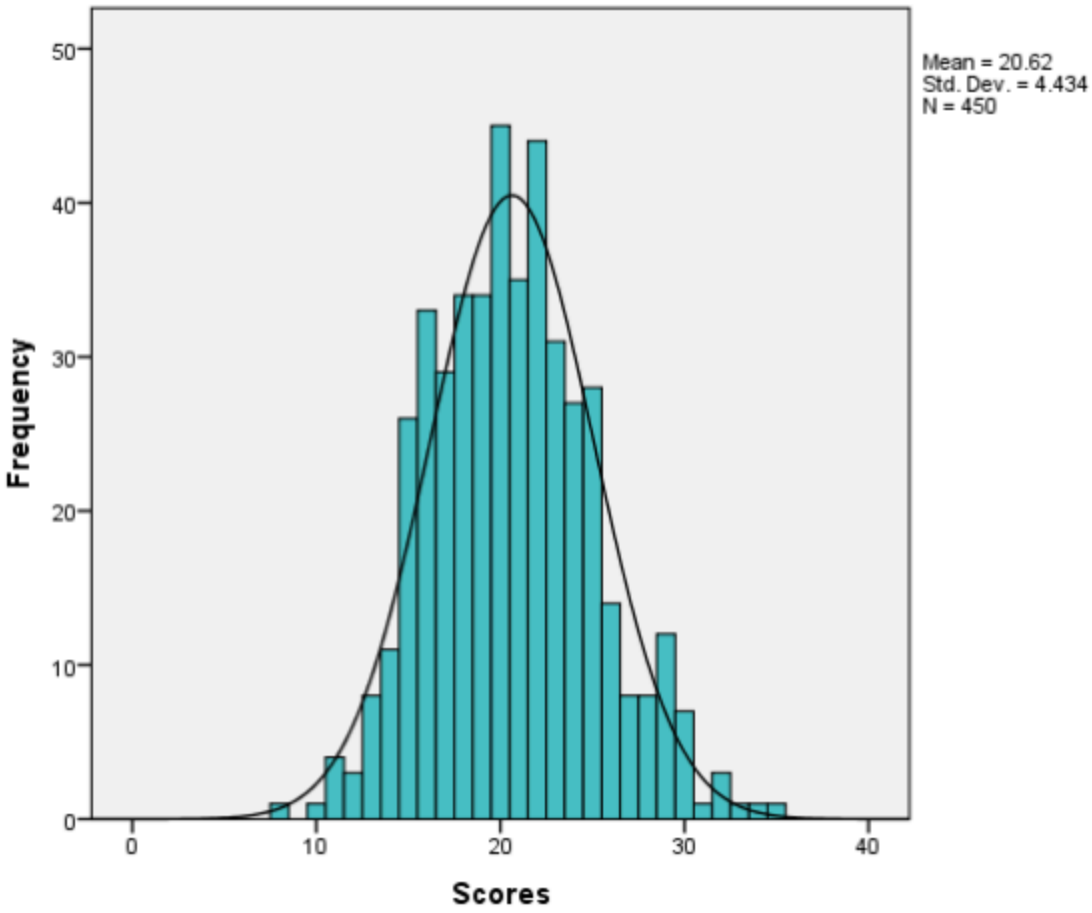


Figure 1

Distribution of students' scores for GEO 112 (Climatology) Test administered on February 26, 2026