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Intentionality and Players of Effective Online Courses in Mathematics

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Mathematics is the engine, vehicle, driver, and language of today's initiatives, innovations, and human endeavors. In this mathematical-driven world, the ability to perform mathematical tasks and logical reasoning is also essential in solving quotidian tasks and problems. Therefore, mathematical competency and problem-solving skills are kept as an integral component in almost every educational curriculum around the globe. However, there are numerous stumbling blocks along the way to successful teaching, conducive learning environment, and good student performances in almost all disciplines, but more prevalent and visible in mathematics. The major concerns of educators responsible for teaching mathematics and mathematics-related courses are to find effective and innovative ways to deliver mathematical content, to extend the concepts and theories beyond the classrooms, to integrate mathematics with important concepts such as gamification, data mining, learning analytics, deep learning, and effective tools such as mobile devices, learning management systems, and digital technology, and to maintain a good record of students' performance. In online deliveries, these concerns are further escalated due to no or limited one-to-one interactions and lack of face time, to mention a few. This article investigates the efficacy and effectiveness of traditional and innovative pedagogical practices used in online mathematic courses at the University of the South Pacific (USP). It examines the interdependence of embedded activities and students' achievement. The results indicate that these online mathematics courses were highly dominated by conventional approaches and were less interactive and engaging, resulting in lower success rates when compared to the courses from other disciplines. To recommend possible ways to enhance the quality of learning and teaching in online mathematics courses, selected online courses from the information system discipline were explored. The reasons for the high online presence in the course were investigated and activities that could lead to collaborative and active learning beyond the passive materials were data mined. The evidence drawn from the statistical analysis highlights the importance of including selected interactive and engaging activities in online learning space of mathematics courses to promote student engagement and help create a sense of community among geographically dispersed students. Overall, based on the observations and theoretical foundation from literature, it can be said that including regular and frequent active assessment strategies, such as weekly quizzes and discussion forums, could extend and promote interactive and engaging learning in online learning space.

Keywords: student interactions, online learning, mathematics, pacific, effective assessment

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INTRODUCTION

The education landscape has recently been revolutionized with the advancements in Information and Communication Technologies (ICT). The infusion of ICT in education has expanded the educational environment from physical locations to the virtual learning space, hence transforming the modality from face-to-face or chalk-and-talk learning to ICT-driven learning with new models and pedagogies, offering more accessibility to the educational opportunities, with greater flexibility at lower costs [1, 2]. Incorporating the appropriate ICT tools and technologies has also enabled educators to deliver complex and intricate concepts in innovative and creative ways, while also using the tools to track their students and make data-driven changes to content and delivery and maintain sound records [3–5]. For example, the use of assistive technologies, edutainment, gamification and more recently blockchain technology [6, 7] and smart learning tools are reported to enhance the learning experience and knowledge creation of students while maintaining sound record keeping and security of payments for the administrators [8, 9]. In addition, effective use of smartphones, tablets, and mobile apps makes it possible to facilitate formative feedback in classrooms and especially making a huge impact in higher education in developing countries ([10–13]). Thus, ICT is becoming a major factor in contemporary education.

On the other hand, although online learning is cost-effective, affordable, scalable, innovative, student-centered, and convenient, there are considerable challenges, in terms of teaching pedagogy, learning enhancement, cybersecurity, cheating and plagiarism, student engagement, and success rate, that need to be addressed with the adaptation of online learning environment [14]. Due to the intrinsic characteristics of the online context, instructors are often challenged to find effective ways to foster student learning and engagement in online courses. Selecting appropriate tools, resources, and materials for online environment is a tedious task, and most of the educators end up adapting and utilizing face-to-face instructional strategies and pedagogies [14], thus enforcing traditional learning in the online context. To a certain extent, such a one-size-fits-all approach is acceptable for blended or hybrid course deliveries where there are some one-to-one instructor-student interactions [14, 15]. However, traditional paradigms and perspectives are not very successful in online instructional programs, and these require more student engagement, interaction, and student-centered pedagogical approaches [15–17]. Similarly, earlier studies examining the efficacy of online learning over traditional learning present contradictory observations. Some studies suggest there are no significant differences between both modalities [18]. On the other hand, some studies indicate that the students in online courses are less likely to complete with a passing grade than students in similar traditional courses [16]. Researchers report poor time-management, poor digital literacy, affordances, minimized student-instructor instructions, student preference and attitude, and personal characteristics as a few of the various reasons for low success and high attrition rates in online courses [19].

In the South Pacific, ICT integrated pedagogies, eLearning and mLearning are popular in HEI. Researchers have reported that the use of technologies in education has extended and enriched educational opportunities for those seeking further education in the Pacific region [8, 20, 21]. Technology-supported pedagogies in the South Pacific region have also been used to facilitate student learning and content delivery efficiently and conveniently [1, 8, 22]. Even though the Pacific Island countries differ in their technological capacities and infrastructure, mobile devices, especially mobile phones and tablet computers, are being used by learners and educators around the Pacific region to access, share, and manage information [3]. Researchers have also found that secondary school students in the South Pacific region are generally competent in using ICT devices and have good digital skills and experience despite poor access to ICT [20, 23]. Moreover, during the recent COVID-19 pandemic in the region, universities lessened the impact of educational disruption by continuing education remotely over the internet and keeping their students' learning on track while keeping them safe and healthy at home. Nevertheless, studies conducted in the South Pacific region have also shown that the underlying issues and challenges in online learning are the same compared to the rest of the world [9, 15].

Likewise, similar challenges are faced by teachers of mathematics in online mode [16]. Mathematics teachers lack proper technological training by the institutes to execute online teaching of mathematics using innovative strategies or design courses for online delivery mode. Furthermore, the mindset of learners from childhood, especially those that are academically challenged in calculations, is that mathematics is difficult to comprehend. This, in turn, leads to a lack of interest in learning mathematics and provides the notion that it is the most challenging subject. Since these students already face so many difficulties in face-to-face mathematics classes, it will be very far-fetched to assume that they will acclimatize to learning mathematics effectively in online mode. The onus is thus on the teacher to teach mathematics in creative ways to inculcate the students' interest and broaden their knowledge to enhance learning mathematics as a subject. Therefore, this motivates to analyze online mathematics courses and suggest appropriate instructional and assessment strategies to build an interactive and cohesive online learning environment for students.

This research presents a case study from The University of the South Pacific (USP), where interaction data and course achievement of selected mathematics courses are investigated to identify and document which course assessments highly associate with the final performance. Also, selected courses from information system discipline are examined to make possible recommendations to enhance interactivity and collaborative and active learning in mathematics courses. Educators can refer to the observations documented in this research, if the need arises to switching course from face-to-face to virtual classrooms, or online platforms, or while designing new online mathematics courses.

This study is organized as follows: Section *Background* documents the background of this research, together with the theoretical foundations from the current literature, Section *Literature Review* describes the research data and method applied to this research; results of analysis and observations are discussed in Section *Methodology*, and recommendations and conclusions are documented in Sections V and VI.

BACKGROUND

The University of the South Pacific (USP) is the regional university in the Pacific region that promotes distance and flexible learning through its online courses. The university is spread across 33 million square kilometers of ocean in the region of the South Pacific. It is known for providing quality teaching and research consultation in an economically and culturally diverse region [3, 24]. The governments of 12 member countries jointly own USP—the Cook Islands, Fiji Islands, Kiribati, Marshal Islands, Nauru, Niue, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, and Vanuatu—and facilitate flexible learning in a variety of modes across 14 campuses in the region. The regional campuses are linked through their own telecommunication system known as USPNet, and courses are offered and delivered through the university's official learning management system [20]. Due to the unique geographical composition of USP across the Pacific region, the university has invested considerable time and effort in online, blended, and cohort-based programs such as eLearning, mLearning, Online Mathematics Diagnostic Test (OMDT), Science Teachers Accelerated Programme (STAP), Early Warning System (EWS), Lecture Capture, Faculty Online Orientation Tool (FOOT), and Tablet Learning Project (TLP) to support teaching and learning processes in the Pacific Region [1, 13, 22].

Since the emergence of eLearning, mLearning, and tablet learning in the region, the university has invested considerable time and effort to appropriately include aforementioned pedagogical methods into their mainstream teaching and learning processes, especially in literacy and mathematical courses as these courses are perceived as challenging and difficult and have continuously recorded low pass rates among students enrolling at university [25]. Even though remediation programs like OMDT, ELSA, peer-assisted learning, and peer mentoring are available to bridge the literacy gap and ensure a smoother transition into the university, educators are trying to foster and facilitate effective student learning and experience in their courses.

Accordingly, this research evaluates two previously offered online mathematic courses offered at USP and analyses the effectiveness and efficiency of deployed assessment tools to find possible ways to maximize student learning and interaction at tertiary level education.

LITERATURE REVIEW

In the current digital era, human intelligence, logical reasoning, and problem-solving abilities are still the most crucial components, in fact, more important than machines and mechanism, in solving daily day-to-day and complex problems [26]. While different subjects in education have their essence and importance and construct different skills and capabilities, Mathematics is the only cross-disciplinary subject that deals with critical thinking, analytical thinking, problem-solving, and quantitative reasoning, thus promoting intelligence development and cognitive thinking. Nonetheless, while confronting complexities and myth regarding this discipline, delivering mathematical concepts and theories has always been a challenging and overwhelming task for mathematics teachers.

Over the last few years, the advancement in information and communication technologies has strengthened and enhanced mathematics teaching and learning. The availability of smart tools and devices has enabled instructors to impart analytical, numerical, and computational concepts and theories in interactive and innovative ways [8]. There are several qualitative pieces of evidence in the current research body concerning the impacts and benefits of infusing ICT in mathematical pedagogies. These include improvement in learner's performance [27], increase in enthusiasm and curiosity in mathematics [27, 28], creation of active and authentic learning environment [29, 30], and expansion of creativity and critical thinking skills [27], thus leading to constructive learning and higher-order thinking [31], while also improving learner's learning attitudes and experiences [31].

eLearning and mLearning in Mathematics Education

With ubiquitous access to technology and internet, many universities and educational institutions are incorporating eLearning practices in their mathematical learning and teaching processes—implementing collaborative and conducive learning environment for their students and enabling administrators and educators to design, report, automate, and deliver mathematical content innovatively and interactively, anytime, from anywhere [8, 29]. A recent study by [32] investigating the effectiveness of the eLearning practices in teaching mathematics, which is seen to be significantly increased during the COVID-19 restrictions and precautionary measures, revealed that use of the e-learning methods has a positive influence on motivation, autonomy, participation, mathematical concepts, results, and grades. Nonetheless, incorporating eLearning in mathematics learning and teaching processes is not a recent act, previously [29] have proposed and explained the mathematical eLearning model, using open source eLearning platform, for making mathematical learning more interesting, meaningful, and applicable to the learners beyond the classroom knowledge. A study by [33] has also shown that the mathematic learning management tool is an effective and efficient solution for improving creative thinking in solving mathematical problems and enhancing students' mathematical ability. Similarly, [34] found that an eLearning system for mathematics education could detect and resolve mathematical misconceptions, as a result, and improve students' attitude and acceptance towards mathematical content.

Moreover, mobile technology leveraged learning, also known as mLearning, in mathematics education is also gaining momentum all around the world, and this is because the use of mobile technologies in education offers more mobility, accessibility, and flexibility to both students and academics [8, 30, 35]. More specifically, it provides access to learning from anywhere and anytime, lets HEI to extend their educational opportunities, enables students to broaden their technological awareness, assists students with disabilities, and motivates learners for lifelong learning [3, 35]. Previously, researchers have published promising results of integrating mLearning in education, especially in mathematics. A study conducted by [36], one of the earliest works found in literature, investigating the impact of mobile-assisted mathematics teaching to preschool kids, showed a positive learning effect on the tested pupils. Reference [30] in Malaysia also found that implementing mobile learning in mathematics education at primary school can be convenient and effective for students to explore mathematical concepts independently and access content and materials wirelessly. Similarly, [35] found a positive and significant relation between mLearning and students' participation in Mathematics, and the use of mobile technologies for learning purposes could increase students' motivation and participation in mathematics learning.

In the South Pacific, the track of education is also gradually transitioning towards technology-enabled learning. There has been an increasing interest in integrating smart technologies and tools into learning and teaching processes in the higher education sector in the Pacific [3, 8, 9]. A survey administered by [37] in Fiji to fifty-five selected educators from the three educational institutes revealed that the educators strongly value the contribution of ICT in improving their teaching and enhancing students' learning and experience. Similar research conducted by [38] in Tonga, to identify, analyze, and document teachers' perceptions of ICT usage, showed that most participants strongly desire to use ICT or are regularly utilizing them in their teaching practices. From the student perspective, a study conducted by [39] on students from agriculture, fisheries, and forestry disciplines at one of the HEI in Fiji revealed that underexamined students had a positive attitude towards ICT and were using them to facilitate learning. Paper [20] investigated digital status and satisfaction of 945 learners and 116 instructors with their online learning environment also revealed digital skills and experience among young learners despite their poor access to ICT instead of instructors with better access. A recent case study investigating student readiness and perception of tablet learning in Fiji and Tuvalu, published by [3], has shown that the participants perceived that tablet devices are effective and innovative learning tools. On the other hand, [40] found that ICT driven learning/instructional materials could enhance student's learning experience and knowledge retention. All in all, the integration of digital technologies has influenced the education sector in the South Pacific region.

Issues and Challenges in Mathematics Education in the Region

While HEI in the Pacific region, including USP, are embracing the ubiquitous technologies to provide high-quality education across the region [8, 41], the educators involved in the learning and teaching processes of mathematics are challenged to alleviate the issues and shortfall of mathematics. A declining trend in mathematic performance and achievement in secondary schools, lack of motivation and interest towards the subject, inability of students to apply mathematical skills and concepts, and inappropriate and ineffective teaching pedagogies and learning environment are a few of the main issues and challenges stressing mathematics educators in the region [42].

The continuous low success rate in national mathematics examinations at higher secondary schools in the region has always been a key concern of educators and the government authorities responsible for education in their countries. In 2019, the secondary schools in the Fiji Islands recorded the lowest success rates in the Year 13 external mathematics examination, causing disappointment and frustration among parents and educators. Previously, the mathematics success rate in national exams was 42 percent in 2015 and 15 percent in 2014 [25]. The mathematic pass rate in Samoa has also been fluctuating since 2013, dropping from 40 percent to 1 percent in 2014—only 16 out of 1,369 Samoan students passed in Year 13 examination, and in 2018 less than 15 percent passed [43], indicating the existence of a weak mathematical foundation and knowledge. Tonga is not spared from the mathematic crisis as well, reporting a drastic drop in pass rate in the secondary entrance examination, dropping from 31 percent to 17 percent during the period 2002–2014 [44], and recently recorded an overall success rate of 27 percent for the Tonga school certificate [45]. Similar situations may have been seen and left unreported in other smaller island nations. Nonetheless, when students from different mathematical backgrounds join the HEI, educators and administrators at the institute are expected to bridge numeracy and literacy gaps and ensure a smoother transition into the professional industry.

Students' attitudes and interests play critical roles in achievements and performance in mathematics; however, students perceive learning mathematics as difficult, boring, and not relevant to their future daily practices [46]. There is an agreement in the literature that learners' interest and attitude towards mathematics and their performance and achievements are directly related. A preliminary study conducted by [46] on 150 students examining the association between the students' attitude and interest towards mathematics, students' perception on mathematic pedagogies and the subject itself, and their mathematics performance found that there is a moderately significant relationship between students' perception of mathematics and their mathematics performance. Article [47] also concluded that there is a significant relationship between interest and mathematics performance among Malaysian students who had lower mathematics performance, and igniting interest among low-performing students could lead to better performance. Study [48] revealed that the students' interest is one of the contributing factors in successful academic performance while [49] stated that interest in mathematics learning could be regarded as a predictor of mathematics achievement. On the other hand, [50] published their analysis showing students' confidence directly influences students' interest in the learning of mathematics, whilst mathematics anxiety and students' knowledge of the usefulness of mathematics also impact students' confidence and motivation. Previously, [51] also found that mathematics self-efficacy and mathematics anxiety significantly affect mathematics performance in Malaysia and Singapore. Consequently, as students' attitudes and interests can be fostered with learning and teaching pedagogies [27], mathematics teachers are striving to rekindle interest and energy in their teaching environment, encourage towards mathematic learning, and offer the world-class learning experience to their students.

Substantial evidence has been published and documented in the literature concerning the impact of teaching styles and strategies in the learning and teaching environment on students' interest, understanding of a subject, and academic performance. Research [52] found that teachers' teaching style has a positive and significant effect on students' motivation and learning achievement. Reference [53] also presented results indicating an association between students' motivation and teachers' teaching style. Even though the evidence is available on the impact of teaching styles on academic achievement, views on effective and efficient teaching styles are contradictory and inconclusive. Study [54] reported that traditional teacher-centered strategies have a positive and significant effect on student achievement, while modern strategies are concentrated in high achieving students. On the other hand, the results published by [55] showed that modern teaching practices are strongly related to student achievement than traditional methodologies. Nonetheless, the onus is on educators and course designers to ensure the right and effective learning environment for their learners, create meaningful opportunities for active and conducive learning, and strategically enhance learners' achievement in the subject.

METHODOLOGY

For this research, two [2] different online courses were used from the mathematics discipline to investigate the degree of association between engagement and performance and the effects of student interaction on academic performance in mathematics (MA) courses. Also, two [2] online courses from Information System (IS) discipline were utilized to derive possible recommendations to improve the success rate in online courses; thus, in total, four [4] courses were used in this study. These courses were offered within the School of Computing, Information & Mathematical Sciences (SCIMS), under the Faculty of Science Technology and Environment (FSTE), using Moodle learning platform. The two [2] consecutive offerings of each identified course were considered to investigate in detail the success of deployed resources in terms of student engagement and interactions and to deeply study the association between embedded activities and students' achievements. Each course included a variety of customized activities to provide a multidimensional learning experience. The details of the courses are presented in **Table 1**.

For each identified course, three [3] sets of data—class list, final grades, and Moodle logs—were extracted from the USP databases. Before the data collection and analysis, ethical clearance was attained from the University Research Ethics Committee. Later, the Learning & Teaching (L&T) office of the Faculty of Science, Technology and Environment (FSTE) provided the class list and grades in CSV format. Simultaneously, the section responsible for Moodle at the Centre for Flexible Learning (CFL) was requested for interaction logs. The logs were given in the SQL format and detailed every interaction a student made within a particular course shell. The logs were processed and queried on a local server, and, later, all three sets were combined into one excel sheet for statistical analysis. **Table 2** lists seventeen [17] course-related variables included in the combined file of a particular course. The number of variables was dependent on the number of activities and resources deployed in a course; thus, the number of variables varied for every discipline course.

Once the final dataset was achieved, the dataset was imported into the Statistical Package for Social Sciences (SPSS) application to examine the association between students' interactions and their performance using correlation. First, Kolmogorov–Smirnov and Shapiro–Wilk tests were conducted to assess the normality of the data and to select the most appropriate statistical measure for finding the correlation coefficient. The hypothesis for these tests was as follows:

$\mathbf{H_0}$: the data follow a normal distribution.
$\mathbf{H_1}$: the data do not follow a normal distribution.

The level of significance selected for this research was $p < 0.05$ level, and inferences were made based on this level of significance; that is, if the p-value is less than the significance level, then the null hypothesis is rejected, and the data is not considered to be normally distributed; otherwise null hypothesis is accepted, and the data follow a normal distribution.

The effectiveness of the activity is evaluated considering students' presence and engagement in that activity. Courses were inspected to identify the effective assessments for the online learning environment and to answer these listed questions:

1. Is there a correlation between student interaction and performance (activity performance) in online activities?
2. Is there a correlation between each activity performance and overall performance (collective assessment)?
3. Is there a correlation between student interaction in each activity and overall performance (final achievement)?
4. Is there a correlation between collective assessed activities and overall performance?

Later, the results were combined and documented in a single table to show whether or not variables are interdependent. Results for each course is documented and discussed in the subsequent sections.

FINDINGS AND DISCUSSION

This section documents the findings of this study based on the evidence gathered due to the discussed methodology. **Tables 3–6**

TABLE 1 | List of discipline courses selected for this research.

Course code	Course title	Discipline	Semester offered	Class count
MA111	Calculus I and linear algebra I	Mathematics	Semester 1, 2018	116
			Semester 1, 2017	75
MA112	Calculus II	Mathematics	Semester 2, 2017	72
			Semester 2, 2016	33
IS121	Information systems I	Information systems	Semester 1, 2018	72
			Semester 1, 2017	126
IS122	Information systems II	Information systems	Semester 2, 2017	32
			Semester 2, 2016	50

TABLE 2 | List of course-related attributes.

Attribute name	Description
NumAssignInteractions	Total no. of interactions with assignment dropbox
TotalAssignMarks	Total assignments marks
NumQuizInteractions	Total no. of interactions with quiz activity
TotalQuizMarks	Total quiz marks
NumTestInteractions	Total no. of interactions test quiz
TotalTestMarks	Total test marks
NumLabInteractions	Total no. of interactions with lab dropbox
TotalLabMarks	Total lab marks
NumForumInteractions	Total no. of interactions with discussion forum
TotalForumMarks	Total discussion forum marks
NumResourceViews	Num. of time resources viewed
NumCourseViews	Num. of time course page viewed
TotalCourseInteraction	Total number of interactions with course shell
TotalCourseWork	Collective course assessment marks
OverallCourseMarks	Final course achievement

TABLE 3 | Kolmogorov–Smirnov and Shapiro–Wilk tests results for MA111 (Sem 1, 2017).

	Kolmogorov–Smirnov[a]			Shapiro–Wilk		
	Statistic	df	Sig	Statistic	df	Sig
Course achievement	0.120	75	0.010	0.938	75	0.001
Overall achievement	0.112	75	0.021	0.966	75	0.041
Overall interactions	0.178	75	0.000	0.656	75	0.000

[a]*Lilliefors significance correction.*

TABLE 4 | Kolmogorov–Smirnov and Shapiro–Wilk tests results for MA112 (Sem 2, 2017).

	Kolmogorov–Smirnov[a]			Shapiro–Wilk		
	Statistic	df	Sig	Statistic	df	Sig
Course achievement	0.113	72	0.023	0.957	72	0.015
Overall achievement	0.070	72	0.200[b]	0.983	72	0.419
Overall interactions	0.087	72	0.200[b]	0.974	72	0.137

[a]*Lilliefors significance correction.*
[b]*This is a lower bound of the true significance.*

tabulate the results of the normality assessment of one of the offerings of each selected discipline courses, carried out using Kolmogorov–Smirnov and Shapiro–Wilk tests. The

TABLE 5 | Kolmogorov–Smirnov and Shapiro–Wilk tests results for IS121 (Sem 1, 2018).

	Kolmogorov–Smirnov[a]			Shapiro–Wilk		
	Statistic	df	Sig	Statistic	df	Sig
Course achievement	0.204	72	0.000	0.841	72	0.000
Overall achievement	0.193	72	0.000	0.868	72	0.000
Overall interactions	0.105	72	0.046	0.912	72	0.000

[a]*Lilliefors significance correction.*

TABLE 6 | Kolmogorov–Smirnov and Shapiro–Wilk tests results for IS122 (Sem 2, 2017).

	Kolmogorov–Smirnov[a]			Shapiro–Wilk		
	Statistic	df	Sig	Statistic	df	Sig
Course achievement	0.130	32	0.187	0.964	32	0.348
Overall achievement	0.092	32	0.200[b]	0.960	32	0.271
Overall interactions	0.168	32	0.022	0.959	32	0.251

[a]*Lilliefors significance correction.*
[b]*This is a lower bound of the true significance.*

Kolmogorov–Smirnov (p-value < 0.05) and Shapiro–Wilk (p-value < 0.05) test results suggested that *overall interactions*, *course achievements,* and *overall achievements* were not all normally distributed at the same time. Therefore, the statistical dependence between the variables was calculated using Spearman's correlation coefficient and documented and discussed in the following sections.

Analysis and Discussion on Mathematics Courses

Tables 7, 8 list correlation coefficient values obtained for both MA courses, using Spearman's correlation coefficient. Spearman's correlation coefficient denoted as r_s, is a statistical measure of the strength of a monotonic relationship between any given two variables. The value of r_s lies between −1 and +1, where a value equal to 0 means that there is no association between the given data attributes, values greater than 0 confirms the existence of a positive relation, and a value less than 0 indicates a negative relation.

The first research question investigated the link between the students' engagement with activity and the corresponding gained

TABLE 7 | Spearman's correlation coefficients for Calculus I and Linear Algebra I (MA111). The first column lists the research questions, the second column lists the interdependent attributes (interactions and marks in utilized activities), and the last two columns list the calculated correlation values for two consecutive deliveries of MA111 course.

Research questions		Sem 2, 2017	Sem 1, 2018
		***r*(70)**	***r*(114)**
Is there a correlation between student interaction and performance in online activities?	a. Assignment dropbox interactions and assignment marks	+0.168	+0.348
	b. Quiz interactions and quiz marks	+0.379	+0.582
Is there a correlation between each activity and overall performance (CW)?	a. Assignment dropbox interactions and CW marks	+0.184	+0.371
	b. Quiz interactions and CW marks	+0.469	+0.428
Is there a correlation between student interaction in each activity and overall performance?	a. Assignment dropbox interactions and overall marks (assessed)	+0.257	+0.310
	b. Quiz interactions and overall marks (assessed)	+0.420	+0.399
	c. All forum interactions and overall marks (nonassessed)	+0.519	+0.397
	d. Course view and overall marks (nonassessed)	+0.374	+0.269
	e. Resources and overall marks (nonassessed)	+0.217	+0.369
Is there a correlation between collective assessed activities and overall performance?	a. Course work and overall performance	+0.904	+0.877
	b. Overall course interactions and overall performance	+0.428	+0.452

TABLE 8 | Spearman's correlation coefficients for Calculus II (MA112). The first column lists the research questions, the second column lists the interdependent attributes (interactions and marks in utilized activities), and the last two columns list the calculated correlation values for two consecutive deliveries of MA112 course.

Research questions		Sem 1, 2016	Sem 2, 2017
		***r*(31)**	***r*(70)**
Is there a correlation between student interaction and performance in online activities?	a. Assignment dropbox interactions and assignment marks	+0.447	+0.168
	b. Quiz interactions and quiz marks	+0.393	+0.379
	c. Homework activity interactions and homework activity marks	+0.447	+0.304
Is there a correlation between each activity and overall performance (CW)?	a. Assignment dropbox interactions and CW marks	+0.338	+0.184
	b. Quiz interactions and CW marks	+0.408	+0.469
	c. Homework activity interactions and CW marks	+0.566	+0.317
Is there a correlation between student interaction in each activity and overall performance?	a. Assignment dropbox interactions and overall marks (assessed)	+0.359	+0.257
	b. Quiz interactions and overall marks (assessed)	+0.354	+0.420
	c. Homework activity interactions and overall marks (assessed)	+0.301	+0.350
	d. All forum interactions and overall marks (nonassessed)	+0.088	+0.519
	e. Course view and overall marks (nonassessed)	+0.147	+0.374
	f. Resources and overall marks (nonassessed)	+0.190	+0.217
Is there a correlation between collective assessed activities and overall performance?	a. Course work and overall performance	+0.605	+0.904
	b. Overall course interactions and overall performance	+0.248	+0.428

marks. Assignment and quiz activities were the only two assessed activities utilized in MA111 course, whereas MA112 additionally included assessed Homework Activities (Forum). Results indicate that there is a positive and statistically significant relationship (p-value < 0.05) between the student engagement and the gained marks in all the offerings of both courses; however, these relationships are weak as the Spearman's correlation coefficient is between 0 and +0.5. Also, a point to note here is that despite these courses were offered fully online with no or limited face-to-face student-educator interactions, very limited assessment tools were used in these courses and overall achievement was heavily relying on the end of the semester assessment. Instead, the literature suggests including and integrating multiple interactive assessment tools well-spread during the duration of the course to create more opportunities to monitor and assess students' learning [56–61] and result in a more engaging and academically rich learning environment [59].

The second research question looked at how interaction in each activity relates and contributes to the performance in continuous assessments. In all the examined offerings of MA111 and MA112, online activities showed a statistically weak positive relation (Spearman's correlation coefficient $< +0.5$), hence justifying the major reason behind the low success rates in online MA courses. Since student interaction and engagement is critical in online education [17, 59, 61], it can be inferred that students are failing to perform well in these online

MA courses due to poor engagement and presence in the online learning space. In addition, an odd conclusion can be inferred that the assessment strategies used in these courses were not sufficient enough to derive any information on students' success at the early stages of the course as none of the employed activities strongly associates with the overall achievement (excluding end of the semester assessments). Nonetheless, existing studies in the literature suggest that increasing the number of activities in an online course positively influences student engagement and student success [61, 62]. Therefore, course designers could regularly consider including additional assessment tools to improve the learning and students' experience in the online learning environment.

The third research question was to verify the effectiveness of activity in student engagement and overall achievement. Again, in both courses, none of the embed activities strongly relate to the overall performance as the Spearman's correlation coefficients for all assessed and nonassessed attributes including course views, forum, and resource interactions were between 0 0 and +0.5+0.5. Forum activities in MA111 and MA112 courses offered in the year 2017 show a statistically strong relation with final performance; however, it does not link overall success in other offerings. The reason for such unexpected behavior is that forum activities in these courses were nonassessed supplementary activities and were used for general queries and weekly announcements. However, the literature emphasizes integrating forum discussions and weekly chat discussions to extend the classroom learning and facilitate learner-to-learner interactions [58, 60, 63].

The last research question studied the linkage between the collective assessed activities and the overall performance. The two attributes contributing to this relationship are the total course interactions and course performance. The results show that the continuous assessments in all the offerings of the examined mathematics courses have a significant strong relation to students' performance and final grade achievement, with the correlation coefficient greater than 0.5; therefore, it is reasonable to claim that collective assessment during the semester directly contributes to the overall performance. On the other hand, results indicate that there is a weak positive association between total interactions and the final achievement in the investigated offerings of MA courses as the obtained correlation coefficient values are less than 0.5. The reason is quite obvious that both of these courses contained very limited assessments tool. Therefore, there are limited opportunities for online engagement. In addition, other factors affecting the students' performance and engagement in these courses may include the complexity and nature of the discipline [58], students' attitude towards learning and assessments [17, 61], and usage of limited active resources [56, 62]. In online courses, where student participation and engagement are critical, educators are discouraged from integrating passive resources. Instead, they are advised to recognize the value of engagement and its role in student retention and success in the online learning environment [63]. Lastly, since regular and frequent assessments can ultimately increase engagement and learning in the online learning environment [56–61], course planners and instructors of these courses could consider including more assessment tools. Learning contracts, interactive lectures, small projects, collaborative assignments, case studies, discussion forums, portfolios, self-assessments, peer evaluations, and weekly assignments with immediate feedback are few of the effective assessment techniques for the online learning environment [58–60, 63]. Hence, underinvestigated courses should be relooked and revised to promote engaging and active learning.

Recommendations

Recommendations for enhancing student engagement and performance in the examined online mathematics courses are derived from the findings recorded during the analysis of successful online IS courses offered by the same faculty within the same learning management system, thus eliminating assumptions regarding the technological resources and opportunities. These recommendations are also backed with the theoretical foundations from the current literature. **Tables 9, 10** tabulate Spearman's correlation coefficient values recorded for both IS courses, namely IS121 and IS122.

Analysis and Discussion on Information System Courses

First, the results obtained for the first research question indicate that there is a positive and statistically significant relationship (p-value < 0.05) between student engagement and the gained marks in all the deployed assessment activities. Both courses commonly included assignment submissions, lab submissions, and quiz activities, while IS121 also utilized forum activities for weekly discussions and homework activities. It should be noted that the lab submissions were weekly assessments where students were asked to complete a set of tasks and submit every week to document their learning and academic competence. Among all deployed assessment activities, lab submissions had the strongest positive relation with $r_s \geq +0.5$ in all the offerings of examined IS courses. Moreover, in IS121, weekly discussions and weekly homework activities, which were implemented using forum activities, also have consistent moderate positive relation across the offerings. Based on these observations, it could be concluded that weekly and frequent assessments could lead to a more academically rich learning space [56–61]. Literature also suggests that deploying multiple assessments during course progression produces better learning than assessing learners at the end of the semester [61, 62]. Researchers have also found that incorporating weekly forum activities discussions in online courses promotes cooperative and collaborative learning. At the same time, it also provides opportunities to assess whether students understand and interpret the acquired knowledge [58, 60, 63]. Since frequencies of activities in an online course have a positive influence on student engagement and student success, it is highly recommended for mathematic courses to include various assessment strategies regularly and avoid heavily relying on end of semester examination.

Moreover, the second research question results indicate a positive relationship between the interaction in deployed

TABLE 9 | Spearman's correlation coefficients for Information Systems 1 (IS121). The first column lists the research questions, the second column lists the interdependent attributes (interactions and marks in utilized activities), and the last two columns list the calculated correlation values for two consecutive deliveries of IS121 course.

Research questions		Sem 1, 2017	Sem 1, 2018
		***r*(124)**	***r*(70)**
Is there a correlation between student interaction and performance in online activities?	a. Assignment dropbox interactions and assignment marks	+0.369	+0.657
	b. Lab dropbox interactions and lab marks	+0.756	+0.778
	c. MST quiz interactions and MST marks	+0.535	+0.737
	d. Homework forum interactions and homework activity marks	+0.646	+0.570
	e. Weekly forum interactions and forum marks	+0.693	+0.528
	f. Quiz interactions and quiz marks	+0.270	+0.706
Is there a correlation between each activity and overall performance (CW)?	a. Assignment dropbox interactions and CW marks	+0.447	+0.690
	b. Lab dropbox interactions and CW marks	+0.609	+0.718
	c. MST quiz interactions and CW marks	+0.532	+0.551
	d. Homework forum activity interactions and CW marks	+0.623	+0.698
	e. Weekly forum interactions and CW marks	+0.615	+0.635
	f. Quiz interactions and CW marks	+0.594	+0.701
Is there a correlation between student interaction in each activity and overall performance?	a. Assignment dropbox interactions and overall marks (assessed)	+0.496	0.677
	b. Lab dropbox interactions and overall marks (assessed)	+0.629	+0.723
	c. MST quiz interactions and overall marks (assessed)	+0.519	+0.543
	d. Activity forum interactions and overall marks (assessed)	+0.689	+0.736
	e. Weekly forum interactions and overall marks (assessed)	+0.691	+0.640
	f. Quiz interactions and overall marks (assessed)	+0.600	+0.645
	g. Course view and overall marks (nonassessed)	+0.577	+0.682
	h. All forum interactions and overall marks (nonassessed)	+0.641	+0.695
	i. Lessons interactions and overall marks (nonassessed)	+0.183	+0.581
	j. Resources and overall marks (nonassessed)	+0.442	+0.507
Is there a correlation between collective assessed activities and overall performance?	a. Course work and overall performance	+0.770	+0.951
	b. Overall course interactions and overall performance	+0.600	+0.771

TABLE 10 | Spearman's correlation coefficients for Information Systems 2 (IS122). The first column lists the research questions, the second column lists the interdependent attributes (interactions and marks in utilized activities), and the last two columns list the calculated correlation values for two consecutive deliveries of IS122 course.

Research questions		Sem 2, 2016	Sem 2, 2017
		***r*(48)**	***r*(30)**
Is there a correlation between student interaction and performance in online activities?	a. Assignment dropbox interactions and assignment marks	+0.570	+0.474
	b. Lab dropbox interactions and lab marks	+0.562	+0.834
	c. Quiz interactions and quiz marks	+0.427	+0.771
Is there a correlation between each activity and overall performance (CW)?	a. Assignment dropbox interactions and CW marks	+0.711	+0.631
	b. Lab dropbox interactions and CW marks	+0.735	+0.534
	c. Quiz interactions and CW marks	+0.520	0.472
Is there a correlation between student interaction in each activity and overall performance?	a. Assignment dropbox interactions and overall marks (assessed)	+0.654	+0.595
	b. Lab dropbox interactions and overall marks (assessed)	+0.696	+0.639
	c. Quiz interactions and overall marks (assessed)	+0.537	+0.500
	d. Course view and overall marks (nonassessed)	+0.679	+0.516
	e. All forum interactions and overall marks (nonassessed)	+0.531	+0.560
	f. Resources and overall marks (nonassessed)	+0.242	+0.483
Is there a correlation between collective assessed activities and overall performance?	a. Course work and overall performance	+0.910	+0.791
	b. Overall course interactions and overall performance	+0.609	+0.684

activities and continuous course achievement. More specifically, in both offerings of IS121, interactions with any embedded activity except assignment submission, namely, lab submissions, weekly quiz activities, Mid Semester Test (quiz activity), homework activities (implemented using forum activities) and weekly forum discussions (forum activities) moderately or strongly correlate with the performance in course, documenting correlation coefficients r_s greater than

+0.5 (p-value <0.05). On other hand, in IS122, only lab submissions ($r_s \geq +0.5$, p-value <0.05) and assignment submissions ($r_s \geq +0.6$, p-value <0.05) moderately correlated with the course achievement. The literature's theoretical foundation and practices also suggest that frequent assessment with immediate feedback is expected to lead to more satisfactory student success during course progression [58–60, 63]. Researchers have also found that projects, portfolios, self-assessments, and peer evaluations could result in more authentic learning and engagement [58, 60, 64]. Therefore, educators and course designers of MA courses should consider including assessments like lab submissions and forum activities on a weekly basis and offer multiple occasions for learning and assessing. Also, including self-assessment and peer assessment activities in their courses could make students responsible for their learning, increase their confidence, and encourage levels of higher-order thinking.

Furthermore, the third research question investigating the association between the interactions in any particular activity and the overall performance in IS courses also reported a positive relationship between these paired variables. However, among all the deployed activities, lab submissions had a significantly high association with overall academic achievement of $r_s \geq +0.5$ in all offerings of the examined IS courses. In addition, in both courses, quiz activities and forum activities also strongly correlate with the final performance ($r_s \geq +0.5$, p-value < 0.05). It is worth noting that, in IS121, forum activities are assessed activities and contributing towards the final grade, whereas, in IS122, Forum activities are nonassessed. Nonetheless, studies in the current literature also found that using forum activities and chat discussions in online courses could lead to an interactive and engaging learning environment. Also, it can quickly indicate whether or not students are participating and engaging in online courses. Similarly, in the past, other researchers have also reported a positive relation between quizzes and the performance of students studying at the tertiary level [65]. It was found that quiz activities have great pedagogical value [65] as it measures the learner's retention of course information and quickly provides informative feedback to both the educator and the learner about their academic excellence. Also, frequent and repeated quizzing is more effective than repeated reading [65], because learners are more actively retrieving and processing information in a quiz than in passive reading.

Lastly, unlike MA courses, total course interactions and course performance (course work) both positively correlate with final achievement with correlation coefficients of $r_s \geq +0.6$ (p-value < 0.05) and $r_s \geq +0.7$ (p-value < 0.05), respectively. This is because IS courses included more frequent activities than MA courses, thus providing more opportunities for engagements and interactions, and course achievement during course progression directly links to final performance [57, 61]. It can be inferred that since these courses are interactive and engaging, the success rate is remarkably high. As far as student interactions are concerned in MA courses, students' engagement in an online learning space can be boosted by including weekly activities. Hence, the final recommendation for MA courses is to revise these courses and replace passive materials with a variety of interactive and engaging resources to support various learning styles and to improve the quality of online learning ultimately. Also, student-student and student-instructor collaboration using compulsory engaging activities like weekly discussion forums and peer evaluations could promote an engaging and active learning environment.

To conclude, MA courses require strategic revisions to accelerate active learning and engagement. Implementing the recommendations mentioned above will result in a more academically rigorous and engaging learning environment and assist educators in improving their teaching methods and maximizing student learning, which is essentially the core objective behind this research.

CONCLUSION AND FUTURE WORK

Given the importance of mathematics, in promoting creativity, logical reasoning, and cognitive thinking; in translating and representing facts and figures; and in providing basic skills and capabilities for acquiring knowledge from other subjects and fields, it is included as a core subject in almost all educational curriculum around the globe. However, low success rate and high dropout rate in mathematic courses, especially in the higher education settings, have always been a major concern of educators and faculties, as these create a barrier to degree completion. The complexity and nature of the discipline, lack of motivation and enthusiasm, and students' attitude towards the subject are some of the key issues seen by the individuals involved in learning and teaching mathematics. This situation gets more complicated and challenging in the online learning environment as there is no direct medium for monitoring and measuring how well learners have received the intended learning, i.e., limited or no synchronous interaction. As a result, educators are often pressured to deliver mathematical concepts and content interestingly and effectively and mitigate the underlying challenges of discipline and the online environment. This necessitated research to gain a better understanding of current practices and make a possible recommendation to improve the effectiveness and quality of course in terms of student learning and engagement.

Analyzing two first-year online mathematics courses allowed investigating the quality of online teaching, online students' quality and ability, and the effectiveness of deployed strategies. The preliminary pieces of evidence from the statistical analysis of MA courses suggest that course engagement and interaction is positively related to the quality of online education and final achievement; however, this relation is statistically weak. Therefore, to maximize interactions and engagements in these courses, a different set of courses from IS discipline that were offered within the same school utilizing the same ICT resources were selected and analyzed, even though both disciplines fall in different domains and follow quite different pedagogical paradigms; that is, the objective of IS courses is to develop technical and personal skills necessary for effective IS professionals. However, MA courses focus on enhancing computational ability and reasoning in solving a variety of mathematical problems, inspirations, and recommendations which could be derived on how to use available ICT resources and improve delivery approaches to promote a conducive online learning environment. In the view of obtained results, it can be inferred that the IS discipline courses were more engaging and interactive as compared to the MA discipline ones, because IS courses included weekly assessments to keep their learners engaged and a variety of other active assessment strategies, such as quizzes and discussion forum, to continue, extend, and assess learning and not delay these till the end of the examination. Therefore, the recommendations for MA courses are to include more active resources to enhance the students' learning beyond the passive materials, incorporate a variety of assessment tools and strategies to create multiple opportunities to engage and interact, and assess students' learning and knowledge retention frequently through weekly or fortnightly assessments.

Since this research only focused on the effectiveness and efficiency of utilized assessment tools in terms of interactivity and performance and investigated only two online mathematics courses, it is recommended to further investigate and validate the findings in other mathematic courses and consider other academic and nonacademic factors which could influence students' interactions and performance such as students' characteristics and motivation, demographic characteristics, socioeconomic status, and technological incompetency. Future research could also explore how additional learning support services such as e-Mentoring, online workshops, and study sessions could enhance and extend students' learning experience in MA online learning space. Nonetheless, the conclusion and recommendations inferred from this study are based on the observations from the current dataset, and, in future studies, a larger dataset would enable more conclusions to be drawn from the data and increase the confidence in generalizability of the results.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

SR conceived of the presented research and carried out the experiment. Both SR and ER contributed to the final version of the manuscript.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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