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Synchronous Versus Asynchronous: Pre-Service Teachers' Performance in Science Formative Assessment Tests

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Abstract

The purpose of the study was to assess the performance of pre-service teachers in three science formative assessment tests in an online learning environment. The participants consisted of 138 pre-service teachers (57 participated in synchronous session and 81 participated in asynchronous sessions). The study used a quasi-experimental design, non-equivalent groups post-test only. Tests were used to collect the data: Energy Concept Test (ECT), Teaching Energy Concept Test (TECT) and Basic Electronics Concept Test (BECT). ANOVA results revealed a significant effect of type of test on test scores of students at the $p < 0.05$ level for the three tests [$F(2, 364) = 9.641$, $p = 0.000$]. For the ECT, there was no significant difference in performance between synchronous group ($M = 15.93$, $SD = 3.098$) and asynchronous group ($M = 14.75$, $SD = 3.691$), $t(1.791)$ $p = 0.076$. For the TECT, there was no significant difference in performance between synchronous group ($M = 13.55$, $SD = 4.069$) and asynchronous group ($M = 13.97$, $SD = 3.312$), t (−0.596) $p = 0.553$. Also, for the BECT, there was no significant difference between synchronous group (M = 16.53, $SD = 2.727$) and asynchronous group (M = 15.19, SD = 3.725), $t(2.287)$ $p = 0.024$. Pre-service teachers' performance in the three tests was higher than average. Online learning is an effective medium for teaching and learning of science and can be analogous to face-to-face instruction. Both synchronous and asynchronous environments prove effective for teaching and learning science.

Subject Areas

Science Education, Online Learning

Keywords

Online Learning, Synchronous, Asynchronous, Pre-Service Teachers,

Science Instruction

1. Introduction

The global higher education landscape has dramatically changed due to the spread of the coronavirus, otherwise known as COVID-19 [1]. According to [2], the coronavirus pandemic is a typical adaptive and transformative challenge for educators and that education leaders must swiftly design responses as the pandemic runs its course. Many governments are implementing measures that limit the number of people congregating in public places. Such measures have disrupted the normal functioning of schools and universities [2].

While school closures seem to present a logical solution to enforcing social distancing within communities, prolonged closures tend to have a disproportionately negative impact on the most vulnerable students [3]. Many countries have turned to distance learning as a means of mitigating for lost time in school [3]. As a result, tertiary institutions in Ghana have adopted online teachings to enable students learn whiles they stay at home. According to [4], online learning is education in which instruction and content are delivered primarily over the Internet. Reference [5] found that online education is variously termed from the literature as "distance education," "e-learning," "online learning," "blended learning," "computer-based learning," "web-based learning," "virtual learning," "tele-education," "cyber learning," "Internet-based learning," and "distributed learning". Paulsen presented the following characteristics of online education as cited in [6]:

1) The separation of teachers and learners which distinguishes it from face-to-face education;

2) The influence of an educational organization which distinguishes it from self-study and private tutoring;

3) The use of a computer network to present or distribute some educational content;

4) The provision of two-way communication via a computer network so that students may benefit from communication with each other, teachers, and staff.

E-learning can and should significantly enhance science teaching and learning and may be used in a blended and coherent fashion to extend onsite learning experiences [7]. Reference [8] cited Koohang & Harman that e-learning is the provision of educational activities related to teaching, learning and knowledge via electronic media. Similarly, [9] presented the concept of e-learning as online education, defined by the provision of training at its own pace or in real time, via the internet, to a device possessed by users. Online teaching and learning can contribute to a good learning science environment and can bring about good science education standards through proper designing and effective utilization of technology [10].

In online education, learning is either asynchronous or synchronous or a combination of both. Asynchronous learning is teaching and learning that do not happen at the same time [11], while synchronous learning refers to teaching and learning that happen at the same time, both of which are conducted through technologies such as Internet [5]. According to International Association for K-12 Online Learning [12], Synchronous learning is online learning in which the participants interact at the same time and in the same space. Asynchronous learning is defined as communication exchanges which occur in elapsed time between two or more people [12]. The appropriate mode of online teaching (*i.e.* whether synchronous or asynchronous) has been the question for many educators. Researchers have tried to determine the media that work best [13]. The rest of this paper is organized as follows: Section 2 presents a review of literature on synchronous and asynchronous online learning; Section 3 is the design of the study, data collection procedure and instruments; Section 4 presents the results of the study; Section 5 is discussion; and Section 6 is conclusion.

1.1. Problem Statement

It has been observed that students face diverse challenges with the emergency remote learning, especially students in remote villages and towns where there is no access to internet connectivity. These students had to participate asynchronously in online learning at their own time and pace.

What will be the performance of students in science assessment tests in an online environment? Which online learning mode should teachers and educators adopt for emergency remote learning? A review of literature revealed a lot of research on students' and teachers' perceptions, motivations, and participation in synchronous and asynchronous online learning. However, the effect of synchronous and asynchronous participations on students' academic performance especially in science is limited. This study intended to determine the effect of synchronous and asynchronous participations on pre-service teachers' performance in three different online science formative assessment tests.

1.2. Research Questions

1) What is pre-service teacher's performance in online science formative tests in synchronous and asynchronous environments?

2) Is there any significant difference in performance of pre-service teachers in online science formative tests between synchronous and asynchronous participation?

2. Literature Review

E-learning is learning process created by combining digitally delivered content with learning support and services [7]. According to [7], E-learning can and should significantly enhance science teaching and learning and may be used in a blended and coherent fashion to extend onsite learning experiences. E-learning

refers to the use of modern technology, such as computers, digital technology, networked digital devices (such as the Internet) and associated software and courseware to facilitate the learning process [14] [15].

One of the modes used in e-learning is synchronous learning, which can be online, real-time, live teacher instruction and feedback, Skype conversations, videoconferencing, chat rooms, and virtual classrooms where everyone is online and working collaboratively at the same time [15].

Online learning environments can be divided into a triad of synchronous, asynchronous and hybrid learning environments. Synchronous learning environments provide real time interaction, which can be collaborative in nature [16], such as an instructor's lecture with a facility of questions-answer session. Synchronous session requires student-teacher presence at the same time and is live, real-time (and usually scheduled), facilitated instruction and learning-oriented interaction [17].

Asynchronous environments are not time bound and students can work on e-tivities on their own pace [18]. Asynchronous mode of learning/teaching has been the most prevalent form of online teaching so far because of its flexible modus operandi [19]. Asynchronous environments provide students with readily available material in the form of audio/video lectures, handouts, articles and power point presentations. These materials are accessible anytime anywhere via Learning Management System (LMS) or other channels of the sort [18]. Asynchronous e-learning is the most adopted method for online education because learners are not time bound and can respond at their leisure [20]. Asynchronous e-learning can be challenging requires strategies to keep students engaged and interested [18]. Synchronous e-learning, on the other hand, refers to learning/teaching that takes place simultaneously via an electronic mode [21].

A synchronous virtual classroom is a place for instructors and students to interact and collaborate in real time. Synchronous learning involves the exchange of ideas and information with one or more participants during the same period [22]. Synchronous learning is described as learning that takes place simultaneously in real-time. Learners attend class at a scheduled time either in a traditional classroom or a course delivered via the web, using various technologies [23]. According to [24], synchronous learning facilitates efficient education and provides both students and teachers with various ways of networking and sharing and collaborating in real-time. E-learning involves asynchronous as well as synchronous modes of communication [19].

Asynchronous online learning is a situation where students interact with each other, over a time gap, with the help of tools such as discussion forums, e-mail, and bulletin boards [25]. Asynchronous communication better supports cognitive participation because of increased reflection and ability to exchange complex information [6]. Synchronous learning mode is more similar to traditional teaching because communication in this mode is carried out in real time [6]. Synchronous communication enables students to watch teachers' presentations and verbally interact with the teachers during learning sessions [26]. Because

synchronous communication mode is carried out in real time, discussions become more dynamic compared to using solely asynchronous communication [27]. The emerging consensus regarding the choice of asynchronous and synchronous modes is that neither is inherently better, but that they complement one another [28].

According to [29], asynchronous communication is self-paced, thereby accommodating learning differences and allowing cognitive room for the careful construction and understanding of content. Reference [19] Asserted that synchronous mode is good for discussing less complex issues and planning tasks. Students are highly motivated to participate in synchronous discussions because responses happen rapidly [19].

3. Design of the Study

The study used a quasi-experimental design, non-equivalent groups post-test only design. One group consisted of students who participated in synchronous online science lectures real-time in a Google classroom. The second group consisted of students who participated in asynchronous online science lectures at their own time and pace in Google classroom platform. The second group did not come online for synchronous sessions, they followed discussions on the online platform's stream, download course materials, lecture notes, videos, presented assignments and quizzes at their own pace at different times. The researchers administered the same treatment (online lectures, discussions, chats) to both groups on the same platform. There was no pre-test. Both groups took the post tests at the same time, after completing each unit. The design of the study is illustrated in **Table 1**.

3.1. Online Learning Platform

Google classroom platform was created at the beginning of the semester in April 2020 and the unique class code given to students to join. By the end of the first week all the students had joined the class. Class tests were created using Google forms and the links shared to students in Google classroom. Google Classroom is a simplified learning management system that was launched by Google in 2014 [30]. Teachers have the ability to attach documents, video, links, and connect to documents in Google Drive. Google Classroom can be used for sharing of tasks, assignments submission as well as assessment and for collaboration [31].

According to [32], the Google classroom design simplifies the instructional interface and options used for delivering and tracking assignments. Reference [32] added that Google classroom is designed to save time in that it integrates and automates the use of other Google applications such as Google docs, slides, and spreadsheets. The process of grading, formative assessment, and feedback is also made simple. A screenshot of the Google classroom platform is shown in **Figure 1**. The main features of the screenshot are the stream tab, classwork tab, people tab, and grades tab.

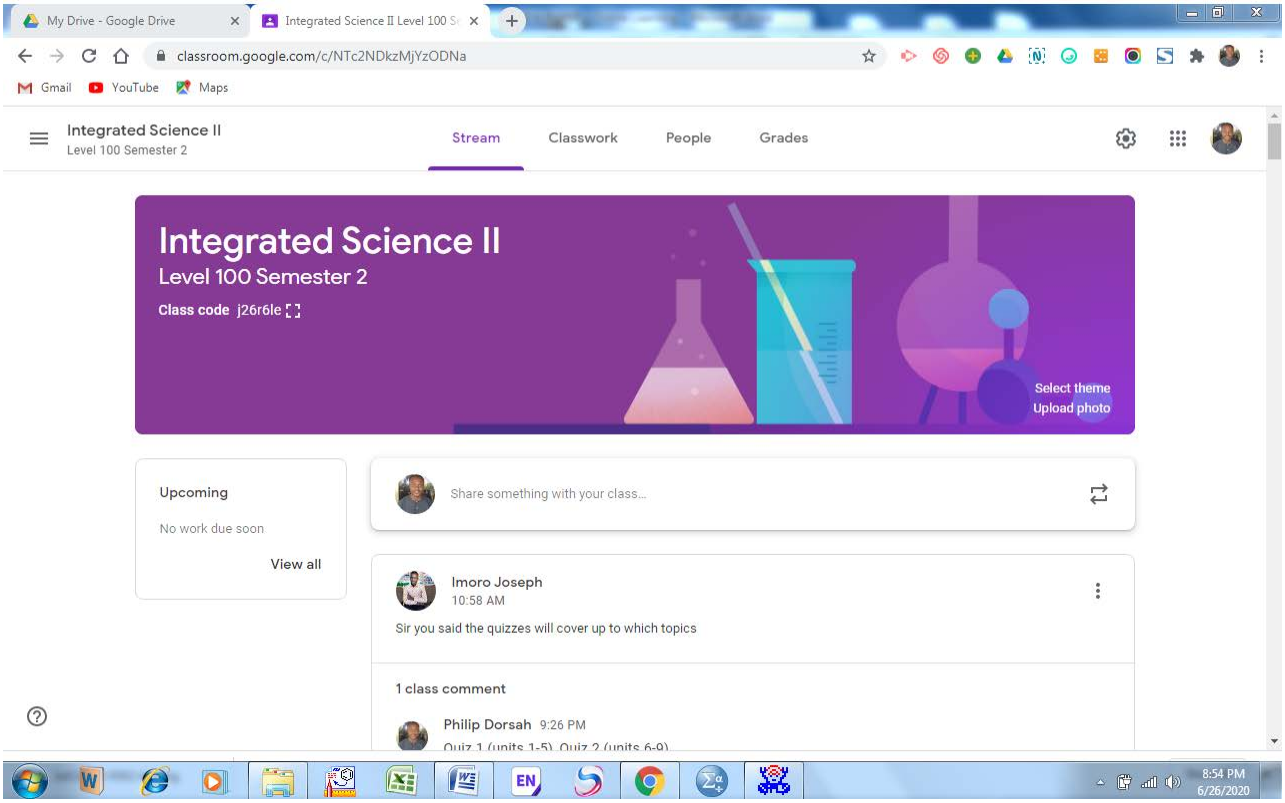

Figure 1. Screenshot of the Google classroom platform.

Table 1. Design of the study.

Group	Intervention	Post-Test
Synchronous	Online Instruction	ECT, TECT, BECT
Asynchronous	Online Instruction	ECT, TECT, BECT

- The Stream tab: is where teachers view and add announcements, assignments, discussion topics, and comments. Students can also view and access announcements, assignments, discussion topics, and comments.
- Classwork tab: Teachers can use this tab to create assignments and quizzes. Students can also see all of their assignments/work listed in chronological order based on the date assigned.
- People tab: Teachers can use this tab to add and remove co-teachers and students to the class. This tab also provides an easy way to email groups of students.
- Grade tab: After a student turns in work, the teacher can add comments, add a grade, and return the work.

3.2. Data Collection Procedure

Data collection process took six weeks. At the beginning of the semester, the course outline, course description and the assessment mode were provided for

the students through the Google classroom platform. The treatment which was mainly online teaching, discussions, online activities, presentations, videos and chats were provided and facilitated by the researcher. The Google classroom platform gave students the opportunity to make comments, ask and respond to questions, post completed assignments and also download course materials. After every online teaching session, the researcher uploaded the lecture notes and other relevant materials on the platform for students to have access. The tests were conducted after completing each unit. Students were always pre-informed of the day and time of the test to enable them prepare adequately.

3.3. Instruments

The instruments for data collection were mainly tests: Energy Concept Test (ECT), Teaching Energy Concept Test (TECT) and Basic Electronics Concept Test (BECT). Each test consisted of 20 multiple choice question (MCQ) items including true or false items. The test items were carefully designed by the authors using the course content and other relevant reference materials. According to [33], Multiple Choice Question (MCQ) tests are one of the most widely used teaching tools, and has translated very successfully into the online environment. Again, [33] are of the view that MCQ quizzes have a role in terms of testing that students have grasped the key facts and ideas. MCQ questions can be used to cement students' understanding of the more subtle points in the lectures, particularly through the use of the carefully constructed feedback. The questions were carefully designed to address the educational objectives outlined in the course content. Students were given immediate feedback after submitting their answers and were also allowed to see their scores after submission. The tests were given to two colleagues to read through for corrections and to ensure content validity of test items. All tests were administered online in Google classroom platform. Each correct item in the test scored 1 point and an incorrect answer scored zero (no point). The total score for each of the three tests was 20 points. Students were allowed to see their scores immediately after submitting. Tests were taken at different times, a week after completing each unit. An example of sample item and sample answer with feedback is given in **Figure 2** and **Figure 3** respectively.

3.4. Study Participants

The participants consisted of 138 pre-service teachers (57 participated in synchronous session and 81 participated in asynchronous sessions). However, not all participants took the tests. This was due to challenges of internet connectivity and so it was not possible to get all students taking the tests.

For synchronous group, 44 students took the ECT (21 males, 23 females), 47 students took the TECT (19 males, 28 females) and 55 students took the BECT (21 males, 34 females). Also, for the asynchronous group, 75 students took the ECT (43 males, 32 females), 65 students took the TECT (40 males, 25 females) and 81students took the BECT (44 males, 37 females).

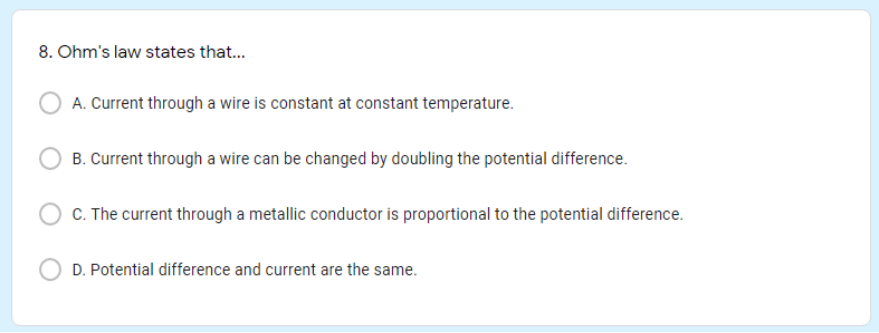

Figure 2. Screenshots of sample test item of the BECT.

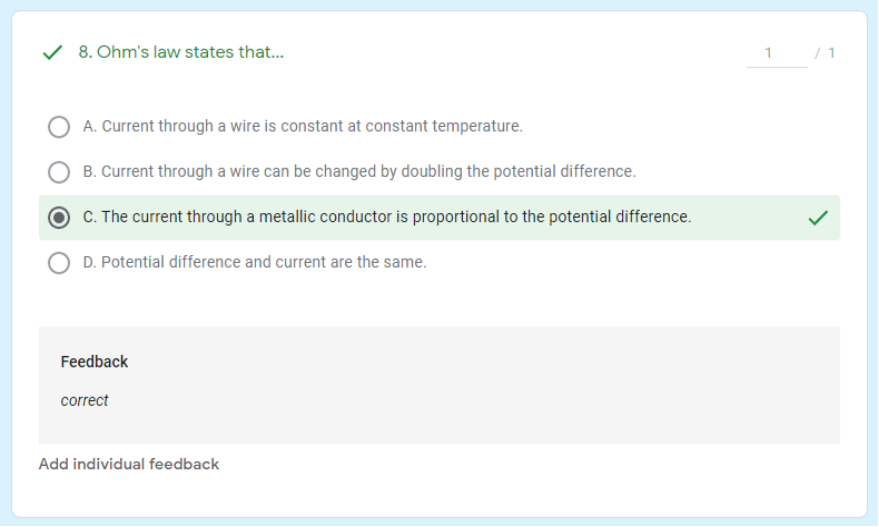

Figure 3. Screenshot of sample response with correct answer and feedback.

4. Results

4.1. Research Question 1

What is pre-service teacher's performance in online science formative tests in synchronous and asynchronous environments?

Table 2 shows the descriptive statistics of pre-service teachers' performance in the three tests for synchronous and asynchronous.

For the energy concept test (ECT), the mean score for synchronous group (M = 15.93, SD = 3.09) and the mean score for asynchronous group (M = 14.75, SD = 3.691). For the teaching energy concept test (TECT), the mean score for synchronous group (M = 13.55, SD = 4.069) and the mean score for asynchronous group (M = 13.97, SD = 3.312). For the basic electronics concept test (BECT), the mean score for synchronous group (M = 16.53, SD = 2.727) and the mean score for asynchronous group (M = 15.19, SD = 3.725). In the ECT, the mean score for synchronous group is higher than asynchronous group. Synchronous group also obtained higher mean score than asynchronous group in the BECT. However for the TECT, the mean scores for the two groups were almost the same. It is evident from the results that, for both groups, pre-service teachers'

performance in the TECT was low compared with their performance in the ECT and the BECT. It also emerged that in all, pre-service teachers performed better in the BECT than they performed in the ECT and the TECT.

ANOVA was performed to see if any significant difference exists in the performance of students in the three tests for both groups combined. Table 3 shows the results of the ANOVA.

The results revealed a significant effect of test type on test scores of students at the $p < 0.05$ level for the three tests [$F(2, 364) = 9.641$, $p = 0.000$]. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the ECT ($M = 15.18$, $SD = 3.517$) was significantly different than the TECT ($M = 13.79$, $SD = 3.637$). Also, the mean score for the BECT ($M = 15.73$, $SD = 3.41$) was significantly different from the TECT ($M = 13.79$, $SD = 3.637$). However, the ECT scores did not significantly differ from the BECT scores.

4.2. Research Question 2

Is there any difference in performance in online science formative tests between synchronous and asynchronous participation?

Independent samples t-test was used to determine if there is any significant difference in the performance of students in the two groups ($\alpha = 0.05$) for the three tests. Table 4 shows the results of the independent samples t-test.

For the ECT, the results show that there was no significant difference in performance between synchronous group ($M = 15.93$, $SD = 3.098$) and asynchronous group ($M = 14.75$, $SD = 3.691$), $t(1.791)$ $p = 0.076$. For the TECT, the results showed that there was no significant difference in performance between synchronous group ($M = 13.55$, $SD = 4.069$) and asynchronous group ($M = 13.97$, $SD = 3.312$), $t(-0.596)$ $p = 0.553$. For the BECT, the results show that there was no significant difference in performance between synchronous group (M = 16.53, $SD = 2.727$) and asynchronous group (M = 15.19, SD = 3.725), $t(2.287)$ $p = 0.024$.

Table 2. Descriptive statistics of scores in the three tests for both groups.

Test	Environment	*N*	*M*	*SD*
ECT	synchronous	44	15.93	3.098
	asynchronous	75	14.76	3.691
	Total	**119**		
TECT	synchronous	47	13.55	4.069
	asynchronous	65	13.97	3.312
	Total	**112**		
BECT	synchronous	55	16.53	2.727
	asynchronous	81	15.19	3.725
	Total	**136**		

Table 3. Results of ANOVA of scores of the ECT, TECT and BECT.

	SS	df	MS	*F*	Sig.
Between Groups	238.32	2	119.16	9.64	0.000**
Within Groups	4499.14	364	12.36		
Total	4737.46	366			

**significant, $p < 0.05$.

Table 4. Independent samples t-test between groups of the ECT, TECT and BECT scores.

Test	*Group*	*N*	*M*	*SD*	*t*	*p*
ECT	Synchronous	44	15.93	3.098	1.791	0.076*
	Asynchronous	75	14.75	3.691		
TECT	Synchronous	47	13.55	4.069	−0.596	0.553*
	Asynchronous	65	13.97	3.312		
BECT	Synchronous	47	16.53	2.727	2.287	0.024*
	Asynchronous	65	15.19	3.725		

*not significant, $p > 0.05$.

5. Discussion

The performance of students in both synchronous and asynchronous environments was above average. This suggests that online-learning environments can be effective in supporting students learning of science just like the traditional face-to-face science classrooms. There was no significant difference in the performance of students in the synchronous group and those in the asynchronous group with respect to the energy concept test (ECT), teaching energy concept test (TECT) and basic electronics concept test (BECT).

However, [34] in a comparative study of synchronous and asynchronous instructional approaches found that students in the asynchronous group performed better in the achievement test than those in the synchronous group. Reference [34] revealed that the students in asynchronous group developed more interest in studying Electrical Engineering than the students in the synchronous group. Reference [35] found that both the synchronous and asynchronous environments were viable and that students should be given a choice of modes. Reference [36] however, concluded that asynchronous environment is a better system of e-learning because it supports interaction anywhere and anytime. Reference [37] also reported that in terms of achievement and attitude outcomes, asynchronous environments had more positive effects than synchronous ones.

Research examining student views on online learning environments suggest both synchronous and asynchronous environments have benefits [38]. In a study, [39] reported that students indicated they understood more and per-

formed better when participating in synchronous environments. Again, [38] reported that students enjoy the flexibility and work at their own pace style provided in asynchronous environments. Asynchronous communication may induce increased cognitive effort since students have more time for reflection [6]. According to [6] "Synchronous communication may also induce increased motivation and decreased ambiguity because of possibilities for immediate feedback" (p. 45). Again, [6] found clarity of design, interaction with instructors, and active discussions among course participants as key factors of students' satisfaction and perceived learning. Synchronous sessions are a good way of reducing distance in distance education [40].

6. Conclusions

It emerged from the study that in general, pre-service teachers' performance in the three online assessment tests was higher than average. This implies that online learning can be an effective model for teaching and learning of science which can be comparable to the traditional face-to-face instruction. Also, synchronous and asynchronous environments are both effective in teaching science and thus educators and teachers may adopt any of the modes for online instruction. Instructors and teachers should ensure that whether synchronous or asynchronous mode, science lessons should be interactive and engaging enough. Research found that communication plays a key role in online learning, where emphasis is placed on student interactions within a group rather than an instructor-led learning experience.

The amount of interactivity in online discussions has been shown to correlate positively with performance on written assignments. Studies also show that online instructors' behaviors such as using humor to break the ice, providing and inviting feedback from students, and addressing students directly by name help to provide a presence that is positively associated with student learning and satisfaction. Social presence is a key component in online education, which is the ability of participants in a community of inquiry to feel that they are socially and emotionally "real" people through the medium of communication being used. Reference [12] identified, among others the following standards for quality online teaching:

1) Ability to construct flexible, digital, and interactive learning experiences that are useful in a variety of delivery modes.

2) ability to select and use a variety of online tools for communication, productivity, collaboration, analysis, presentation, research, and online content delivery as appropriate to the content area and student needs.

3) Ability to use student centered instructional strategies that are connected to real-world applications to engage students in learning (e.g., peer based learning, inquiry-based activities, collaborative learning, discussion groups, self-directed learning, case studies, small group work, and guided design).

4) Ability to apply strategies for engagement in online learning environments,

e.g., asking questions to stimulate discussion.

5) Ability to provide prompt feedback, communicate high expectations, and respect diverse talents and learning styles.

6) Ability to develop and deliver assessments, projects, and assignments that meet standards-based learning goals and assess learning progress by measuring student achievement of learning goals.

7) Ability to create or select and implement a variety of formative and summative assessments that assess student learning progress and utilize student feedback to improve the online learning experience.

8) Ability to provide consistent feedback and course materials in a timely manner, and use online tool functionality to improve instructional efficiency.

9) Ability to track student enrollments, attendance records, etc.

Limitations of the Study

The main limitation of the study was internet connectivity challenges that students encountered. Due to poor or lack of internet connectivity, not all participants were able to take all the tests. Another limitation could come from the type of test items; one disadvantage of multiple choice tests is the limited types of knowledge that can be assessed.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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