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Effect of Asynchronous Learning on Students' Academic Achievement in Chemistry at the Secondary Level

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Abstract: This study was carried out to examine the impact of asynchronous learning on the academic performance of chemistry students. The entire population consisted of students enrolled in 9th-grade Chemistry during the 2023-2024 academic year. Random sampling techniques were employed to select students, ensuring that both genders were represented in the sample. A total of one hundred students were allocated to a control group and an experimental group. The pretest results confirmed that both groups had similar academic abilities since their performances in the 8th grade were matched. Various topics from the 9th grade were chosen for the intervention. Two types of tools were used: one being the pretest and the other involving asynchronous videos and emails. The asynchronous videos included recorded lectures and animations, while WhatsApp was utilized for communication and student guidance. The WhatsApp group also responded to students' inquiries about the asynchronous videos. This intervention lasted for a duration of three months. At the end of the three-month period, a post-test was given to assess the results. The compiled data was analyzed using a t-test. The findings indicated that the academic performance of the students in the experimental group surpassed that of the control group. It was also observed that the academic performance of students in the experimental group improved significantly, as evidenced by the differences between the pretest and post-test scores. The study concluded that asynchronous learning positively influenced the academic success of the students in the experimental group.

Keywords: Asynchronous Learning, Videos, Email, WhatsApp

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Introduction

Learning is referred to as a complete change of behaviour or state of mind as a result of the addition of new things to the mind. There are three parts to this definition, including the duration of change in knowledge is not for a short time. Rather, it is for a long time that the change of knowledge structure and content structure takes place inside the memory, and the third part is the cause of the change in behaviour or knowledge. Cause refers to the learner's experience in the learning environment rather than drugs, motivation, fatigue, physical conditions or interventions.

Electronic learning involves acquiring knowledge through the use of gadgets, digital devices, electronic platforms, and online resources. It allows learners to access courses or materials through digital means and the Internet. E-learning is characterized by self-paced and flexible learning styles. Unlike traditional education, e-learning does not require the simultaneous presence of teachers and students. The significance of e-learning became particularly evident during the Covid-19 pandemic. Additionally, electronic learning has gained importance as a supplementary approach alongside formal education. Incorporating technology into the teaching and learning process, especially through electronic resources like emails, videos, audio files, and e-books, has an impact on educational practices.

However, many students are not well-acquainted with the e-learning system, which affects its effectiveness on a broader scale. Students generally prefer conventional and formal modes of education. Many students engage in active learning experiences. Normally, students take much interest in using electronic devices to play online games and learn other informal things. The new generation is more accustomed to the new learning styles used for electronic learning. Dabbagh & Ritland (2005) mentioned that the success of electronic learning can be ensured if students are well disciplined, Technology literate, independent, directed, show their comfort zone and can share information with others.

Asynchronous e-Learning

This is a kind of e-learning which is not synchronous. In this type of eLearning, both learner and teacher cannot be online at the same time. The technologies or software which are involved in asynchronous eLearning include emails, blogs, eBooks, CDs, DVDs, or discussion forums. Learners can download the relevant material at any time and learn from the downloaded material. Learners can also have conversations with teachers at any time to seek help regarding the learning resources. Learners can also communicate with other learners. Most learners prefer this type of learning because they learn at their preferred time, which does not disturb their daily routines and commitments (Amiti, 2020). According to Perveen (2016), an environment that utilizes asynchronous tools includes already available resources such as audio lectures, PowerPoint presentations, articles, and handouts. This material can be accessed online at any time and shared with others through asynchronous tools. Raymond et al. (2016) offered examples of online teaching resources: "The instructor may choose to present the lesson via videotape, Digital Video Disc (DVD), YouTube, or podcast, while students can engage via communication methods such as email, WhatsApp, and others. As the distance between the teacher and students increases, shyness diminishes due to less pressure from the instructor (Mairing et al., 2021; Perveen, 2016). Conversely, learners appreciate the flexibility and can progress at their own pace, style, and speed, which is a feature of asynchronous environments" (Coogle & Floyd, 2015).

Asynchronous Learning in Chemistry

Allowing students to use their smartphones to create lab videos and then publish them has been very beneficial. Students are allowed to see what each other is doing, critique it, and even learn from it. Asynchronous Learning (AL) is based on the fact that students can learn course material at different times and locations, in contrast to synchronous learning, in which students learn face-to-face with teachers by using a conventional method. The asynchronous learning environment provides students with teaching materials and tools for instruction, discussion, and registration. However, there are no face-to-face lectures (Setiadi et al., 2021). The key to a successful asynchronous learning course is to provide students with material with which they can continually interact. Technology has facilitated the use of asynchronous learning and made it a viable alternative to face-to-face learning. Nowadays, with the introduction of more powerful computers, powerful and speedy internet and a number of educational applications and software, now we can have interactive lessons. Not only students but also the common man can interact with each other with online sources or shared materials on asynchronous tools. Students can get the information which they need on the web. Now, students can also check their marks and grades.

Asynchronous E-Language Learning in Pakistan

Online learning environments can be divided into three categories: synchronous, asynchronous, and hybrid models. Synchronous learning environments enable real-time interaction, often promoting collaboration through activities (Mairing et al., 2021), such as an instructor-led lecture followed by a question-and-answer segment. However, synchronous classes require that both students and instructors are present at the same time. In contrast, asynchronous environments are not bound by time constraints, allowing students to engage with materials at their own pace. A hybrid online setting combines synchronous sessions with a series of asynchronous activities. It is called hybrid because it incorporates aspects of both simultaneous and non-simultaneous learning, acknowledging that the instructional design for synchronous and asynchronous teaching may require entirely different approaches (Varkey et al., 2023).

An asynchronous method of teaching and learning has been the predominant form of online education thus far due to its adaptable characteristics. Asynchronous environments provide chemistry students with access to a wide array of materials, such as audio and video lectures, handouts, articles, and PowerPoint presentations. This content is available at any time and from any place through Learning Management Systems (LMS) or similar platforms. An LMS is a set of tools that includes course materials and sets up a communication channel between students and instructors, similar to a conventional classroom. Other names for LMS include Course Management System (CMS) and Virtual Learning Environment (VLE) (Zeng & Luo, 2024). The term CMS is older and is now used less frequently, as it implies a simple management of course content, whereas LMS refers to a system that enhances the learning experience. Though VLE also implies support for the educational process, it is more commonly linked to systems that support blended learning settings. Some institutions develop their own LMS, while others either use an open-source option or purchase an LMS (Prawira et al., 2021).

The Virtual University of Pakistan, as explored in this case study, has created its own Learning Management System (LMS) to offer a virtual learning experience for students. Asynchronous e-learning is the most commonly used approach for online education, allowing learners the flexibility to respond at their own pace. This opportunity for delayed responses enables students to utilize their higher-order thinking abilities, as they can contemplate a problem for a longer duration, potentially fostering divergent thinking. Instead of impromptu reactions, responses become more thoughtfully constructed. Consequently, the asynchronous format promotes self-paced, independent, and student-centred learning (Zeng & Luo, 2024). Thus, asynchronous e-learning can bridge students' prior knowledge with new concepts. Reducing dependency on memory and notes while encouraging discussions within peer groups enhances critical thinking and deep learning. The online nature lessens feelings of shyness by minimizing direct interactions with the instructor, which can lower the fear associated with traditional classroom settings. With decreased pressure compared to real-time interactions, the affective filter is lowered, enabling learners to respond in a more innovative and creative manner (Setiadi et al., 2021). The likelihood of frustration due to technological issues—such as slow internet and connectivity problems—is minimized, as students have ample time to engage in e-tivities. However, asynchronous e-learning presents challenges, as only a well-planned set of strategies can keep students engaged and motivated in this learning environment, helping them develop confidence, participation, problem-solving abilities, analytical skills, and higher-order thinking (Prawira et al., 2021). Furthermore, the system operates at the student's own pace, requiring self-discipline to remain active and interactive in tracking e-tivities. While discussions in forums and blogs can help maintain engagement, digressions can lead to distractions. Delayed feedback may also contribute to frustration, and there are limited opportunities for social interaction, leaving students to seek ways to network independently.

Asynchronous e-learning can integrate all L2 teaching techniques that facilitate delayed feedback and responses, such as through emails and discussion boards. Asynchronous language instruction can encourage learners to pose questions that necessitate lengthy responses. The written format of communication allows for greater reflection and expression of ideas than what is typically possible in face-to-face verbal interactions (Zeng & Luo, 2024). Learners have sufficient time to contemplate fellow students' language use and can craft their own messages with thoughtful design and enhancement for accuracy. Written communication can also benefit those students who tend to be passive readers and do not engage actively in written discussions. Forum discussions can support discourse development for shy students due to the anonymity they provide. However, the asynchronous format has drawbacks, such as diminished direct feedback and a lack of immediate interaction (Moorhouse & Wong, 2022).

Efficacy of an Asynchronous Online Preparatory Chemistry Course

In light of the ongoing challenges in enhancing retention and engagement in STEM fields, undergraduate institutions are making concerted efforts to ensure that students are well-equipped for college-level Chemistry and mathematics. Since the year-long general chemistry course often poses difficulties for student achievement in STEM disciplines, preparatory classes or summer bridge programs focused on teaching essential skills for general chemistry have become prevalent in undergraduate chemistry curricula (Varkey et al., 2023; Mavropoulos et al., 2021). At various colleges in District Sahiwal, all science students are mandated to enrol in general chemistry, and it is also typical for general chemistry to serve as a prerequisite for other science courses within the colleges of Sahiwal District. The

growing necessity to ensure that incoming first-year students are sufficiently prepared for this course is reflected by the fact that, within the UC system, six out of nine undergraduate campuses provide an in-person preparatory chemistry course. This preparatory chemistry course has been part of the university course catalogue for over ten years but has been offered sporadically, depending on the availability of personnel and resources (Rehman & Fatima, 2021).

In light of resource limitations and the aim to provide a summer course that serves as a bridge experience for new first-year students, we began efforts to develop an online version of our conventional in-person preparatory chemistry course. Faculty members often approach online teaching with skepticism, particularly older, more seasoned instructors (Setiadi et al., 2021). Nevertheless, there is increasing evidence indicating that online learning, when executed with full-time undergraduate students in four-year degree programs, can be as effective, and frequently more effective, than traditional teaching methods. Research on the effectiveness of online instruction in undergraduate chemistry is not as extensive, but a recent study by Falconer and colleagues indicates that an online general chemistry course, incorporating both lectures and lab work, performs comparably to its in-person counterpart.

Across the globe, including in Pakistan, students are given homework assignments. Completing these assignments greatly contributes to the accumulation of knowledge and the development of skills among learners. In particular, science subjects, such as chemistry, often require significant revision and outside assistance. Students seek clarity by engaging in additional coaching and completing homework independently at home. Those students who receive support at home regarding their weak chemistry concepts and abstract notions tend to excel. Providing them with materials that reinforce and augment their classroom learning helps to bolster their understanding and conceptual clarity. This additional support and supplementary resources can be delivered in various ways, including asynchronous methods. By offering pre-recorded videos of the concepts presented in class, students can improve their academic performance. Additionally, sharing guidelines via email can motivate students, making their home learning experience easier and more supported. Therefore, this study aims to investigate the impact of asynchronous learning on the academic success of chemistry students in the Sahiwal district.

Research Objectives

Objectives of this study were to:

1. Find out the effect of Pre-recorded video lessons on the academic achievement of 9th-grade chemistry students.
2. Find out the effect of emails on the academic achievement of 9th-grade chemistry students.

Research Methodology

Research Design

Experimental Research with a pre-test and post-test control group design was used.

Population

All 9th-class students studying the subject of Chemistry in the private schools of district Sahiwal during the session 2022-23 were the population of this study.

Sample

A total of one hundred (100) students were selected for this study. They were divided into two groups, each with fifty (50) students. Out of these 50 students 25 were male and25 were female.

Sampling Technique

A criterion was determined for the selection of students. First on the list were the private schools of Chicha Wattni City that were sought. Lists of students contained phone numbers of the parents or the students. The sample was selected purposefully by selecting the students through involving their parents. All the students have experience with online classes. Most of the students are aware of the video lessons and check WhatsApp and emails. As the sampling technique was purposeful hence, when the total number of male students became 50, male students were contacted

till they were selected 50. All students were divided into two groups; one experimental group and the other control group were formulated, and one group was assigned an experimental group, whereas the other group was assigned a control group.

Variables of the Study

Independent Variables: Video Lectures, Emails, WhatsApp guidance and normal study at home are independent variables.

Dependent Variable: Academic achievement is the dependent variable.

Tool Development

1. Pretest and Post-test: A test was developed from the first five units of 9th-grade chemistry recommended by the BISE Sahiwal Board. The test contains MCQs and Short questions. The researcher primarily developed 36 MCQs and 12 short questions. A rubric was developed by the researcher to evaluate the answers to each short question. Each MCQ carries one mark for each correct selection of options.

2. Videos Lectures of the Chemistry: Khan academy video lectures and other video lectures available free for students were arranged for the students for preparation of Chemistry lesson at their homes.

3. Emails and WhatsApp: For providing guidance to the students regarding asynchronous learning, email group

Tool Validation Process

Pretest and post-test were validated by five experts of Chemistry subject for content validity. For concurrent validity they were validated by supervisor and two other educationists. As video lecturers were arranged already no need was felt for their validation.

Procedure of the Study

After the selection of the sample, all students were called to a private school (Allied School) for the conduct of the pretest. The pretest was marked, and all marks were arranged in descending order for both male and female students. All the students were divided into two groups on the basis of almost equal marks. This process is called equating the groups. All students were getting conventional teaching interventions. After school, students have to do homework and learn their lessons. The difference in intervention was that the experimental group students were treated with asynchronous learning by providing them with videos and motivating them through emails and WhatsApp groups. WhatsApp groups and emails were also used for on-demand guidance. The experimental group students were provided video lectures on the selected topics of the first five units of 9th-grade chemistry. Intervention /treatment to the experimental group lasted with effect from 1st September 2023 to 15th November 2023.

Actually, these video lectures and guidance, with the help of emails and WhatsApp groups, were provided only to experimental group students. Students were also guided and motivated to seek help from videos and the answers to queries through WhatsApp groups. Parents were also involved to ensure that experimental group students were doing homework regularly at their convenience. The schedule of interventions, along with details of topics, is given in Table 1.

Table 1

Video Lectures for Chemistry 9th Grade

Unit	Dates	Topics	Activities (Video Lectures)
1	Sep (1-14)	Fundamentals of Chemistry	1. Branches of chemistry, reasoning questions on Branches 2. Basic Definitions 3. Chemical Species 4. Avogadro Number and Mole 5. Chemical Calculations

Unit	Dates	Topics	Activities (Video Lectures)
2	Sep (15-28)	Structure of Atoms	1. Theories and experiments related to atomic structures. 2. Electronic Configuration 3. Isotopes
3	29th Sep to 16th Oct	Periodic Table and Periodicity of Properties	1. Periodic Table 2. Atomic size and atomic radius 3. Shielding Effect 4. Ionization Energy 5. Electron Affinity 6. Electronegativity
	Oct 12-Oct 16	Assessment and feedback	Unit 1-3
4	Oct (12-25)	Structure of Molecules	1. Why do atoms react? 2. Chemical bonds 3. Types of Bonds 4. Intermolecular forces 5. Nature of Bonding and Properties
5	26th Oct to 8th Nov)	Physical States of Matter	1. Typical Properties of gaseous 2. Laws related to gaseous. 3. Typical Properties of Liquids 4. Typical Properties of solids 5. Types of solids 6. Allotropy
Post-test	Post-test was conducted on 11th November, 2023		

Data Analysis and Interpretation

Table 2

Comparison of Control Group and Experimental Group Students on Pretest (Independent Sample t-test) N = 50

Groups	Mean	Std. Deviation	t	*p*
EG	25.06	4.36	0.47	0.65
CG	24.96	4.29		

(P-value > 0.05)

Both control group and experimental groups have same number of students i.e 50 students in each group. Mean values and standard deviation values on pretest were almost same. This revealed that academic performance of the students of both groups was same. The value of p was 0.65 greater than 0.05 whereas t value was 0.47. It was found that all students of experimental group and control group students were at same level of academic achievement.

Table 3

Comparison of Control Group and Experimental Group Students on Post-test (Independent Sample t-test) N = 50

Groups	Mean	SD	t	*p*
EG	44.47	7.45	8.47	0.000
CG	35.37	5.39		

(P-value < 0.05)

Mean values and standard deviation values on post-test were 44.47 & 35.37 respectively. This revealed that academic achievement of the students of experimental group was better. The value of p value 0.000 was smaller than 0.05 whereas t value was 8.47.

Table 4

Effect of Asynchronous Videos and Emails on the Academic Achievement of Students; Experimental Group Pretest and Post-test Comparison (Independent t-test)

Groups	Mean	SD	t	*p*
Exp. Gp Pretest	25.06	4.36	7.93	.000
Exp Gp posttest	44.47	5.45		

(P-value < 0.05)

Mean values of experimental group academic achievements on pretest and post-test were 25.06 & 44.47 respectively. This revealed that academic achievement of the students of experimental group was better in post-test. The value of p 0.000 was smaller than 0.05 whereas t value was 7.93.

Table 5

Effect of Conventional Teaching on Academic Achievement of Students; Control Group Pretest and Post-test Comparison (Independent t-test)

Groups	Mean	SD	t	*p*
Exp. Gp Pretest	24.96	4.29	6.74	.000
Exp Gp posttest	35.37	5.39		

(P-value < 0.05)

Mean values of Control group academic achievements on pretest and post-test were 25.06 & 35.37 respectively. This revealed that academic achievement of the students of experimental group was better in post-test. The value of p=0.000 was smaller than 0.05 whereas t value was 6.76.

Table 6

Comparison of EXPERIMENTAL Group (Female) and Experimental Group (Male) Students on Post-test (Independent Sample t-test) N = 25

Groups	Mean	SD	t	*p*
EG (Female)	23.70	3.43	4.23	0.026
EG (Male)	20.28	3.98		

Mean values and standard deviation values on post-test were 23.70 & 20.28 respectively. This revealed that academic achievement of the students of experimental group(female) was good compared to experimental group (male0 on post-test. The value of p value 0.026 was smaller than 0.05 whereas t value was 4.23.

Findings and Discussion

1. It was found that all students of experimental group and control group students were at same level of academic achievement (Table 2).
2. It was found that academic achievement of experimental group was better than academic achievement of control group. This was due to intervention of asynchronous videos (Table 3).
3. It was found that the academic achievement of experimental group students treated with asynchronous videos and emails was improved on the post-test (Table 4)
4. It was found that the academic achievement of the control group students treated with conventional teaching was improved on the post-test, but this improvement was less compared to the experimental group (Table 5)
5. It was found that academic achievement of girls in experimental was little bit better than the experimental group (male) students on post-test (Table 6).

While a large number of studies found positive effects on student academic achievements in the online or hybrid environment compared to FTF instruction (e.g. Feeley & Parris, 2012; Means et al., 2010), mixed and negative findings also exist (e.g. Figlio et al., 2013; Xu & Jaggars, 2013). However, compared to the positive and negative results, many more studies have shown "no significant difference" between online and FTF instruction (e.g. Bernard et al., 2004; McCutcheon et al., 2015; Zhao et al., 2005).

Conclusions and Recommendations

Findings reveal that when both experimental and control groups were equated on the basis of pretest and 8th class results, they had the same academic achievement level at the beginning of the experiment. After the compilation of the results of the pretest and arranging the academic achievement in descending order, the t-test was applied to ensure statistical results. Statistical results proved that both experimental and control groups were the same. Hence, it was concluded that students of the experimental group and control group were at the same academic level before the start of the intervention. The intervention of asynchronous learning with the help of lesson videos, emails, and WhatsApp groups for the experimental group of students resulted in an improvement in their academic achievement. The academic achievement of experimental group students was better than that of control group students who were not provided with asynchronous learning. It was concluded that there was a significant difference in the academic achievement of experimental students when their pretest and post-test were compared. There was a prominent difference in means and standard deviation of students when they were tested after the treatment of asynchronous learning. It was also seen that students of the control group also showed better results on post-tests. This means normally, students of the control group also learned when they were not treated with any asynchronous learning platform. However, when the mutual academic achievement of the control group students was compared with that of the experimental group students, it was found that the experimental outperformed on the post-test.

It was concluded that intervention of asynchronous learning enhanced the academic achievement of the experimental group students. The academic achievement of male and female students in experimental group students was compared on post-test. It was found that female students' academic achievement was better, as seen by mean scores, but there was no significant difference, as the t-test result revealed. Hence, it was concluded that females took much more interest in asynchronous videos for the preparation of their lessons compared to male students.

It is recommended that other tools of asynchronous learning be used to determine their effectiveness in improving students' academic achievement. It is recommended that female students of the experimental group showed more academic achievement comparatively; hence, multiple platforms for learning through asynchronous mode may be used for significant achievement of female students. It is recommended that asynchronous learning styles be explored, and different tools be matched with learning styles. It is also recommended that asynchronous learning be tested using other subjects and other levels of classes.

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