Journal name	International e-Journal of Educational Studies
Abbreviation	IEJES
e-ISSN	2602-4241
Founded	2017
Article link	http://doi.org/10.31458/iejes.1341206
Article type	Research Article
Received date	11.08.2023
Accepted date	09.10.2023
Publication date	21.10.2023
Volume	7
Issue	15
pp-pp	705-722
Section Editor	Prof.Dr. Naim UZUN
Chief-in-Editor	Prof.Dr. Tamer KUTLUCA
Abstracting & Indexing	Education Source Ultimate Database Coverage List EBSCO Education Full Text Database Coverage List H.W. Wilson Index Copernicus DRJI Harvard Library WorldCat SOBIAD

Article Name	An Evaluation of Online Science Classes Based on Students’ Science Learning Experiences

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Conceptualization, literature review, methodology, implementation, data analysis, translation, and writing.

Abstract

Online science courses have become increasingly popular due to their accessibility and convenience. Consequently, evaluating their quality is essential for ensuring students receive a rigorous and valuable education. This study investigates the effectiveness of online science classes in terms of student- faculty interaction, time on task, active learning and cooperation among students by considering the participant students' experiences and their evaluations of online science courses. The participants were 2034 students from different middle (year 5 to 8) and high schools (year 9 to 12) during 2022-2023 academic year. All of the participants attended online science classes from 2nd half term of 2019-20 and whole school year of 2020-21. The data was collected by using the Student Evaluation of Online Teaching Effectiveness (SEOTE) scale, which was developed by Bangart (2005). The student responses were evaluated based on their school year, frequency of attendance, and means used to access online science classes. The findings of the study revealed that the participant students were not satisfied with online science learning experiences in terms of faculty-student interaction, time on task, cooperation among students and active learning practices. The study also found that faculty-student interaction, time on task, cooperation among students were important predictor of active learning for online science learning practices. Based on the findings the study suggests that when designing or implementing online science classes, students’ engagement, teacher-faculty interaction, creating opportunities for students to cooperate and helping students to actively engage in the activities should be taken into consideration by teachers.

To cite this article:

Aslan-Efe, H. (2023). An evaluation of online science classes based on students’ science learning experiences. *International e-Journal of Educational Studies, 7* (15), 705-722. https://doi.org/10.31458/iejes.1341206

Research Article

An Evaluation of Online Science Classes Based on Students' Science Learning Experiences *

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Abstract

Online science courses have become increasingly popular due to their accessibility and convenience. Consequently, evaluating their quality is essential for ensuring students receive a rigorous and valuable education. This study investigates the effectiveness of online science classes in terms of student- faculty interaction, time on task, active learning and cooperation among students by considering the participant students' experiences and their evaluations of online science courses. The participants were 2034 students from different middle (year 5 to 8) and high schools (year 9 to 12) during 2022-2023 academic year. All of the participants attended online science classes from 2nd half term of 2019-20 and whole school year of 2020-21. The data was collected by using the Student Evaluation of Online Teaching Effectiveness (SEOTE) scale, which was developed by Bangart (2005). The student responses were evaluated based on their school year, frequency of attendance, and means used to access online science classes. The findings of the study revealed that the participant students were not satisfied with online science learning experiences in terms of faculty-student interaction, time on task, cooperation among students and active learning practices. The study also found that faculty-student interaction, time on task, cooperation among students were important predictor of active learning for online science learning practices. Based on the findings the study suggests that when designing or implementing online science classes, students' engagement, teacher-faculty interaction, creating opportunities for students to cooperate and helping students to actively engage in the activities should be taken into consideration by teachers.

Keywords: Online science teaching, evaluation, active learning, students' experiences

1. INTRODUCTION

Online science learning has become increasingly prevalent in recent years, and several studies have explored students' experiences with this mode of instruction. Research has explored students' experiences of online science learning, highlighting both the benefits and challenges associated with this mode of learning. Students enjoy the flexibility and convenience of online science learning, as it allows them to study at their own pace and access course materials from anywhere with an internet connection (Al Rawashdeh, 2021; Yüksel, 2022). Studies have documented effective online science courses in promoting student learning outcomes, including knowledge acquisition, critical thinking skills, and problem-solving abilities (Cortázar et al., 2021) as well as providing an engaging and interactive learning experience, with multimedia-rich resources and simulations that enhance students' understanding of scientific concepts (Widiyatmoko, 2018). Online discussions and collaborations with peers and instructors can also contribute to a sense of community and promote active learning (Faja, 2013). Online science courses have also been found to increase student motivation and engagement in science learning, particularly for students who may not have had access to traditional science courses (Hsu, Rowland-Goldsmith, & Schwartz, 2022). Despite these documented benefits of online learning

Received Date: 11/08/2023 **Accepted Date:** 09/10/2023 **Publication Date:** 21/10/2023
* ***To cite this article:*** Aslan-Efe, H. (2023). An evaluation of online science classes based on students' science learning experiences. *International e-Journal of Educational Studies, 7* (15), 705-722. https://doi.org/10.31458/iejes.1341206
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science learning different studies have identified challenges in students' experiences with online science learning, including a lack of social interaction and peer support, difficulties with time management, limited interaction with instructors, and a lack of motivation and technological issues, such as slow internet connection and software compatibility issues, which can hinder their learning experience (Barrot, Llenares, & Del Rosario, 2021). Studies, also, suggested that students may face challenges in staying motivated and engaged with the course material without the structure of traditional face-to-face instruction (Singh, Steele, &Singh, 2021). Additionally, online science courses require students to take greater responsibility for their learning, which can be challenging for some learners. Therefore, support from instructors and access to resources such as online tutorials and peer support groups are crucial for student success (Rotar, 2019).

1.1. Literature Review

The rapid integration of educational technologies, including computer simulations, games, and various software for learning and evaluation, has led to changes in instructional strategies at all levels of education (Brinkley- Etzkorn, 2018; Çoban, 2020). Online classroom activities such as Moodle, hybrid, and remote learning have become available tools for teachers to guide, facilitate, and support students in achieving learning outcomes (Singh & Arya, 2020). The demand for online courses is driven by factors such as flexibility, self-paced learning, enhanced computer and internet skills, richer content, and unlimited exercise opportunities at a lower cost than in-person classes (Kulal & Noyak, 2020). The blending of various online applications and processes can help instructors provide better learning environments for students (Lauran et al., 2014). The integration of online or remote learning technologies such as Moodle, computer simulations, games, and various software has facilitated a shift from a teacher-centered learning approach to a more student-centered one, as it allows for active engagement with the presented material (Kulal & Noyak, 2020). This shift has led to a focus on constructivist learning experiences, where learners actively construct meaning and knowledge during the learning process, as being crucial to the success of online learning (Bangert, 2005). As a result, teachers are adopting various student-centered teaching strategies and methods, such as inquiry-based and project-based learning activities, group work, higher-order thinking skills, interactivity, and learner choice (Bakioglu & Cevik, 2020).

The integration of educational technology has had a significant impact on educational institutions, students, and teachers, as previous knowledge and skills have become outdated and obsolete (Kulal & Nayak, 2020). In this new paradigm, it is crucial for teachers to guide, facilitate, and support students in reaching their learning goals during online learning experiences, as argued by Brinkley- Etzkorn (2018). As a result, teachers must now create learning environments that cater to students' personal learning styles, academic achievements, and interests, enabling them to perform better and gain a deeper understanding of the subject matter (Bangart, 2005). It is important to note that online teaching requires a different approach compared to traditional face-to-face instruction. Hence, the inclusion of e-pedagogy, which involves training instructors for effective online communication and course facilitation, is crucial for a successful online teaching experience (Kleinman, 2004). However, despite the shift from traditional in-person learning to online learning, the adaptation of online teaching can be time-consuming and presents various barriers, such as technical, pedagogical, and administrative issues. Moreover, there is an increasing requirement for appropriate science standards that include hands-on activities, such as inquiry-based learning, problem-solving, student investigation and discovery, and application of knowledge (Loucks-Horsley, Stiles, & Hewson, 1996). Hand-on activities in science classes offer students a valuable opportunity to actively engage in scientific experiments by observing and operating scientific processes, objects, and instruments (Hong, Liu, Liu, & Zhao, 2021). However, designing effective online science classes can be challenging for many science educators (Miller, 2008). Recent studies examining the effectiveness of online learning during the COVID-19 pandemic found that teachers faced difficulties in adapting to online instruction (Korkmaz & Toraman, 2020; Yao et al., 2020), which was compounded by technostress caused by the overload, complexity, insecurity, and uncertainty of using online technologies (Ozamiz-Etxebarria, Berasategi Santxo, Idoiaga Mondragon, & Dosil Santamaría, 2021). Furthermore, studies investigating teachers' perceptions of online learning during the COVID-19 pandemic have documented that teachers encountered problems such as poor internet connections, low student participation, and pressure from school administrators (Bakioglu & Cevik, 2020).

Online instruction has a significant impact on students as they are the key players in the learning process. According to Cheung and Kan (2002), high-achieving students in traditional classroom settings are most likely to experience a decline in academic performance in online courses compared to lower-performing students who tend to thrive in online environments. Noesgaard and Orngreen's (2015) review of 61 studies on e-learning effectiveness showed that 41 studies found it to be effective, six found it not effective, and 14 found it partly effective. The emergence of COVID-19 has presented a challenge for evaluating the effectiveness of online learning. UNESCO (2020) reported that more than 1.5 billion students in 194 countries were affected by the pandemic, leading to a switch from in-person to remote learning across all levels of education. While online learning was already gaining popularity in higher education, a survey of 6,000 educators in Georgia found that it was not effective for most students and led to increased depression, anxiety, and social isolation (Dalton, 2021). Technical knowledge, connectivity issues, and problems with communication between students and teachers are among the reasons for student reluctance towards online learning (Singh & Arya, 2020). Additionally, outdoor learning activities such as field instruction for environmental science topics pose a challenge during online instruction. Barton (2020) reported a substantial reduction in learning outcomes and less active and more instructional-centred remote learning activities for field activities based on instructors' views on field instruction and remote teaching alternatives. Humphrey and Wiles (2021) found that students perceived online science classes as less effective than face-to-face learning because it was difficult to stay engaged and learn the course material during online classes. The study also revealed that the course instructor did not adapt well to online teaching. Additionally, research suggests that students' motivation to learn is best fostered in face-to-face learning environments, where instructors can identify nonverbal cues and make necessary adjustments to content and instructional methods (Singh et al., 2021).

Humphrey and Wiles (2021) suggest several strategies to motivate students during online classes, including clearly expressing and maintaining expectations for achieving learning outcomes, involving students in decision-making about topics, assigning challenging tasks, and providing opportunities for evaluation through writing and online discussions. The popularity of online learning is expected to continue to rise, both as a means of enhancing the learning process and as a substitute for in-person classes during the COVID-19 pandemic. Agustina and Cahyono (2017) assert that online instruction is seen as a modern tool for enhancing learning rather than a replacement for in-person instruction. As such, hybrid and blended learning are recommended as they allow instructors to combine the best elements of online and in-person instruction (Singh et al., 2021).

1.2. Context for the study

The resent devastating earthquake in south east of Turkey that affected 11 cities and claimed more than 50.000 lives has turned the attention to online learning again after one a half year of experience during Covid 19 pandemic. The decision to switch to online learning by the board of higher education institution was heavily criticized by a large section of the nation since online learning was not seen as effective taking the previous experience imposed by the conditions of Covid-19 era into account. In order to alleviate the criticism, the board has taken another decision to ask universities to use hybrid learning after two months of online learning only. The previous experiences of online learning have led to a general view that online learning is not as effective as face to face learning and that it does not provide equal opportunities for students particularly from low soci-economic background as there are problems related to the availability of instruments such as computers since there are usually more than a student in a family and opportunities to access internet as well as lack of social interaction that affects students' personal as well as academic development.

Online science courses have become increasingly popular due to their accessibility and convenience, but evaluating their quality is essential for ensuring students receive a rigorous and valuable education (Dziuban, Picciano, Graham, & Moskal, 2016). Evaluating online science courses includes assessing the course content and curriculum to ensure that they are comprehensive, accurate, and up-to-date. The quality of instruction and teaching is another crucial factor, with experienced and knowledgeable instructors who can communicate material effectively and engage students in active learning (Graham, & Woodfield, & Harrison, 2013). Assessing online education is a crucial process that helps to draw valid conclusions about teaching effectiveness. Engaging in scholarly inquiry that evaluates the effectiveness of instruction on student learning can inform teaching practices (Rapanta, Botturi, Goodyear, Guàrdia, & Koole, 2020). This study investigates the effectiveness online science classes in terms of student- faculty interaction, time on task, active learn and cooperation among students by considering the participant students' experiences and evaluations of online science courses. The research questions that guide this study are as follows:

1. How do participating students evaluate online science courses using the SEOTE scale?
2. Are there any differences in students' evaluations of online science courses based on their year of study?
3. Do students' evaluations of online science courses differ based on the medium they use to participate?
4. Are there any differences in students' evaluations of online science courses based on the frequency of attendance?
5. How does student-faculty interaction, time on task, and cooperation among students affect active learning in online science courses?

2. METHOD

The study employs a quantitative approach using the student evaluation of online teaching effectiveness (SEOTE) scale as the data collection tool and analysing the data through descriptive and inferential statistics.

2.1. Participants

Students willing to take part in the study to evaluate online science classes were 2034 individuals from different grades and gender (Table 1). A half of the participant students (n: 1015) were taking classes for middle school (year 5 to year 8) and the rest were students studying at high school (year 9 to 12) during 2022-2023 academic year.

Table 1. Number of the participant students based on their school year, means for access to online courses and gender

Grade	N	%	Access	N	%	Gender	N	%
Year 6	175	8.6	Computer	256	12.6	Female	1143	56,2
Year 7	504	24.8	Tablet	393	19.3	Male	891	43,8
Year 8	355	17.5	Phone	1302	64	Total	2034	100
Year 9	174	8.6	Smart TV	53	2.6			
Year 10	487	23.9	More than one	30	1.5			
Year 11	250	12.3	Total	2034	100			
Year 12	89	4.4						
Total	2034	100						

The table above demonstrates that the participant students mainly used phones as means to access online classes science classes (64%). This was followed by tablets (19.3%) and computers (12.6%).

2.2. Data Collection Instrument

The study collected data using the Student Evaluation of Online Teaching Effectiveness (SEOTE) scale, which was developed by Bangart (2005) based on the seven principles of effective teaching outlined by Chickering and Gamson (1987). The SEOTE scale consists of 25 items that measure four dimensions: student-faculty interaction (SFI-12 items), active learning (AC- 6 items), time on task (TOT- 4 items), and cooperation among students (CAS- 3 items). Students responded to each item using a six-point Likert scale ranging from strongly agree to strongly disagree. The stratified alpha value for the whole scale was .951 for this study, indicating high internal consistency. Additionally, the Cronbach alpha values for each dimension were as follows: .894 for student-faculty interaction, .851 for active learning, .809 for time on task, and .700 for cooperation among students. The mean values for the instrument items were categorized as strongly disagree, disagree, mildly disagree, mildly agree, agree, and strongly agree based on the following ranges:
1.00-1.82: Strongly disagree; 1.83-2.65: Disagree; 2.66-3.48: Mildly disagree; 3.49-4.32: Mildly agree 4.33-5.16: Agree; 5.17-6.00: Strongly agree.

2.3. Data Analysis

The responses from the participating students to the items on the SEOTE were analyzed in line with the research questions using SPSS 28. The student responses were evaluated based on their school year, frequency of attendance, and means used to access online science classes. Descriptive statistics, one-way ANOVA, and MANOVA were used for data analysis. When statistically significant differences emerged, multiple comparisons were conducted using either Tukey HSD or Games-Howell tests. As the sample sizes were often unequal across the participant groups, a test for homogeneity of variances was run to determine whether the assumption was met. If the Levene test result for homogeneity of variances was significant, the Welch test was preferred, and Games-Howell was used for multiple comparisons. If Box's test of equality of covariance matrices and Levene's test of equality of error variances were not significant ($p>.05$), a MANOVA test was employed to determine the significance of differences in the participant students' scores for the evaluation of online science courses scale. Moreover, multiple regression was used to analyse the effects of student-faculty interaction, time on task, and cooperation among students on active learning for online science courses.

3. FINDINGS

The findings were presented by considering the research questions.

3.1. RQ1 Students' Evaluation of Online Science Courses based on Descriptive Analysis

3.1.1. Students- faculty interaction

Table 2 presents descriptive statistics on the participant students' responses to items for student and faculty interaction. The table reveals that the items "The instructor was respectful of students' ideas and views" (mean: 3.67), "The instructor was enthusiastic about online teaching" (mean: 3.28), and "Flexibility was permitted when completing course assignments" (mean: 3.21) received the highest mean scores from the participant student responses. Conversely, the items "The course was designed so that technology would minimally interfere with learning" (mean: 2.77), "The amount of contact with the instructor was satisfactory" (mean: 2.83), and "I was provided with supportive feedback related to course assignments” (mean: 2.97) had the lowest mean scores for the sub-dimension of student and faculty interaction in online instruction.

Table 2. Students responses to items related to student and faculty interaction for online instruction

Items	N	Mean	SD
The instructor communicated effectively.	2034	3.18	1.717
The instructor was enthusiastic about online teaching.	2034	3.28	1.681
The instructor was accessible to me outside of the course.	2034	3.09	1.737
The amount of contact with the instructor was satisfactory. (e.g., email, discussions, face-to-face meeting, etc.)	2034	2.83	1.681
I felt comfortable interacting with the instructor and other students.	2034	3.09	1.734
My questions about WebCT were responded to promptly.	2034	3.13	1.693
My questions about course assignments were responded to promptly.	2034	3.11	1.663
I was provided with supportive feedback related to course assignments.	2034	2.97	1.631
This course used examples that clearly communicated expectations for completing course assignments.	2034	3.17	1.683
The instructor was respectful of students’ ideas and views	2034	3.67	1.884
The course was designed so that technology would minimally interfere with learning.	2034	2.77	1.754
Flexibility was permitted when completing course assignments.	2034	3.21	1.683

The participant students’ disagreement with the items in the subscale can be inferred from the mean average of 3.48 and below, except for one item. This indicates that they did not find the interaction between students and faculty during online classes effective or satisfactory.

3.1.2. Time on task

The evaluation of time on task was carried out using four items on the scale (as shown in Table 3). The item that received the highest mean score was "the course allowed me to take responsibility for my own learning" ($\bar{x}$= 3.28), followed by "The course was designed to provide an efficient learning environment" ($\bar{x}$= 3.08) and "The course allowed me to complete assignments across a variety of learning environments" ($\bar{x}$= 3.02). On the other hand, the item "The course was structured to be user friendly" received the lowest mean score ($\bar{x}$= 2.99) from the participant students. It is noteworthy that all mean scores for the items related to time on task were below the 3.48 threshold, indicating that the participant students disagreed with the items from a statistical standpoint.

Table 3. Students responses to items related to student and time on task for online instruction

Item	N	Mean	SD
The course allowed me to take responsibility for my own learning.	2034	3.28	1.803
The course was structured to be user friendly.	2034	2.99	1.603
The course was designed to provide an efficient learning environment.	2034	3.08	1.711
The course allowed me to complete assignments across a variety of learning environments.	2034	3.02	1.727

According to the results presented in Table 3, the participant students did not perceive the course structure as being designed to be user-friendly, offering diverse and effective learning environments, and encouraging them to take ownership of their learning.

3.1.3. Cooperation among students

There are three items for cooperation among students in the SEOTE scale (Table 4.). The data analysed revealed that the cooperation among students during online science classes were generally low.

Table 4. Students' responses to items related to cooperation among students for online instruction

Item	N	Mean	SD
The course was structured so that I could discuss assignments with other students.	2034	2.72	1.641
This course included activities and assignments that provided students with opportunities to interact with one another.	2034	3.01	1.704
The course was used to stimulate thoughtful discussions.	2034	2.99	1.654

Among these items, the one that received the highest mean score was "This course included activities and assignments that provided students with opportunities to interact with one another" ($\bar{x}$=3.01). This was followed by "The course was used to stimulate thoughtful discussions" ($\bar{x}$=2.99). On the other hand, the item with the lowest mean score in this subsection was "The course was structured so that I could discuss assignments with other students" ($\bar{x}$=2.72). These findings suggest that students felt that online classes did not offer enough opportunities for cooperation during their science learning experiences.

3.1.4. Active learning

The mean values for students' responses to active learning items ranged from 3.29 to 3.03, as shown in Table 5. Among these items, "The assignments for this course were of appropriate difficulty level" and "This course used a variety of assignments and activities that allowed students to demonstrate understanding of critical course concepts" received the highest mean score of 3.29. On the other hand, the item with the lowest mean score was "This course used realistic assignments and problem-solving activities that were interesting and motivated me to do my best work" with a mean score of 3.03. Similarly, the item "The course used realistic assignments and problem-solving activities related to situations that I am likely to encounter outside of this course or in a future job situation" also had a mean score of 3.05. These results suggest that students were not fully motivated or interested in the realistic assignments and problem-solving activities used in the online science course.

Table 5. Students responses to items related to active learning for online instruction

Item	N	Mean	SD
This course included interactive assignments and links to examples from the Web that directly involved me in the learning process.	2034	3.07	1.696
This course used realistic assignments and problem-solving activities that were interesting and motivated me to do my best work.	2034	3.03	1.752
This course provided good examples and links to other examples published on the Web that helped to explain concepts and skills.	2034	3.17	1.680
The assignments for this course were of appropriate difficulty level.	2034	3.29	1.736
The course used realistic assignments and problem-solving activities related to situations that I am likely to encounter outside of this course or in a future job situation.	2034	3.05	1.717
This course used a variety of assignments and activities that allowed students to demonstrate understanding of critical course concepts.	2034	3.29	1.788

These findings indicate that students did not perceive their online science experiences to offer suitable prospects for active learning.

3.2. RQ2 differences in the Participant Students' Evaluations of Online Science Courses based on the Participants' Year of Study

Table 6 provides descriptive statistics, indicating that students in lower grades (6th, 7th, 8th, and 9th) scored higher than those in higher grades (10th, 11th, and 12th) in all four subsections of the online science scale, including student-faculty interaction, time on task, cooperation among students, and active learning. The results suggest that students in lower grades had better interactions with their teachers, spent more time on task, engaged in better cooperation with peers, and experienced more active learning opportunities compared to their counterparts in higher grades.

Table 6. The participant students' evaluation of online science courses based on grade

Variable	Grade	N	Mean	SD	Variable	Grade	N	Mean	SD
SFI	6	175	3.36	1.084	**CAS**	6	175	3.23	1.27
	7	504	3.40	1.09		7	504	3.28	1.27
	8	355	3.22	1.18		8	355	2.90	1.29
	9	174	3.20	1.13		9	174	2.96	1.33
	10	487	2.90	1.06		10	487	2.60	1.21
	11	250	2.76	1.18		11	250	2.64	1.36
	12	89	2.81	1.50		12	89	2.53	1.48
	Total	2034	3.12	1.16		Total	2034	2.91	1.31
TOT	6	175	3.34	1.31	**AL**	6	175	3.42	1.25
	7	504	3.49	1.27		7	504	3.52	1.23
	8	355	3.25	1.38		8	355	3.27	1.33
	9	174	3.13	1.35		9	174	3.20	1.36
	10	487	2.76	1.29		10	487	2.85	1.17
	11	250	2.64	1.33		11	250	2.72	1.29
	12	89	2.73	1.54		12	89	2.78	1.55
	Total	2034	3.09	1.37		Total	2034	3.15	1.30

The Welch test was employed to determine the statistical significance of the differences, as shown in Table 7.

Table 7. The Welch test results for student and faculty interaction based on year of study

Variable	Robust Tests of Equality of Means				Eta-squared
		df1	df2	Sig.	
Student Faculty Interaction	15.077	6	576.540	<.001	.043
Time on Task	21.030	6	579.212	<.001	.057
Cooperation among students	16.840	6	578.332	<.001	.047
Active learning	20.042	6	575.995	<.001	.054

The Welch test result shows that the participant students' evaluation of online science classes in terms of student and faculty interaction based on the participants year of study differed significantly, F_{Welch} (6, 576,54):15.077, p<.001 (Table 8). Similarly, the participant students' responses to the items related to time on task differ significantly across years of study, F_{Welch} (6, 579.212) =21.020, P<.001. In the same vain, the participant students' mean scores for "cooperation among students" subsection items were statistically significant based on students' year of study, F_{Welch} (6,578.332) =16.840, p<.001. The similar results are also evident for the active learning subsection as the mean differences for the participant students' responses to active learning items were statistically significant, F_{Welch} (6,575.995) =20.042, p<.001 (Table 7). But the same results also show that the effect of the participant students grade on the results of students' evaluation of online science courses are small, $\eta^2_{student\text{-}faculty\ interaction}$=.043; $\eta^2_{time\ on\ task}$=.057; $\eta^2_{cooperation\ among\ students}$=.047; $\eta^2_{active\ learning}$=.054. A η^2 value that is below .059 is considered as a small effect size (Cohen, 1988).

In order to determine the source of this significant difference among the participant students' mean score, Games- Howell multiple comparison test was used (Table 8).

Table 8. Games- Howell multiple comparison test for time on task based on year of study

Dependent Variable	(I) Grade	(J) Grade	Mean Difference (I-J)	SE	Sig.	Dependent Variable	(I) Grade	(J) Grade	Mean Difference (I-J)	SE	Sig.
SFI	6	10	.45*	.095	<.001	**CAS**	6	10	.63*	.111	<.001
		11	.60*	.111	<.001			11	.59*	.129	<.001
		12	.54*	.179	.046			12	.70*	.184	.004
	7	10	.49*	.068	<.001		7	8	.37*	.088	<.001
		11	.64*	.089	<.001			10	.68*	.078	<.001
		12	.58*	.166	.012			11	.64*	.103	<.001
	8	10	.31*	.079	.002			12	.75*	.166	<.001
		11	.46*	.097	<.001		8	10	.30*	.087	.010
TOT	6	10	.58*	.115	<.001	**AL**	6	10	.57*	.108	<.001
		11	.70*	.129	<.001			11	.71*	.125	<.001
		12	.61*	.190	.028			12	.64*	.190	.017
	7	9	.37*	.117	.032		7	10	.67*	.076	<.001
		10	.73*	.081	.000			11	.80*	.098	<.001
		11	.85*	.101	<.001			12	.74*	.173	<.001
		12	.76*	.172	<.001		8	10	.42*	.088	<.001
	8	10	.49*	.094	<.001			11	.55*	.108	<.001
		11	.61*	.111	<.001						

The table presented above indicates that the statistically significant differences in all subsections are observed between lower grade and upper grade students, where the former have higher mean scores. Further analysis using Games-Howell multiple comparison test revealed that the significant differences obtained from the Welch test were due to the mean differences between the mean scores of 6th-grade students and those of 10th, 11th, and 12th-grade students. A similar pattern was observed between the mean scores of 7th and 8th-grade students and those of 10th, 11th, and 12th-grade students (Table 8).

3.3. RQ3 Differences in the Participant Students' Evaluations of Online Science Courses based on the Medium for Participating Online Science Courses

A MANOVA test was used to analyse students' evaluation of online science courses based on their means for participating in on line science courses. This was carried to find out if the medium for participating in online science classes had any effect on the participant students' evaluation of online science classes (Table 9).

Table 9. MANOVA results for the evaluation of online science classes based on the medium for participating

Multivariate Tests[a]							
Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.601	762.544[b]	4.000	2026.000	.000	.601
	Wilks' Lambda	.399	762.544[b]	4.000	2026.000	.000	.601
	Hotelling's Trace	1.506	762.544[b]	4.000	2026.000	.000	.601
	Roy's Largest Root	1.506	762.544[b]	4.000	2026.000	.000	.601
Access	Pillai's Trace	.015	1.946	16.000	8116.000	.013	.004
	Wilks' Lambda	.985	1.948	16.000	6190.170	.013	.004
	Hotelling's Trace	.015	1.948	16.000	8098.000	.013	.004
	Roy's Largest Root	.009	4.645[c]	4.000	2029.000	<.001	.009

a. Design: Intercept + Access
b. Exact statistic
c. The statistic is an upper bound on F that yields a lower bound on the significance level.

Multivariate tests show (Table 9) that there was statistically significant difference in the students' evaluation of online science courses based on a student's means to access to online course, F (16,6190.17) =1.948, $p<.05$; Wilk's Λ=0.985, partial η^2 =.004. Despite the significance in p value, the effect size is very small, which means the medium of participating in online science classes had very small effect on the participant students' evaluation of online science classes.

Table 10. Tests of between-subjects effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	SFI	20.189[a]	4	5.047	3.743	.005	.007
	TOT	19.345[b]	4	4.836	2.603	.034	.005
	CAS	10.081[c]	4	2.520	1.453	.214	.003
	AL	12.062[d]	4	3.015	1.762	.134	.003
Intercept	SFI	4075.593	1	4075.593	3022.625	.000	.598
	TOT	3983.490	1	3983.490	2143.760	.000	.514
	CAS	3460.674	1	3460.674	1995.015	<.001	.496
	AL	4175.705	1	4175.705	2439.940	.000	.546
Access	SFI	20.189	4	5.047	3.743	.005	.007
	TOT	19.345	4	4.836	2.603	.034	.005
	CAS	10.081	4	2.520	1.453	.214	.003
	AL	12.062	4	3.015	1.762	.134	.003
Error	SFI	2735.826	2029	1.348			
	TOT	3770.246	2029	1.858			
	CAS	3519.627	2029	1.735			
	AL	3472.424	2029	1.711			
Total	SFI	22607.319	2034				
	TOT	23237.875	2034				
	CAS	20734.778	2034				
	AL	23676.722	2034				

a. R Squared = .007 (Adjusted R Squared = .005)
b. R Squared = .005 (Adjusted R Squared = .003)
c. R Squared = .003 (Adjusted R Squared = .001)
d. R Squared = .003 (Adjusted R Squared = .001)

The table 10 displays that the mean for access to online courses had a significant effect both on students and faculty interaction (F (4,2029) =3.743; $p<.05$; partial η^2 =.007) and time on task (F (4,2029) =2.603; $p<.05$; partial η^2 =.007). But this relation was insignificant for both cooperation among students and active learning subsections of online science evaluation ($p>.05$).

Multiple comparisons show that statistical significances stem the differences between the use of tablet and phone and tablet and smart Tv for student faculty interaction (Table 11). Similarly, between tablet and phone for time on task. Students using tablets to participate in online classes had higher mean scores the items related to student and faculty interaction and time on task in comparison to students using phone or smart Tv.

Table 11. Multiple comparisons

Multiple Comparisons
Tukey HSD

Dependent Variable	(I) means for access to online courses	(J) means for access to online courses	Mean Difference (I-J)	Std. Error	Sig.
Student Faculty İnteraction	Tablet	Phone	.1954*	.06683	.029
		Smart Tv	.5250*	.16992	.017
Time on Task	Tablet	Phone	.2422*	.07846	.017

3.4. RQ4 Differences in the Participant Students' Evaluations of Online Science Courses based on the Frequency of Attendance for Online Science Courses

One-way ANOVA was used to analyse whether there were statistically significant differences in students' evaluation of online science courses based on their frequency of attendance in online science courses (Table 12).

Table 12. ANOVA results for evaluation of online science courses based on the frequency participation in online courses

		N	Mean	SD	ANOVA	Eta-squared
Student Faculty Interaction	Attended in all online classes	190	3.74	1.27	F=69.45	.093
	Attended in most online classes	344	3.63	1.08		
	Attended in some of the online classes	474	3.18	1.05	Sig=<.001	
	Attended only in few online classes	1026	2.82	1.12		
	Total	2034	3.12	1.16		
Active Learning	Attended in all online classes	190	3.80	1.35	F=62.81	.085
	Attended in most online classes	344	3.70	1.25		
	Attended in some of the online classes	474	3.21	1.20	Sig:<.001	
	Attended only in few online classes	1026	2.82	1.26		
	Total	2034	3.15	1.31		
Time on Task	Attended in all online classes	190	3.72	1.43	F=53.65	.073
	Attended in most online classes	344	3.61	1.34		
	Attended in some of the online classes	474	3.16	1.26	Sig=<.001	
	Attended only in few online classes	1026	2.77	1.31		
	Total	2034	3.09	1.37		
Cooperation among Students	Attended in all online classes	190	3.54	1.44	F=39.47	.055
	Attended in most online classes	344	3.30	1.26		
	Attended in some of the online classes	474	2.92	1.25	Sig=<.001	
	Attended only in few online classes	1026	2.65	1.27		
	Total	2034	2.91	1.32		

The results reveal that the frequency of attendance in online science classes were a significant factor for all four subsection of the evaluation scale; F(3,230)=69.45, p<.05, η^2 =.093 for student and faculty interaction, F(3,230)=62.81, p<.05, η^2 =.085 for active learning, F(3,230)=53.65, p<.05, η^2 =.073 for time on task and F(3,230)=39.47, p<.05, η^2 =.055. Results from the table 12 shows that despite significant differences in students' evaluation of online science courses based on students' frequency of attendance, the size for all four subsections are small. Therefore, it can be concluded that attendance frequency in online science classes did not emerged as an important factor for the participant students' evaluation of online science classes. Multiple comparisons were calculated to find out the source of the differences emerged in the way-ANOVA test (Table 13).

Table 13. Multiple comparisons for students' evaluation of online science classes based on the attendance frequency

Tukey HSD Dependent Variable	(I) Attendance frequency	(J) Attendance frequency	Mean Difference (I-J)	SE	Sig.
Student Faculty Interaction	All	Some	.56244*	.09528	<.001
		Few	.92110*	.08764	<.001
	Most	Some	.45102*	.07859	<.001
		Few	.80969*	.06913	<.001
	Some	Few	.35867*	.06163	<.001
Active Learning	All	Some	.59641*	.10761	<.001
		Few	.98012*	.09898	<.001
	Most	Some	.49233*	.08877	<.001

		Few	.87604*	.07808	<.001
	Some	Few	.38371*	.06960	<.001
Time on Task	All	Some	.55861*	.11296	<.001
		Few	.94795*	.10391	<.001
	Most	Some	.45284*	.09318	<.001
		Few	.84218*	.08197	<.001
	Some	Few	.38934*	.07306	<.001
Cooperation among Students	All	Some	.61595*	.11006	<.001
		Few	.88460*	.10123	<.001
	Most	Some	.37677*	.09079	<.001
		Few	.64542*	.07986	<.001
	Some	Few	.26865*	.07119	<.001

The table for multiple comparisons reveals that in all subsection the statistically significant differences were between attending in all online science classes and attending in same and few online science classes, between attending in most online science classes and attending in some and few online science classes and between attending in some online science classes and attending in few online science classes (Table 13).

3.5. RQ5 the Effect of Student- Faculty Interaction, time On- Task and Cooperation among Students on Active Learning for Online Science Learning

Multiple regression analysis was used to test if student and faculty interaction, time on task and cooperation among students significantly predicted active learning for online science instruction.

Table 14. A model summary for multiple regression

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.884[a]	.782	.781	.61238	1.766

a. Predictors: (Constant), Student Faculty İnteraction, Cooperation among Students, Time on Task
b. Dependent Variable: Active Learning

The table above displays that the model explains 88.4% of the variation in the dependent variable.

Table 15. ANOVA results for the regression model

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2723.209	3	907.736	2420.544	.000[b]
	Residual	761.277	2030	.375		
	Total	3484.486	2033			

a. Dependent Variable: Active Learning
b. Predictors: (Constant), Student Faculty Interaction, Cooperation among Students, Time on Task

The overall model is significantly useful in explaining active learning for online science courses (Table 15), $F\ (3, 2030) = 2420.54$, $p < .05$.

Table 16. Coefficients for the regression model

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	SE	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	.071	.039		1.813	.070		
	Time on Task	.256	.018	.267	14.256	<.001	.306	3.263
	Cooperation among Students	.161	.016	.162	9.907	<.001	.402	2.488
	Student Faculty Interaction	.582	.022	.518	25.899	<.001	.269	3.716

a. Dependent Variable: Active Learning

The results from table 16 show that with one-unit increase in student and faculty interaction, active learning increases .58 point during online science instruction, which was found to be a significant change, $t(2030)=25.90$, $p<.05$.Also, with one-unit increase in time on task, active learning increases .26 point during online science instruction, which was found to be a significant change, $t(2030)=14.26$, $p<.05$. Similarly, with one-unit increase in cooperation among students, active learning increases .16 point during online science instruction, which was found to be a significant change, $t(2030)=9.91$, $p<.05$. The equation to predict active learning from student and faculty interaction, cooperation among students and time on task for the evaluation of online science courses is:
Active learning=.071+(.058*SFI) +(.26*TOT) +(.16*CAS)

4. DISCUSSION and CONCLUSION

The current study investigated students' evaluation of online science experiences in terms of student- faculty interaction, time on task, cooperation among students and active learning. The overall findings showed that the participant students saw the online science classes less effective in comparison to face to face science learning in all four dimensions investigated. Also, in all four dimension of the online science learning evaluation that include student faculty interaction, time on task, cooperation among students and active learning, lower grade students responded more positively to the items related to online science classes compared to upper grade students. There are difference approaches to investigating the effectiveness of online or face to face learning in the literature. Some studies usually compare these two ways of learning by focusing on their benefits or disadvantages in areas such as flexibility, cost effectiveness, access, skills (Kulal & Nayak, 2020; Lauran et al., 2014). Learner preference, interactivity, workload, performance, and challenges (Mather & Sarkans, 2018) are also studied when comparing the two ways of learning. Previous studies comparing online learning to face to face learning reported that the main reasons students preferred face to face learning to online line learning was the opportunity to interact with peers and faculty as learning was enhanced through immediately available feedback, lack of motivation to attend online classes, and difficulties in time management for online classes (Mather & Sarkans, 2018). Selvaraj, Vishnub, Benson and Mathew (2021) studied students' and teachers' approach to online learning during the COVID 19. The study found that both students and teachers believed face to face learning are better in terms of knowledge transfer and learning efficacy and that student were more attentive in face to face learning. Comparing online learners' views to that of face to face learners, Mather and Sarkans (2018) found that online learners valued flexibility and convenience while face to face learners saw the importance of peer and faculty interaction as the main element of face to face learning. Bernard et al. (2009) found that online learning can be more effective than face-to-face learning when there is a high level of interaction between students and instructors. Similarly, Cook (2007) argues that online learning can be more effective than face-to-face learning in certain contexts, such as when students have access to multimedia resources and interactive simulations. A meta-analysis by Means, Toyama, Murphy, Bakia and Jones (2010) found that online learning was more effective compared to traditional face-to-face learning. Ganesh, Paswan, and Sun (2015) investigated four dimensions, overall evaluation, perceived competence, perceived communication, and perceived challenge, to find out how students rate online learning and face to face learning. The results of their study indicated that students rate traditional classes better on all four dimensions. The effectiveness of online learning is also well documented in the literature particularly when online science learning enriched with applications such as web 2.0 tools as students' motivation increases since learning activities resembles games and students compete with their peers (Hoic-Bozic, Holenko Dlab & Mornar, 2016). Lack of interaction with the instructors as seen a major factor that affect students' online learning experience (Hollister, Nair, Hill-Lindsay & Chukoskie, 2022). Student-student and student -faculty interactions are among the main benefits of the face to face learning that provide students to with opportunities to clarify and misunderstanding, misconception or response to questions during the learning process (Paul & Jefferson, 2019; Singh et al.,2021). Yao, Rao, Jiang, and Xiong (2020) found that teachers' involvement related to their teaching efficiency; their role as teacher and feedback provider was still critical to learning during online classes. In addition, more online communication between teachers and students positively affected student performance (Yao et al., 2020).

The majority (64%) of the participant of this study used mobile phone to attend online science courses. This is in line with the findings of previous studies that investigated online classes. Muthuprasad, Aiswarya, Aditya and Girish (2021) reported that students mostly used mobile phones for online class that was followed by laptops, tablets and only a few participant students used desktops to attend online classes Similarly, Gamage and Perera, (2021) found while students frequently used laptops and smartphones and they seldomly resorted to desktop computers. With rapid development of smart phone technologies, the mobile phones are seen as important instrument to support online science learning as it has potential to motivate students, help for inquiry-based learning, enhance learning through the applications for virtual learning and simulations, promote science process skills such as collaboration, critical thinking and decision making (Suarez et al., 2018). Previous studies reported that in lower- or middle-income groups, students faced problems of access to online courses (Barrot, et al., 2021). From the data collected from for the study, it was not clear whether the participant students preferred to use mobile phones or they did not have any other option as usually in a family of more than one student studying in different grades had to attended in online classes simultaneously during Covid 19 lockdown and that it was probably not possible for all students in a family to attend online classes through computers simply because families could not afford many computers.

The current study also investigated whether the medium used by students to attend online science classes had any effect in evaluating the effectiveness of online science classes. The findings of the study showed that students using tablets to attend on line classes had more positive views on the effectiveness of online science in terms of student- faculty interaction and time on task in comparison to students using phones or smart tv. Garcia-Mendoza (2014) compared the participation, interaction and collaboration between students using desktops and student using smartphones. The study found that mobile phones had a great potential for online learning in comparison to desktops in terms of student interaction, time on task and collaboration among students. In the same vein, Anshari, Almunawar, Shahrill, Wicaksono, and Huda (2022) found the use of smartphones in classes positively affected students' academic achievement. There are also studies that found challenges with the use of smartphones for online learning. Dolgunsoz and Yildirim (2021) found that students were mostly using smartphones for online classes but these devices were not effective as the participant students faced problems such as overheating of the phones, limited screen size for effective learning and problems of connectivity. The same study also found that tablets were not popular among students and the researcher recommended the use of notebooks for online learning. Similarly, Tal and Kurtz (2015) found that while using notebook or laptops is helpful for creating learning-supportive activities, smartphones can promote distractive activities in the learning environment. Kenar, Balci and Gokalp (2013) found that the use of tablet had positive impacts on students' attitudes toward technology and technology usage in the courses.

The study found that the frequency of attendance for online science classes was a major factor in students' evaluation of online science classes since students who attended in all or most of the online science classes had higher opinions for the effectiveness of online science classes in terms of student- faculty interaction, time on task, cooperation among students and active learning. Hollister, Nair, Hill-Lindsay and Chukoskie (2022) found that students' frequency for synchronous online learning was low and usually they preferred recorded classes rather than attending live online classes that negatively affects their learning experiences. Lu and Cutumisu (2022) did not find any relation between attendance and academic outcomes but, study suggested that, attendance enhances academic performance by utilizing active engagement in online learning and improved performance in formative assessments. The results of the study carried out by Hong et al. (2021) indicated that the level of online learning ineffectiveness among high school students had negative correlation between the quantity of online experimental courses and the duration of online hands-on learning.

One of the elements that often becomes a subject of discussion in online science learning is the fact that national curriculums persistently promotes student-centred learning that encompasses students' active engagements in the scientific processes that include hands on activities (Hong et al., 2021) during the knowledge building but online science learning can be challenging for active learning (Miller, 2008). In contrast, the increasing integration of available online tools such as games, simulations, virtual/ augmented realties etc. provides opportunities for students and teachers to increase student motivation, enhance science learning and make science learning fun (Lauran et al., 2014; Kulal & Nayak, 2020). Therefore, based on the participant students' views, the study was also interested in finding out whether in online science classes student-faculty interaction, time on task and cooperation among students were important in terms of active learning. The study revealed that these three factors were important elements of active learning in online science classes. The previous studies in the field found that engagement (Widiyatmoko, 2018) interaction between student- faculty and student- student (Faja, 2013), and working together for task (Bakioglu & Cevik, 2020; Kulal & Noyak, 2020) are important elements of active learning in online science teaching.

This study investigated the participant students' online science learning experiences to evaluate the effectiveness of online science courses by using the four subsections identified in the Student Evaluation of Online Teaching Effectiveness (SEOTE) scale developed by Bangart (2005). The participant students were not satisfied with online science learning experiences in terms of faculty-student interaction, time on task, cooperation among students and active learning practices. Although several factors such as participant students' motivation for online learning, availability of resources, teacher's expertise and connectivity problems can affect students' views for the evaluation of online science learning experiences, a relatively large group of participants' views from different grades and schools are important when considering online science learning activities. Therefore, assuring students engagement, teacher-faculty interaction, creating opportunities for students to cooperate and heling students to actively engage in the activities need consideration by teachers when designing or implementing online science classes. This consideration may well begin in preservice teacher education as the Covid-19 and the recent earthquake that effected a large part of Turkey have demonstrated, online teaching, in general and science in particular since the pace of educational technology that helps learning science is extremely high with new developments almost daily, has already become an important part of our instructional strategy. The study, also, confirmed that in online science learning interaction between student and faculty, time on task and cooperation among students are predictors of active learning. Therefore, when online science active learning activities for students are developed these three areas should be considered.

Ethics Committee Decision

Ethical approval and written permission for this study were obtained from the Social and Human Sciences Scientific Research and Publication Ethics Committee of Dicle University with the decision dated 14/04/2021 and numbered 59225

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