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An Analysis of Social Studies Instructional Applications for the Development of Astronomy Literacy in 7th Grade Students

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Abstract: The European Astronomical Union (EAU) designated the year 2019, as the "Year of Astronomy Literacy," prompting countries worldwide to place greater emphasis on space and astronomy education and to adjust their curricula accordingly. Integrating astronomy literacy into the social studies curriculum is particularly crucial, as the course aims to educate citizens who are able to adapt to evolving national and global conditions and who possess strong problem-solving capabilities. The purpose of this study is to equip the seventh-grade students with cognitive, affective and behavioral competencies related to astronomy literacy within the context of the social studies course. The Astronomy Literacy Scale developed by Özdemir was administered as both a pre-test and a post-test. The research was conducted in Yenişehir district of Bursa, one of Turkey's provinces, during the first semester of the 2023-2024 academic year. The study employed a quasi-experimental design involving 22 students in the experimental group and 22 in the control group. The instructional application was implemented over a five-week period, with two class hours per week. Data were analyzed using the SPSS statistical software package. Following the application, 't was found that there were statistically significant differences between the experimental and control groups across the cognitive, affective and behavioral domains, consistently favoring the experimental group. The findings indicated that the instructional practices integrated into the social studies course contributed meaningfully to the students' astronomy literacy and improved their cognitive, affective and behavioral astronomy-related skills.

Keywords: *Social studies, astronomy, astronomy literacy skills, students, applications.*

Introduction

From antiquity to the present, the existence of the universe, the motion of celestial bodies, and the sun's role as a source of heat and light have sustained human curiosity and driven efforts to investigate and comprehend the cosmic phenomena. The systematic organization of accumulated knowledge eventually gave rise to the science of astronomy. Astronomy literacy refers to the ability to understand and critically evaluate the universe, outer space, celestial bodies, and the movements that occur within these domains (Benli-Özdemir, 2023). In this day and age, individuals are required to possess a basic capacity to understand and question the physical environment they inhabit, along with the dynamic processes unfolding on Earth and throughout the universe. Such competence is attainable through the development of effective astronomy literacy skills. Individuals with advanced astronomy literacy demonstrate strong spatial and abstract thinking, are able to interpret maps and navigate effectively, can infer the consequences of Earth's and other planets' movements, and can meaningfully interpret the developments related to space exploration and research (Taşcan and Ünal, 2015).

The social studies course is an interdisciplinary domain that integrates the social sciences and humanities with the aim of developing essential citizenship competencies (Keskin, Coşkun Keskin, and Taş, 2019). Social studies as a formal subject originated in the United States in 1916 and was implemented in

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schools beginning in 1920. The National Curriculum Standards for Social Studies (NCSS), the leading authority on social studies education in the U.S., emphasized in its 1994 definition that the field encompassed not only the social and human sciences but also drew upon concepts from the natural sciences. At the primary level, the concepts and skills related to astronomy were typically introduced through life sciences courses, whereas at the secondary level they were primarily taught through science and social studies courses.

As far as review of the relevant literature's concerned, there is a substantial body of studies concerning astronomy and astronomy literacy. These studies include those that highlighted the importance of astronomy within the educational contexts (Albrecht and Voelzke, 2010; Erbudak and Yeşilbursa, 2023; Eriksson, 2019; Percy, 2005; Pompea and Russo, 2020; Rosenberg, Bladon, Russo, and Christensen, 2014; Slater, Slater, and Dwyer, 2010); investigations examining students' metaphors and perceptions related to the concept of astronomy (Arıkurt, Durukan, and Şahin, 2015; Bitzenbauer, Navarrete, Hennig, Ubben, and Veith, 2023; Güleç and Çelik, 2022; Grubic, 2022; Çelik, Güleç, and Atasoy, 2025; Karamustafaoğlu and Aktürk, 2016; Uçar and Aktamış, 2019); and studies analyzing teachers' and preservice teachers' attitudes and perspectives toward astronomy (Kuzey, 2020; Yeşil-Asana and Benzer, 2020; Erbudak and Yeşilbursa, 2024; Ezberci Çevik, Bozdemir, Candan Helvacı, and Kurnaz, 2020; Canlas, Picardal, and Picardal, 2024). Furthermore, while some other studies focused on astronomy as a disciplinary subject (Plummer, 2009; Blown and Bryce, 2018; Shen and Confrey, 2007; Yerlikaya and Yerlikaya, 2016; Merakchi, 2018; Eriksson, 2019; Salimpour and Fitzgerald, 2022; Salimpour et al., 2024; Likavcan, 2024), others on studies that established connections between social studies and astronomy (Ekiz and Akbaş, 2006; Berea et al., 2019; Güleç and Çelik, 2022; Erbudak and Yeşilbursa, 2023).

Astronomy literacy over the years has come to be investigated from multiple perspectives within the relevant literature. The studies emphasizing the significance of astronomy literacy were prominent (Alejandro, 2007; Çelik and Güleç, 2025; Love, Murphy and Bonora, 2013; Remie, 2019; Yerlikaya and Yerlikaya, 2016). Additionally, several studies focused on developing the instructional programs aimed at improving the astronomy literacy (Aranbica, Pinochet, and Campusano, 2021; Salimpour, Fitzgerald, and Hollow, 2024; Ünal, 2024), while others assessed students' levels of astronomy literacy and related competencies (Benli Özdemir, 2022; Benli Özdemir, 2023; De Beasi, Orellana, Escapil, and Olaizola, 2015). Given that the studies in astronomy literacy is crucial for cultivating a deeper understanding of the universe in which we live, it is essential to provide the students with the astronomy literacy skills and to explore the effective methods for fostering their development. Therefore, the present study aimed to enhance seventh-grade students' cognitive, affective and behavioral astronomy literacy skills through a five-week instructional program consisting of two-hour sessions each week.

The study first examined the learning areas where astronomy is included in the 2018 social studies curriculum. The examination revealed that information related to astronomy is included in the learning areas of Individual and Society, Culture and Heritage, People, Places and Environment, and Global Connections. In the 2018 Science Curriculum, learning outcomes and skills related to astronomy are addressed more intensively, with a separate learning area called Earth and the Universe (Çelik, 2024). While science education focuses more on cognitive domains, social studies education should include skills related to affective and behavioral domains in relation to astronomy. To this end, learning outcomes related to astronomy can be added to the existing learning areas (Ekiz and Akbaş, 2006; Çelik, 2024).

This study examined the effect of instructional practices designed to develop astronomy literacy on the seventh-grade students' astronomy literacy scores, comparing the experimental and control groups through pre-test and post-test measurements. Specifically, the study sought answers to the following research questions:

1. Is there a statistically significant difference, between the experimental and control groups' pre-test and post-test mean scores on the overall Astronomy Literacy Scale?
2. Is there a statistically significant difference, between the experimental and control groups' pre-test and post-test mean scores on the cognitive dimension of the Astronomy Literacy Scale?
3. Is there a statistically significant difference, between the experimental and control groups' pre-test and post-test mean scores on the affective dimension of the Astronomy Literacy Scale?
4. Is there a statistically significant difference, between the experimental and control groups' pre-test and post-test mean scores on the behavioral dimension of the Astronomy Literacy Scale?

Materials and Methods

This section presents the procedural steps followed throughout the study, detailing the implementation process from the initial preparation phase to data collection and analysis.

Model of the Study

Experimental studies are conducted in an attempt to identify the effect of conditions deliberately created or manipulated by the researcher on a dependent variable (Akcan, 2023, p. 90). Fraenkel, Wallen, and Hyun (2011) described the experimental studies as the systematic observation of outcomes that occurred when specific applications or treatments were introduced. In the field of education, experimental methods are frequently employed in order to compare the instructional approaches and to assess the extent of learners' progress. Büyüköztürk, Çakmak, Akgün, Karadeniz and Demirel (2014) classified the experimental studies into two main categories: single-factor and multi-factor designs. They further stated that multi-factorial designs could be divided into four types; weak experimental designs, true experimental designs, factorial designs, and quasi-experimental designs.

This study used a quasi-experimental design developed by Campbell and Stanley (1996). This is because a quasi-experimental design gives the researcher the opportunity to test the tools they have developed (Akcan, 2023). Specifically, the pretest–posttest matched control group design developed by Campbell and Stanley (1996) was chosen. This particular design allows for a degree of control during the testing of researcher-developed instruments. The inclusion of pretests enables researchers to determine the initial equivalence of groups prior to the application and to interpret the posttest results accordingly (Karasar, 2018, p. 132).

In order to ensure the internal validity, equivalent experimental and control groups were established. The independent variables of the study were the students' group assignment (experimental or control) and their gender, while the dependent variable was their astronomy literacy skill level.

Validity and Reliability in Quantitative Data Analysis

Validity refers to the extent to which a scale measures the construct it is intended to measure without capturing the unrelated characteristics. Reliability, on the other hand, concerns the degree to which a scale consistently and accurately measures the phenomenon for which it was designed (Yıldırım and Şimşek, 2018). The study included the opinions of two experts: a linguistics specialist and a social studies education specialist. In order to ensure the content validity of the Astronomy Literacy Scale and the scale was administered to a total of 16 students so as to establish whether the items were interpreted as intended. According to the results of the Exploratory Factor Analysis, the Kaiser–Meyer–Olkin (KMO) coefficient of the scale was calculated as .702, and it was found that the average reliability coefficient was .75. These values indicated that the scale was both valid and reliable for measuring astronomy literacy.

Data Collection Process

In the present study, initially the necessary permissions were first obtained from Benli Özdemir (2022), the developer of the Astronomy Literacy Scale. Following this, the scale was reviewed by a Turkish language expert and the required adaptations were made. Since it was not ethically appropriate to disclose the actual class sections, the students who participated voluntarily and submitted parental consent forms were selected from the sections designated as 7H and 7G. The scale used in both the pre-test and post-test was comprised of three dimensions; cognitive, affective and behavioral. Initially, the pre-test was administered to both the experimental and control groups. One week after the pre-test, a 10-lesson astronomy literacy instructional plan was implemented by the researcher. The astronomy literacy outcomes were developed by the practitioner, with careful attention to aligning them with the relevant topics in the social studies curriculum. The specific learning achievements addressed in each application are presented in Table 1 below.

Table 1. *Astronomy literacy in social studies achievements regarding the cognitive, affective and behavioral skills*

Application	Achievement	Sub-Achievement	Method	Resource	Evaluation
1-2	Students can analyze the role of media in social change and interaction.	Students can analyze celestial bodies through social media platforms, and they may develop positive attitudes toward the lives and responsibilities of astronauts as a result of these engagements.	Instruction through media-based teaching complemented by the question-and-answer method.	NASA YouTube Spacekamp Turkey videos	Students are asked to imagine themselves as astronauts and write a reflective account of a typical day in the life of an astronaut.
3-4	Students can analyze the role of media in social change and interaction.	Students can follow astronomy-related developments through media applications such as Google Sky, Google Maps, StarWalk, and NASA platforms.	Instruction through media-based teaching complemented by the question-and-answer method.	NASA star walk Skymap google earth Googlemap	Students are asked to use these applications to ask one another questions and to identify objects in space as well as objects on Earth.
5-6	Students can develop an understanding of the processes that compelled the Ottoman Empire to undergo change, particularly in relation to contemporaneous developments in Europe.	Students can develop an interest in learning about astronomical developments that took place in Europe during the Early Modern and Modern periods.	Lecture method, question and answer method,	visual information cards	Students are asked to play the astro game “Söyleçiz-tabu” and explain the picture cards and again explain the information cards this time by drawing.
7-8	Students can draw inferences about the factors influencing human settlement from past to present by engaging in case study analyses.	Based on the factors influencing human settlement, students can recognize the necessity of astronomy studies for the future and follow current developments in the field of astronomy.	Lecture method Case study method	Question and answer method Case study from the eyes of an astronaut	A case study titled “From the perspective of the astronaut” is distributed to the students, and they are asked to read this case, answer the follow-up questions, and fill in the missing parts of the text.
9-10	Students can evaluate the effects of advancements in production technology on social and economic life.	Students can research the effects of astronomy-related spacecraft on social and economic life.	Narration method Question and answer method Evidence-based teaching method	Information cards related to spacecraft and discourses concerning Turkey’s space studies. Students can solve concept puzzles related to spacecraft.	The class conducts a panel study on spacecraft, during which the contributions of spacecraft technology to the national economy and to individuals’ daily lives are evaluated.

The instructional applications were implemented with the experimental group. One week after the completion of these applications, the post-test was administered to both the experimental and control groups.

Study Group

According to Karasar (2018), the sampling process in a research study is shaped by factors such as the research method, purpose, accessibility, and the degree of control that can be maintained. In the present study, the participants were selected using the convenience sampling, a type of non-random sampling method. Convenience sampling involves choosing a sample that is readily available and easily accessible to the researcher (Fraenkel et al., 2011).

This study was conducted in Turkey. The sample of the study consisted of 22 seventh-grade students enrolled in a school affiliated with the Ministry of National Education in the Yenişehir district of Bursa during the first semester of the 2023–2024 academic year. A total of 44 students participated: 22 in the experimental group and 22 in the control group. In selecting the classes to be included in the study, the information regarding students' academic achievement levels and socioeconomic backgrounds was obtained from the classroom teachers. The classes with similar achievement levels and balanced gender distributions were chosen. Both the experimental and control groups were coded separately by gender. Each group consisted of 22 students, including 11 girls and 11 boys, ensuring equivalence in terms of the gender variable. The students who did not submit parental consent forms were excluded from the study. In order to uphold the ethical standards, all participant information was kept confidential.

After the Astronomy Literacy Scale was administered to the experimental group as a pre-test, a five-week astronomy literacy skill development program was implemented. For this purpose, lesson plans and activities developed by the researcher were utilized. In the social studies lesson plans, 10 lesson plans related to cognitive, affective, and behavioral dimensions utilized teaching methods such as media-based instruction, question-and-answer method, lecture, case study instruction, and evidence-based teaching. Additionally, the researcher designed activities such as flashcards about spacecraft, concept puzzles, a case study from the astronaut's perspective, and an astronomy-related "draw, speak, draw, taboo, astronomy" game. For detailed information on the implemented methods, please refer to Table 1. In alignment with the learning achievements in the social studies curriculum, the sub-achievements related to astronomy were created. As an example of learning outcomes and sub-outcomes, the following sub-outcome has been created for the learning outcome "Discuss the role of media in social change and interaction" in the 7th grade Individual and society learning area: "Analyzes celestial bodies in space through social media. Develops positive attitudes towards the lives and missions of astronauts." For detailed information about social studies learning outcomes and sub-outcomes please refer to Table 1. Instructional activities were designed to enhance students' affective and behavioral dispositions toward astronomy, in addition to supporting their cognitive development. Following the administration of the pre-test to the control group, the lesson taught proceeded according to the standard Ministry of National Education curriculum without the inclusion of the astronomy literacy application.

Quantitative Data Collection Tools

"The *Astronomy Literacy Scale*" developed by Benli Özdemir (2022) was employed in the study. The original scale is comprised of three dimensions; cognitive, affective and behavioral and contains 16 items, of which 11 are positively worded and 5 are negatively worded. The scale retained its original structure and utilized a five-point Likert-type response format. The total scores ranged from a minimum of 16 to a maximum of 80. The scale was translated from English into Turkish and linguistic equivalence was established. A Turkish language expert reviewed the translated items to ensure the linguistic accuracy and cultural appropriateness. Each item was subsequently evaluated individually based on the expert feedback. Following this process, the scale was administered to a pilot group of ten students in the 7th and 8th grades, who were asked to explain the meaning of each item in order to verify comprehension. Through these steps, the linguistic consistency and equivalence of the instrument were confirmed. Exploratory Factor Analysis was conducted to assess the construct validity of the scale. It was found that the Kaiser–Meyer–Olkin (KMO) value was.702, indicating acceptable sampling adequacy and the Bartlett's Test of Sphericity was significant ($p < .05$), demonstrating that the data were suitable for factor analysis

Evidence indicates that the *Astronomy Literacy Scale* is a valid and reliable instrument for assessing students' astronomy literacy skills. The internal consistency coefficients reported by Benli Özdemir (2022) are .70 for the cognitive dimension, .72 for the affective dimension, and .84 for the behavioral dimension. The Cronbach's alpha coefficient for the overall scale is .75, demonstrating that the reliability

of the instrument exceeds the commonly accepted threshold of .70. In this respect, the scale can be considered a psychometrically sound tool for measuring astronomy literacy. The cognitive dimension of the scale evaluates students' knowledge of astronomy-related concepts. The affective dimension assesses their attitudes, perceptions, and interest toward astronomy and the behavioral dimension captures information related to their astronomy-related behaviors. In the present study, data were analyzed separately within the cognitive, affective and behavioral sub dimensions.

Collection and Analysis of Quantitative Data

Data were collected from both the experimental and control groups as a pre-test during the study period, after which the application was initiated. One week following the completion of the application, a post-test was administered to both groups. The quantitative data obtained for the study were analyzed using the SPSS 24 statistical software package. Prior to conducting inferential analyses, the distribution of the data was examined to determine whether it met the assumptions of normality. Initially, measures of central tendency, that is, mode, median and mean were reviewed. The close proximity of these values was considered an important indicator of normal distribution. Subsequently, skewness and kurtosis coefficients were analyzed. The fact that these coefficients fell within the acceptable range (+2/−2), combined with a non-significant result in the test of homogeneity of variances ($p > .05$), suggested that the data were normally distributed. As the sample size in each group was fewer than 50 participants, the Shapiro–Wilk test was also employed to assess normality. The non-significant Shapiro–Wilk values further confirmed that the data did not deviate from normality. Accordingly, parametric statistical tests were utilized in the data analysis. A dependent samples t-test was applied to compare the related groups and an independent samples t-test was utilized for comparisons between the unrelated groups. The Shapiro–Wilk test results for the normality analysis are presented in Table 2 below.

Table 2. *Normality Test Result*

	Shapiro-Wilk		
	Statistic	**Df**	**Sig**
Pre-test scale	,975	44	,441
Pre-test cognitive Dimension	,973	44	,385
Pre-test Affective Dimension	,973	44	,381
Pre-test Behavioral Dimension	,976	44	,487
Post-test Scale	,969	44	,275
Post-test cognitive Dimension	,969	44	,284
Post-test Affective Dimension	,934	44	,014
Post-test Behavioral Dimension	,953	44	,069

The results of the quantitative data analyses were systematically tabulated and interpreted in the findings section.

Role of the Researcher

The researcher conducted the study at the school where she was employed. Following the administration of the pre-test to both the experimental and control groups during the same week, without introducing any application, the instructional treatment was initiated in the experimental group and continued for five weeks. Each week, two class hours from the social studies course were allocated to the application activities on the predetermined dates. The implementation phase concluded at the end of the five-week period. One week after the completion of the application, the post-test was administered to the students in both the experimental and control groups.

Ethics Committee Approval

Ethical approval for the present study was obtained from the Bursa Uludağ University Social and Humanities Research and Publication Ethics Committee (Decision No. 2023/07; Date: 25.07.2023).

Materials and methods are the second section of an IMRAD paper. Its purpose is to describe the experiment in such retail that a competent colleague could repeat the experiment and obtain the some or equivalent results. Provide sufficient detail to allow the work to be reproduced. Methods already published should be indicated by a reference: only relevant modifications should be described.

Results

Findings and Discussion on the Pre-Test and Post-Test Mean Scores of the Students in the Experimental and Control Groups on the Astronomy Literacy Scale Scores

Under this heading, the findings related to the four sub-questions are presented and examined under separate sub-sections.

4.1.1. Is there a statistically significant difference, between the experimental and control groups' pre-test and post-test mean scores on the overall Astronomy Literacy Scale? Table 3 illustrates the dependent samples t-test results for the pre-test and post-test scores obtained by the students in the experimental group on the Astronomy Literacy Scale (ALS).

Table 3. *Dependent Samples t-Test Results for the Pre-Test and Post-Test Astronomy Literacy Scores of the Students in the Experimental Group*

	N	Mean	Ss	Sd	T	p
Pre-test	22	3,27	,48	21	-9,34	,000
Post-test	22	4,12	,33			

An examination of Table 3 indicates a statistically significant difference between the pre-test mean score (3.27) and the post-test mean score (4.12) of the students in the experimental group [$t(21) = –9.34$, $p < .05$]. The mean scores showed that this significant difference favored the post-test, suggesting that the application contributed to an improvement in students' astronomy literacy levels.

4.1.2. Is There a Significant Difference Between the Pre-Test and Post-Test Astronomy Literacy Scores of the Students in the Control Group? Table 4 presents the dependent samples t-test results for the pre-test and post-test scores obtained by the students in the control group on the Astronomy Literacy Scale (ALS).

Table 4. *Dependent Samples t-Test Results for the Pre-Test and Post-Test Astronomy Literacy Scores of the Students in the Control Group*

	N	Mean	Ss	Sd	T	p
Pre-test	22	3,36	,49	21	2,699	,01
Post-test	22	3,32	,48			

An examination of Table 4 shows that there was a statistically significant difference between the pre-test mean score (3.36) and the post-test mean score (3.32) of the students in the control group [$t(21) = 2.70$, $p < .05$]. However, the difference between the two mean scores was minimal.

4.1.3. Is There a Significant Difference Between the Pre-Test and Post-Test Astronomy Literacy Scores of the Students in the Experimental and Control Groups? Table 4 presents the independent samples t-test results for the pre-test and post-test scores obtained from the Astronomy Literacy Scale (ALS) by students in the experimental and control groups.

Table 5. *Independent Samples t-Test Results for the Pre-Test and Post-Test Astronomy Literacy Scores of the Students in the Experimental and Control Groups*

	Groups	N	X	Ss	Sd	t	p
Pre-test	Experimental	22	3,27	,49	42	-,653	,518
	Control	22	3,36	,50	42		
Post-test	Experimental	22	4,13	,34	42	6,390	,000
	Control	22	3,32	,49	42		

An examination of Table 5 shows that there was no statistically significant difference between the pre-test astronomy literacy scores of the experimental and control groups, as indicated by the similarity in their mean scores [t(42) = –0.65, p > .05]. However, a comparison of the post-test scores revealed a statistically significant difference between the two groups [t(42) = 6.39, p < .05]. This finding suggested that the instructional application provided to the experimental group had a positive impact on their astronomy literacy levels.

4.1.4. Is There a Significant Difference Between the Pre-Test and Post-Test Astronomy Literacy Scores of the Students in the Experimental and Control Groups by Gender? Table 6 presents the independent samples t-test results conducted to establish whether the pre-test and post-test scores obtained from the Astronomy Literacy Scale (ALS) by the students in the experimental and control groups differed by gender.

Table 6. *Independent Samples t-Test Results for the Pre-Test and Post-Test Scores of the Experimental and Control Groups by Gender*

Group	Gender	Process	X	ss	Sd	t	P
Experimental	Male	Pre-test-Post-test	-1,00	,43	10	-7,644	,000
	Female	Pre-test- Post-test	-0,71	,40	10	-6,03	,000
Control	Male	Pre-test- Post-test	0,73	,09	10	2,797	,019
	Female	Pre-test- Post-test	,020	,08	10	1,00	,341

An examination of Table 6 shows that there was a statistically significant difference between the pre-test and post-test scores of both male students [t(10) = –7.64, p < .05] and female students [t(10) = –6.03, p < .05] in the experimental group. In contrast, it was found that there was no significant difference between the pre-test and post-test scores of male students [t(10) = 2.80, p > .05] or female students [t(10) = 1.00, p > .05] in the control group. Considering the degree of change observed among the male and female students in the experimental group, the results suggested that male students exhibited greater improvement in astronomy literacy following the application.

Findings and Discussion on the Pre-Test and Post-Test Mean Scores of the Experimental and Control Groups for the Cognitive Dimension of the Astronomy Literacy Scale

4.2.1. Is There a Significant Difference Between the Pre-Test and Post-Test Scores on the Cognitive Dimension of Astronomy Literacy for the Students in the Experimental Group? Table 7 presents the dependent samples t-test results for the pre-test and post-test scores obtained by the students in the experimental group on the cognitive dimension of the Astronomy Literacy Scale. The findings are summarized below.

Table 7. *Dependent Samples t-Test Results for the Pre-Test and Post-Test Scores of the Students in the Experimental Group on the Cognitive Dimension of the Astronomy Literacy Scale*

	N	Mean	Ss	sd	T	p
Pre-test	22	3,35	,54	21	-5,265	,000
Post-test	22	3,99	,44			

An examination of Table 7 indicates a statistically significant difference between the pre-test mean score (3.35) and the post-test mean score (3.99) of the students in the experimental group [t(21) = –5.27, p < .05]. The comparison of mean scores showed that this difference favored the post-test, with students achieving higher scores following the application. This particular finding suggested that in addition to the targeted instructional activities aimed at developing the cognitive dimension of astronomy literacy, the cumulative learning that occurred throughout the process contributed positively to the students' cognitive perception. It may also be inferred that students' confidence in their astronomy-related knowledge improved after the application.

4.2.2. Is There a Significant Difference Between the Pre-Test and Post-Test Scores of the Students in the Control Group on the Cognitive Dimension of Astronomy Literacy? Table 8 presents the dependent samples t-test results for the pre-test and post-test scores obtained by the students in the control group on the cognitive dimension of the Astronomy Literacy Scale. The findings are summarized below.

Table 8. *Dependent Samples t-Test Results for the Pre-Test and Post-Test Scores on the Cognitive Dimension of the Astronomy Literacy Scale for the Students in the Control Group*

	N	Mean	Ss	Sd	T	p
Pre-test	22	3,50	,56	21	,358	,724
Post-test	22	3,49	,50			

An examination of Table 8 reveals that there was no statistically significant difference between the pre-test mean score (3.50) and the post-test mean score (3.49) of the students in the control group [t(21) = 0.36, p > .05]. This result indicated that the cognitive dimension scores of the control group did not change from pre-test to post-test, suggesting that students' cognitive astronomy literacy remained stable in the absence of the application.

4.2.3. Is There a Significant Difference Between the Pre-Test and Post-Test Scores on the Cognitive Dimension of Astronomy Literacy for the Students in the Experimental and Control Groups? Table 9 presents the independent samples t-test results for the pre-test and post-test scores obtained by the students in the experimental and control groups on the cognitive dimension of the Astronomy Literacy Scale. The findings are summarized below.

Table 9. *Independent Samples t-Test Results for the Pre-Test and Post-Test Scores on the Cognitive Dimension of the Astronomy Literacy Scale for the Students in the Experimental and Control Groups*

	Groups	N	X	Ss	sd	t	p
Pre-test	Experimental	22	3,35	,54	42	-,935	,355
	Control	22	3,50	,56	42		
Post-test	Experimental	22	3,99	,44	42	3,469	,001
	Control	22	3,49	,51	42		

An examination of Table 9 indicates that there was no statistically significant difference between the pre-test cognitive dimension scores of the experimental and control groups, as reflected in their similar mean scores [t(42) = –0.94, p > .05]. However, comparison of the post-test scores revealed a statistically significant difference between the two groups [t(42) = 3.47, p < .05]. This finding suggested that the instructional application administered to the experimental group had a positive impact on students' cognitive astronomy literacy.

4.2.4. Is There a Significant Difference Between the Pre-Test and Post-Test Scores on the Cognitive Dimension of the Astronomy Literacy Scale for the Students in the Experimental and Control Groups by Gender? Table 7 presents the pre-test and post-test scores of students in the experimental and control groups on the cognitive dimension of the Astronomy Literacy Scale. Independent samples t-test results are provided to establish whether these scores differed by gender.

Table 10. *Independent Samples t-Test Results for the Pre-Test and Post-Test Scores of the Experimental and Control Groups by Gender*

Group	Gender	Process	X	Ss	sd	T	p
Experimental	Male	Pre-test – Post-test	-,64	,61	10	-3,52	,00
	Female	Pre-test – Post-test	-63	,56	10	-3,76	,00
Control	Male	Pre-test – Post-test	,064	,22	10	1,00	,341
	Female	Pre-test – Post-test	-,03	,09	10	-1,399	,192

An examination of Table 10 indicates that there was a statistically significant difference between the pre-test and post-test scores of both male students [t(10) = –3.52, *p* < .05] and female students [t(10) = –3.76, *p* < .05] in the experimental group. This finding indicated that both male and female students benefited from the instructional application in terms of cognitive astronomy literacy. In contrast, it was found that there was no statistically significant difference between the pre-test and post-test scores of male students [t(10) = 1.00, *p* > .05] or female students [t(10) = –1.40, *p* > .05] in the control group. This result indicated that without the application, students' cognitive dimension scores remained stable regardless of gender.

Findings and Discussion on the Pre-Test and Post-Test Mean Scores of the Experimental and Control Groups for the Affective Dimension of the Astronomy Literacy Scale

4.3.1. Is There a Significant Difference Between the Pre-Test and Post-Test Scores on the Affective Dimension of Astronomy Literacy for Students in the Experimental Group? Table 11 presents the dependent samples t-test results for the pre-test and post-test scores obtained by the students in the experimental group on the affective dimension of the Astronomy Literacy Scale. The findings are summarized below.

Table 11. *Dependent Samples t-Test Results for the Pre-Test and Post-Test Scores of the Students in the Experimental Group on the Affective Dimension of the Astronomy Literacy Scale*

	N	Mean	Ss	Sd	t	p
Pre-test	22	3,46	,60	21	-6,312	,000
Post-test	22	4,34	,36			

An examination of Table 11 indicates a statistically significant difference between the pre-test mean score (3.46) and the post-test mean score (4.34) of students in the experimental group [$t(21) = –6.312$, $p < .05$]. The comparison of mean scores demonstrated that this significant difference favored the post-test, reflecting a substantial increase in students' affective scores following the application. These results suggested that the instructional activities implemented in the experimental group had a significant and positive effect on students' affective engagement with astronomy.

4.3.2. Is There a Significant Difference Between the Pre-Test and Post-Test Scores on the Affective Dimension of Astronomy Literacy for the Students in the Control Group? The pre-test and post-test scores of the control group were examined. Table 12 presents the dependent samples t-test results for the pre-test and post-test scores obtained by the students in the control group on the affective dimension of the Astronomy Literacy Scale.

Table 12. *Dependent samples t-test results on the pre-test and post-test scores of the affective dimension of the astronomy literacy scale of the students in the control group*

	N	Mean	Ss	Sd	T	P
Pre-test	22	3,44	,73	21	3,578	,002
Post-test	22	3,37	,76			

An examination of Table 12 indicates that there was no significant difference between the pre-test mean score ($M = 3.50$) and the post-test mean score ($M = 3.44$) of the students in the control group [$t(21) = 0.36$, $p > .05$]. This finding suggested that the pre-test and post-test scores of the control group did not differ for the affective dimension of astronomy literacy.

4.3.3. Is There a Significant Difference Between the Pretest and Posttest Scores on the Affective Dimension of Astronomy Literacy for the Students in the Experimental and Control Groups? Table 13 presents the pretest and posttest scores of students in the experimental and control groups for the affective dimension of the astronomy literacy scale. Independent samples t-test results were also reported.

Table 13. *Independent samples t-test on the pre-test and post-test scores of the affective dimension of the astronomy literacy scale of the students in the experimental and control groups*

	Groups	N	X	Ss	sd	t	p
Pre-test	Experimental	22	3,46	,61	42	-,075	,941
	Control	22	3,45	,73	42		
Post-test	Experimental	22	4,34	,37	42	5,348	,000
	Control	22	3,37	,77	42		

An examination of Table 13 indicates that there was no statistically significant difference between the pre-test scores of the affective dimension of astronomy literacy for the experimental and control groups, based on the students' pre-test mean scores [$t(42) = 0.8$, $p > .05$]. In contrast, a comparison of the post-test scores revealed a statistically significant difference between the experimental and control groups [$t(42) = 5.35$, $p < .05$]. These results suggested that the instructional application provided to the experimental group had a positive effect.

4.3.4. Is There a Significant Difference Between the Pretest and Posttest Scores of Students in the Experimental and Control Groups on the Affective Dimension of the Astronomy Literacy Scale by Gender? Table 14 presents the pretest and posttest scores of students in the experimental and control groups on the affective dimension of astronomy literacy. Independent samples t-test results are provided to establish whether any differences existed based on gender.

Table 14. *Independent samples t-tests on the pre-test and post-test scores of the experimental and control groups by gender*

Group	Gender	Process	X	Ss	sd	t	p
Experimental	Male	Pre-test – Post-test	-1,17	,72	10	-5,35	,00
	Female	Pre-test – Post-test	-,59	,43	10	-4,48	,00
Control	Male	Pre-test – Post-test	,06	,08	10	2,39	,38
	Female	Pre-test – Post-test	,09	,11	10	2,631	,06

An examination of Table 14 indicates a significant difference between the pretest and posttest scores of male students in the experimental group [t(10) = -5.35, p < .05] and female students [t(10) = -4.48, p < .05], suggesting a significant effect of the application. In contrast, no significant difference was observed between the pretest and posttest scores of male students [t(10) = 2.39, p > .05] and female students [t(10) = 2.63, p > .05] in the control group. These results suggested that the male students achieved greater affective achievements than the female students.

Findings and Discussion on the Pre-Test and Post-Test Mean Scores of the Experimental and Control Groups on the Behavioral Dimension of the Astronomy Literacy Scale.

4.4.1. Is There a Significant Difference Between the Pretest and Posttest Scores of Students in the Experimental Group on the Behavioral Dimension of the Astronomy Literacy Scale? The pretest and posttest scores of the experimental group students on the behavioral dimension of the Astronomy Literacy Scale were compared. Table 15 presents the results of the dependent samples t-test conducted on the pretest and posttest scores of the students in the experimental group.

Table 15. *Dependent samples t-test results for the experimental group on the behavioral dimension of the Astronomy Literacy Scale*

Group	N	Mean	Ss	sd	t	p
Pre-test	22	2,71	,97	21	-7,876	,000
Post-test	22	4,01	,54			

An examination of Table 15 indicates a significant difference between the pre-test mean score (2.71) and the post-test mean score (4.01) of the students in the experimental group [t(21) = -7.88, p < .05]. Comparison of the group means showed that this significant difference favored the post-test scores (mean = 4.01).

4.4.2. Is There a Significant Difference Between the Pre-Test and Post-Test Scores of Students in the Control Group on the Behavioral Dimension of the Astronomy Literacy Scale? The pre-test and post-test scores of the control group students on the behavioral dimension of the Astronomy Literacy Scale were compared. Table 16 presents the results of the dependent samples t-test conducted on the pre-test and post-test scores of the students in the control group.

Table 16. *Dependent samples t-test results for the control group on the behavioral dimension of the Astronomy Literacy Scale*

Group	N	Mean	Ss	Sd	T	p
Pre-test	22	2,89	,83	21	1,418	,171
Post-test	22	2,81	,78			

An examination of Table 16 indicates no significant difference between the pre-test mean score (2.89) and the post-test mean score (2.81) of the control group students [t(21) = 1.42, p > .05]. These results suggested that the pre-test and post-test scores of the control group on the behavioral dimension of astronomy literacy did not differ significantly.

4.4.3. Is There a Significant Difference Between the Pretest and Posttest Scores of the Behavioral Dimension of Astronomy Literacy of the Students in the Experimental and Control Group? The pretest and posttests of the Experimental Control group regarding the behavioral dimension of the Astronomy Literacy Scale were compared. Table 17 contains the independent samples t-test results regarding the pre-test and post-test scores obtained by the students in the experimental and control groups from the behavioral dimension of the astronomy literacy scale.

Table 17. *Independent samples t-test on the pre-test and post-test scores of the behavioral dimension of the astronomy literacy scale of students in the experimental and control groups*

	Group	N	X	Ss	Sd	t	p
Pre-test	Experimental	22	2,71	,98	42	-,664	,510
	Control	22	2,89	,83	42		
Post-test	Experimental	22	4,01	,55	42	5,84	,000
	Control	22	2,82	,79	42		

An examination of Table 17 indicates that there was no statistically significant difference between the pre-test scores of the experimental and control groups in the behavioral dimension of astronomy literacy, as reflected in the students' pre-test mean scores [$t(42) = -0.66$, $p > .05$]. In contrast, the comparison of post-test scores revealed a significant difference between the experimental and control groups [$t(42) = 5.84$, $p < .05$]. These findings suggested that the instructional approach implemented with the experimental group had a positive effect on students' behavioral astronomy literacy.

4.4.4. Is There a Significant Difference Between the Pre-Test and Post-Test Scores of Students in the Experimental and Control Groups on the Behavioral Dimension of the Astronomy Literacy Scale by Gender? The pre-test and post-test scores of the experimental and control groups for the behavioral dimension of the Astronomy Literacy Scale were compared in terms of the gender variable. Table 18 presents the results of the independent samples t-test conducted to establish whether the pre-test and post-test scores of students in the experimental and control groups differed by gender.

Table 18. *Independent samples t-test on the pre-test and post-test scores of the experimental and control groups, analyzed according to gender*

Group	Gender	Process	x	Ss	sd	t	p
Experimental	Male	Pre-test- Post-test	-1,48	,79	10	-6,20	,00
	Female	Pre-test- Post-test	-1,12	,74	10	-4,49	,00
Control	Male	Pre-test- Post-test	,12	,16	10	2,39	,38
	Female	Pre-test- Post-test	,03	,31	10	,319	,756

An examination of Table 18 indicates that there was a significant difference between the pre-test and post-test scores of both male [$t(10) = -6.20$, $p < .05$] and female [$t(10) = -4.49$, $p < .05$] students in the experimental group, suggesting a significant effect of the application. In contrast, no significant difference was observed between the pre-test and post-test scores of the male [$t(10) = 2.39$, $p > .05$] or the female [$t(10) = 3.19$, $p > .05$] students in the control group. These findings suggested that the male students in the experimental group exhibited more positive behavioral changes toward astronomy compared to the female students in the same group.

Discussions and Conclusions

The relationship between the scores obtained from the Astronomy Literacy Scale and the pre-test and post-test scores of the experimental and control groups was examined in the present study. In this sense, an initial analysis was conducted to establish whether there was a significant difference between the pre-test and post-test scores of students in the experimental group.

The results of the study indicated that the instructional methods, techniques, and activities employed positively influenced the post-test achievements. The students were able to develop their astronomy literacy skills through engaging and interactive approaches, including concept puzzles, question cards, Tell-Tabuastro and other hands-on activities. These methods facilitated the acquisition of various

astronomy literacy skills, such as understanding and observing planetary and constellation movements, drawing inferences, interpreting space-related developments and keeping up with scientific advancements. Consequently, these activities contributed to the development of a range of related behavioral competencies (Taşcan and Ünal, 2015; Merakchi, 2018).

It was revealed that there was no significant difference between the pre-test and post-test scores of astronomy literacy among the students in the control group. This suggested that the existing social studies curriculum topics, such as *Individual and Society* and *Culture and Heritage*, did not contribute to the development of astronomy literacy skills in the control group during the study period. Therefore, it is recommended that astronomy be included in the social studies program, as it can enhance students' conceptual understanding and cognitive development. Astronomy has interdisciplinary connections with social studies, drawing from fields such as sociology, geography, and history (Erbudak and Yeşilbursa, 2023; Güleç and Çelik, 2022; Likavcan, 2024; Salimpour et al.,2024). Moreover, it was also found that there was a significant difference between the pre-test and post-test scores of the experimental and control groups in favor of the experimental group. This indicated that the instructional applications implemented in the experimental group effectively improved the students' astronomy literacy skills.

The study investigated whether there was a significant difference between the pre-test and post-test scores of astronomy literacy in the experimental and control groups, taking gender into account. The results indicated that the male students in the experimental group achieved higher scores in astronomy literacy compared to the female students. This difference may be attributed to a greater interest in space and astronomy among the male students.

Additionally, the study investigated whether there was a significant difference in the pre-test and post-test score averages of the experimental and control groups in the cognitive dimension of the Astronomy Literacy Scale. The results showed a significant improvement in the cognitive scores of students in the experimental group. Even though the study did not include a specific application targeting the cognitive dimension, it was revealed that exposure to various space-related applications and videos contributed positively to the students' cognitive astronomy skills. These results are consistent with those of the previous studies suggesting that astronomy education, including the use of innovative approaches such as augmented reality, can enhance the cognitive dimension of students' astronomy literacy (Arıcı, 2013; Benli-Özdemir, 2023).

No significant difference was found between the pre-test and post-test scores of the students in the control group regarding the cognitive dimension of astronomy literacy. This finding suggested that the learning areas covered by the current social studies curriculum during the one-and-a-half-month study period did not significantly contribute to the cognitive development of students' astronomy literacy. Therefore, integrating astronomy-related content into the social studies curriculum could help enhance students' cognitive astronomy skills (Erbudak and Yeşilbursa, 2023; Güleç and Çelik, 2022; Kuzey, 2020; Yeşil-Asana and Benzer, 2020). In contrast, a significant difference was found between the pre-test and post-test scores of students in the experimental and control groups for the cognitive dimension of astronomy literacy. This indicated that the applications implemented in the experimental group, including the virtual program and various applications, effectively improved the students' cognitive astronomy skills. These results are consistent with previous findings in the field of social studies (Yılmaz and Çolak, 2012; Çolak, 2014; Yılmaz, 2019; Yıldırım and Şimşek, 2023).

Furthermore, the study examined whether the cognitive achievements differed by gender. The results showed that the male students achieved greater cognitive achievements than the female students, suggesting potential gender-related differences in engagement or responsiveness to the applications.

The study investigated whether there was a significant difference between the pre-test and post-test scores of the experimental and control groups in the affective dimension of the Astronomy Literacy Scale. Analysis of the experimental group revealed a significant difference between the pre-test and post-test scores, indicating that the application positively impacted the students' attitudes toward astronomy literacy. These findings suggested that the applied activities fostered the students' interest in astronomy and enhanced their curiosity. Previous research supports this particular result, showing that engaging and varied instructional approaches in astronomy education can increase students' interest and motivation in the subject (Glover, Miller, Averis, and Door, 2007; Çöl and Karaca, 2020; Pompea and Russo, 2020; Rosenberg et al., 2014; Slater, Slater, and Dwyer, 2010).

No significant difference was found between the control group's pre-test and post-test scores for

the affective dimension of astronomy literacy. This finding indicated that the content covered in the social studies curriculum during the research period was insufficient to enhance the students' interest and curiosity in the astronomy-related topics. Furthermore, this result supported the conclusion drawn from our review of the social studies textbooks namely, that the textbooks did not adequately foster the astronomy literacy and aligned with the evaluations provided by the participating teachers.

The study revealed a significant difference was between the pre-test and post-test scores of students in the experimental and control groups with respect to the affective dimension of astronomy literacy. This particular finding suggested that interactive applications, such as StarWalk and SkyMap, as well as educational websites (e.g., NASA, TUA, TÜBİTAK) and activities involving concept puzzles and games were effective in fostering the students' positive attitudes toward astronomy (Aktamış and Arıcı, 2013; Yılmaz, 2019).

While a significant difference was identified between the pre-test and post-test scores related to the affective dimension of astronomy literacy across gender in the experimental group, no such difference emerged in the control group. Within the experimental group, it was found that the male students developed a more positive affective attitude toward astronomy literacy compared to their female counterparts.

The study examined whether there was a significant difference between the pre-test and post-test scores of the experimental and control groups on the affective dimension of the astronomy literacy scale. Analysis of the experimental group revealed a significant difference between students' pre-test and post-test scores in this dimension. This finding indicated that the instructional activities implemented during the application positively impacted the students' affective attitudes toward astronomy literacy, increased their interest in astronomy and enhanced their curiosity. Previous studies similarly emphasized that incorporating diverse and engaging applications in astronomy instruction increased students' interest in both the subject and the course (Glover et al., 2007; Ezberci Çevik et al., 2020; Canlas et al., 2024; Çöl and Karaca, 2020).

No significant difference was found between the control group's pre-test and post-test scores on the affective dimension of astronomy literacy. This finding suggested that the astronomy-related content included in the social studies curriculum during the research period was insufficient to enhance the students' interest and curiosity in astronomy. Moreover, this result supported the conclusion drawn from our analysis of the social studies textbooks that the textbooks did not adequately promote astronomy literacy and aligned with the teachers' evaluations indicating similar shortcomings.

The study revealed a significant difference between the pre-test and post-test scores of students in the experimental and control groups regarding the affective dimension of astronomy literacy. This finding indicated that interactive tools such as StarWalk and SkyMap along with educational websites (e.g., NASA, TUA, TÜBİTAK) and activities involving concept puzzles and games, were effective in fostering the students' positive attitudes toward astronomy (Aktamış and Arıcı, 2013; Arıkurt et al., 2015; Bitzenbauer et al., 2023; Taşcan, 2019; Yılmaz, 2014).

While a significant difference was revealed between the pre-test and post-test scores related to the affective dimension of astronomy literacy across gender in the experimental group, no such difference emerged in the control group. Within the experimental group, it was found that the male students developed a more positive affective attitude toward astronomy literacy than the female students.

The study investigated whether there was a significant difference between the pre-test and post-test scores of the experimental and control groups in the behavioral dimension of the astronomy literacy scale. In this context, a significant difference was first identified between the pre-test and post-test scores of the students in the experimental group. This difference indicated that the students exhibited measurable achievements in the behavioral dimension of astronomy literacy. During the application, the students engaged in activities related to the lives of astronauts, utilized sky observation programs such as StarWalk and SkyMap in a structured manner, and were guided in recognizing and effectively using these tools. Consequently, the students developed increased awareness of and positive behavioral tendencies toward space and the sky. These findings suggested that the diverse astronomy-related applications contributed positively to the students' behavioral outcomes (Benli Özdemir, 2022; Aktürk, Yazıcı and Bulut, 2013; Kulaca, 2023; Çelik, Güleç and Atasoy, 2025; Karamustafaoğlu and Aktürk, 2016; Likavcan, 2024; Uçar and Aktamış, 2019).

No significant difference was found between the control group's pre-test and post-test scores in the behavioral dimension of astronomy literacy. Since only the social studies curriculum was implemented and no astronomy-focused applications were introduced, the findings indicated that the content of the social studies program alone did not sufficiently support the development of students' astronomy literacy or related behavioral skills. However, previous studies demonstrated that the students' astronomy com-

petencies could be enhanced through the use of diverse, targeted applications (Aktamış and Arıcı, 2013; Peten and Şirin, 2020).

A significant difference in the behavioral dimension of astronomy literacy was revealed between the pre-test and post-test scores of the experimental and control groups, in favor of the experimental group. This particular result indicated that the instructional activities implemented in the experimental group effectively enabled the students to attain the behavioral competencies required for astronomy literacy. Consistent with this finding, numerous studies reported that the diverse astronomy-related activities enhanced the students' academic performance and strengthened their skills related to space and astronomy (Tian, Endo, Urata, Mouri and Yasuda, 2014; Taşcan, 2019; Kalkan and Yener, 2022).

A significant difference was identified between the pre-test and post-test scores of the experimental and control groups in the behavioral dimension of astronomy literacy when examined in relation to gender. In the experimental group, the male students exhibited more positive behavioral changes toward astronomy compared to the female students. In contrast, no significant gender-related differences were observed among the students in the control group.

This is possible to attribute this result to the absence of any instructional applications in the control group that could have generated a positive effect. Overall, the findings indicated that the activities implemented to enhance the students' astronomy literacy made a meaningful contribution to the development of students' cognitive, affective and behavioral competencies (De Beasi et al., 2015; Love, Murphy and Bonora, 2013; Remie, 2019; Salimpour et al., 2024; Ünal, 2024).

Recommendations

- Astronomy applications such as StarWalk, Skymap, and GoogleEarth, which actively engage students in lessons to develop cognitive, affective, and behavioral skills, can be used.
- Activities such as adaptations of Taboo games, concept puzzles, and flashcards related to astronomy topics can be conducted. • Different and fun teaching methods such as the case study method and evidence-based teaching method can be used in social studies lessons.
- To improve astronomy literacy, schools should be equipped with the essential materials and equipment such as telescopes, sky observation tools, and appropriate technological resources that support practical and inquiry-based learning experiences.
- In-service training programs can be provided for the social studies teachers to enhance their awareness of astronomy and to support the effective integration of astronomy-related content into their instructional practices.
- Students may be taken on annual visits to space-related museums or educational centers to enrich their learning experiences and strengthen their interest in astronomy.
- Astronomy advancements and educational programs implemented by the leading space-faring nations can be scrutinized and adapted for use within the Turkish education system to enhance the quality and scope of astronomy instruction.

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Conflict of interests

The Authors that there is no conflict of interest.

Data availability statement

The original contributions presented in the study are included in the article; further inquiries can be directed to the corresponding authors.

Institutional Review Board Statement

This study was conducted in strict accordance with the ethical standards of research involving human participants and in line with the principles of the Declaration of Helsinki. The research protocol was reviewed and approved by the Bursa Uludag University Research and Publication Ethics Committee / Social and Human Sciences Research and Publication Ethics Committee (Approval Number: [2023-07], Approval Date: [August 25, 2023]).

Prior to participation, informed consent was obtained from all participants. The participants were informed of the study's objectives, procedures, potential risks and benefits, as well as their right to withdraw at any stage without any negative consequences.

All ethical considerations were observed, including the confidentiality of personal information, voluntary participation, and data protection in accordance with application.

Author Contributions

Conceptualization, data curation, methodology, writing- original draft, M.E.Ç; Software, Visualization, writing- review & editing, validation S.G.; formal analysis, funding, research, project management, resources, and supervision were all performed by M.E.Ç and S.G.

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