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About, Aims and Scope	Hakkında, Amaç ve Kapsam
International Journal of Education and Artificial Intelligence (IJEDAI) is an international, peer-reviewed journal published twice a year (in May and November), whose publication languages are English and Turkish. It publishes original and review studies in the field of education and artificial intelligence. All the manuscripts submitted to the IJEDAI are reviewed in a double blind review process. The aim of IJEDAI is to convey the current developments in the fields of education and artificial intelligence in the world and to be beneficial to science and humanity by sharing original studies. Articles to be accepted for IJEDAI may be from education and artificial intelligence studies, as well as from scientific fields related to education and artificial intelligence in a multidisciplinary manner.	International Journal of Education and Artificial Intelligence (IJEDAI) yayın dili İngilizce ve Türkçe olan, yılda iki kez (Mayıs ve Kasım aylarında) yayımlanan uluslararası, hakemli bir dergidir. Eğitim ve yapay zekâ alanında orijinal ve derleme çalışmalarını yayınlamaktadır. IJEDAI, gönderilen makaleler için en az iki hakem tarafından değerlendirilen çift-kör hakem değerlendirme sürecini benimsemektedir. IJEDAI 'nin amacı dünyadaki eğitim ile ilgili çalışmalarda ve yapay zekânın eğitim alanındaki uygulamalarında kaydedilen güncel gelişmeleri aktarmak; özgün çalışmaların paylaşılmasını sağlayarak bilim ve insanlığa faydalı olmaktır. IJEDAI için kabul edilecek makaleler eğitim ve yapay zekâ çalışmalarının yanı sıra, multidisipliner olarak eğitim ve yapay zekâ ile ilgili çeşitli bilim alanlarından olabilir.
Articles published in the IJEDAI reflect only the views of the author(s). Responsibility for the published content and articles belongs to the author. Editor, editorial board and publisher; accepts no responsibility or liability for the content of the authors' articles and opinions. IJEDAI is an "open access" journal and adopted the “open access policy”. Authors have their copyrights under the "Creative Commons Attribution-NonCommercial 4.0 International Licence". Details of the publication policies are available on the journal's website.	Dergide yayınlanan makaleler yalnızca yazar(lar)ın görüşlerini yansıtır. Yayınlanan makale ve içeriklerdesorumluluk yazara aittir. Editör, yayın kurulu ve yayıncı; yazarların makale ve içeriklerine yönelik sorumluluk ya da yükümlülük kabul etmemektedir. IJEDAI "açık erişim" dergisi olup, "açık erişim politikasını" benimsemiştir. IJEDAI, "Creative Commons Attribution-NonCommercial 4.0 International Licence" ile lisanslanmıştır. Yayın politikalarının detaylarına dergi web sayfasında yer verilmiştir.
The template for manuscript is not mandatory for articles submitted for review. The template have to be used for accepted papers.	Değerlendirmeye gönderilen makaleler için makale yazım Word dosyası formatı başlangıçta zorunlu değildir, fakat yayın için kabul edilen makalelerde zorunlu olarak kullanılması gerekmektedir.

Indexing:

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International Journal of Education and Artificial Intelligence

Publishing Policy & Ethics

International Journal of Education and Artificial Intelligence (IJEDAI) is a peer-reviewed, electronic, and scientific journal which adheres to the following ethical principles and considerations in order to publish articles in the field of education and artificial intelligence. The aim of IJEDAI is to convey current developments in education and artificial intelligence in education in the world, and to benefit science and humanity by sharing original studies. Articles to be accepted for IJEDAI can be from various scientific fields related to education and artificial intelligence, as well as multidisciplinary studies.

Articles sent to IJEDAI for publication are reviewed through a double-blind process and published online. For the IJEDAI Journal, the ethical responsibilities, roles and duties for the journal editor, authors, reviewers and publisher are explained below.

The ethical duties and responsibilities in IJEDAI have been prepared by taking into account the ethical and publication policies of internationally journals and the guidelines published by the "Committe on Publication Ethics" - COPE as open access. In other matters not mentioned in IJEDAI, COPE's ethical principles are taken into account.

The editor-in-chief can take part in determining the of the editorial board/Editor and improving the quality of the journal. If the Editor-in-Chief sees necessary, he/she may assign an Editor for the article or may conduct the scientific assessment of the article himself/herself. Authors/Editors/Reviewers must be taken into consideration the ethical codes: Authorship, Plagiarism (including self-plagiarism), Data fabrication / data falsification, Duplicate submission, Corrections and retractions, Human and Animal Rights, Conflicts of interest / Competing interests, Intellectual property

Ethical Responsibilities of Author(s)

The authors should submit their original works to IJEDAI in the field of education and artificial intelligence. All of sources used in the articles must be cited in accordance with the latest published style of the American Psychological Association (APA). Authors must certify that their manuscripts are their original work. Authors are expected to adheres to International Standards for Authors developed by the Committee on Publication Ethic (https://publicationethics.org/files/International%20standards_authors_for%20website_11_Nov_2011.pdf)

'Copyright Transfer Form' must be filled out and upload by the corresponding author for articles submitted to the journal. Individuals who have not contributed to the study of a manuscripts must not be indicated as authors. Any studies published in any journal or as a book cannot be sent to IJEDAI. Authors cannot submit their study, which is currently under review in another journal, to IJEDAI at the same time. If there are any conflicting interests regarding the submitted article, they must be declared. It should be stated whether the submitted articles are derived from conferences/thesis/projects and similar research. Articles published in full text (proceeding paper) at conferences cannot be submitted for publication for IJEDAI. For studies requiring human participation, authors are required to obtain "Ethics Committee Approval" from the relevant institutions.

In giving ethics committee approvals, such as the Declaration of Helsinki (https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects/#:~:text=The%20World%20Medical%20Association%20(WMA,identifiable%20human%20material%20and%20data). It is important to verify that recognized standards are valid. If it is necessary, raw data regarding their articles may be requested from the author(s) within the framework of the evaluation processes. Authors are obliged to keep their raw data for at least 5 years after their articles are published.

Ethical Responsibilities of Reviewers

IJEDAI has adopted a double-blind peer review process for submitted manuscripts, which are reviewed by at least two reviewers. After the reviewers review process, in case of uncertainty, the final decision is taken with the opinion of the editor or a third referee. The reviewers are required to notify the editor of their decision as to whether the

Yayın Politikası & Etik

International Journal of Education and Artificial Intelligence (IJEDAI) eğitim ve yapay zekâ alanındaki bilimsel makaleleri yayımlamak amacıyla aşağıda belirtilen etik ilkeler ve kurallara bağlı olarak basılan hakemli bir dergidir. IJEDAI 'nin amacı dünyada eğitim alanında ve eğitimde yapay zekânın kullanımı ile ilgili kaydedilen güncel gelişmeleri aktarmak; özgün çalışmaların paylaşılmasını sağlayarak bilim ve insanlığa faydalı olmaktır. IJEDAI için kabul edilecek makaleler eğitim ve yapay zekâ çalışmalarının yanı sıra, multidisipliner olarak eğitim ve yapay zekâ ile ilgili çeşitli bilim alanlarından olabilir.

IJEDAI 'ne yayınlanmak için gönderilen makaleler çift-kör hakem süreciyle değerlendirilmekte ve dergi çevrimiçi olarak yayımlanmaktadır. IJEDAI Dergisi'ne yönelik dergi editörünün, yazarların, hakemlerin ve yayıncının etik sorumlulukları, rolleri ve görevleri aşağıda açıklanmıştır.

IJEDAI 'de yer alan etik görev ve sorumluluklar, uluslararası dergilerin etik ve yayım politikaları incelenerek ve açık erişim olarak "Committe on Publication Ethics" - COPE tarafından yayımlanan yönergeler dikkate alınarak hazırlanmıştır. IJEDAI'da belirtilmeyen diğer hususlar da COPE 'da belirtilmiş olan etik prensipleri dikkate alınır.

Baş Editör, editör kurulu üyelerinin belirlenmesinde ve dergi kalitesinin geliştirilmesinde her aşamada görev alabilir. Baş Editör gerekli gördüğü takdirde makaleye bir editör görevlendirebilir veya makalenin bilimsel değerlendirmesini kendisi yapabilir. Yazarlar/Editörler/Hakemler in dikkat edeceği etik kurallar; Yazarlık, İntihal, veri uydurma / veri tahrifatı, tekrarlı gönderim, düzeltmeler ve geri çekilme, insan ve hayvan hakları, çıkar çatışmaları / rekabet menfaatler, fikri mülkiyet

Yazarların etik sorumlulukları

Yazarların IJEDAI Dergisi'ne gönderdikleri makalelerin eğitim ve yapay zeka alanında özgün çalışmalar olması gerekmektedir. Makalelerde yararlanılan tüm kaynaklar American Psychological Association (APA)'nın yayınlanan son sitiline uygun bir şekilde gösterilmelidir. Yazarlar, yazılarının kendilerine ait olduğunu belgelendirmelidir. Yazarların Yayın Etiği Komitesi tarafından geliştirilen Yazarlar için Uluslararası Standartlara uymaları beklenmektedir https://publicationethics.org/files/International%20standards_authors_for%20website_11_Nov_2011.pdf)

Dergiye gönderilen makaleler için sorumlu yazar tarafından 'Telif Hakkı Devir Formu' doldurulmalı ve dergiye gönderilmelidir.

Bir makale çalışmasında katkısı bulunmayan kişiler yazar olarak belirtilmemelidir. Daha önce herhangi bir şekilde başka bir dergide veya kitap olarak yayımlanmış çalışmalar IJEDAI'ye gönderilemez. Yazarlar, başka bir dergide henüz değerlendirme aşamasında olan çalışmasını aynı anda IJEDAI 'ye gönderemez. Gönderilen makaleye yönelik çıkar çatışmaları durumları varsa belirtilmelidir. Gönderilen makalenin konferans/tez/proje araştırmalardan türetilme durumu belirtilmelidir. Konferanslarda tam metin olarak yayınlanan makaleler IJEDAI için yayına gönderilemez. Yazarlar etik kurul onayı gerektiren çalışmaları için ilgili kurumlardan "Etik Kurul Onayı" almaları gerekmektedir. Etik kurul onaylarının verilmesinde Helsinki Bildirgesi gibi (https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects/#:~:text=The%20World%20Medical%20Association%20(WMA,identifiable%20human%20material%20and%20data) tanınmış standartların geçerli olduğu doğrulanması önemlidir. Gerekli durumlarda, yazar(lar)dan değerlendirme süreçleri çerçevesinde makalelerine ilişkin ham veri talep edilebilir. Yazarlar, makaleleri yayımlandıktan sonra ham verilerini en az 5 yıl süreyle saklamakla yükümlüdürler.

Hakemlerin Etik Sorumlulukları

IJEDAI gönderilen makaleler için en az iki hakem tarafından değerlendirilen çift-kör hakem değerlendirme süreci benimsenmiştir. Hakem değerlendirmelerinden sonra belirsizlik durumunda editörün veya üçüncü bir hakemin görüşü ile nihai karar alınır. Hakemler, değerlendirdikleri makalenin yayımlanabilir olup olmadığına ilişkin

manuscript they have reviewed is publishable or not and their reasons for so doing so.

The ethical responsibilities of Reviewers at IJEDAI are as follows:

Reviewers are expected to read publishing principles, aim and scope of the IJEDAI. Reviewers must review the manuscripts related to their field of expertise. Reviewers must review manuscripts which they do not have any conflict of interests. Manuscripts must be evaluated by reviewers within the framework of unbiased and objective manner. Reviewers should use constructive, polite, and scientific language in review reports and reviewing process. Reviewers should not make comments that may be disrespectful, insulting, offensive or slanderous. Reviewers should complete the manuscript review process within a specific time frame given to them.

Ethical Responsibilities of Editors

IJEAI editors and field editors must adhere to the ethical responsibilities based on guidelines for editors published by "Committee on Publication Ethics" (COPE). The editor manages all processes until the manuscripts sent to the journal are published. The general responsibility of editors is as follows; Ensuring the general development of the journal, managing processes to increase the quality of studies published in the journal, updating the ethical policies together with other members of the journal's editorial boards.

Editors must also adhere to the responsibilities listed below.

Relations with readers:

The editors should ensure that the non-peer-reviewed sections of the journal (letters, essays, etc.) are identified. The editors should make efforts to ensure that the articles published in accordance with the purpose and scope of the journal are align with the knowledge and skills of the readers. The editors should consider reader feedback regarding journal publishing, scope, and ethics.

Relations with the reviewers;

Editors must choose reviewers in related field of the study and update the pool of reviewers. Editors must provide necessary information for questions of reviewers about manuscript review process and remind reviewers about timing. Editors must ensure guidelines needed by reviewers during manuscript review process. Editors must be careful any conflict of interest between authors and reviewers. Editor should evaluate reviewers in terms of performance, timing, polite, and quality.

Relations with the authors;

Editors must provide the guidelines and a template needed by authors during the manuscript submission process. Editors must be careful about conflict of interest between authors and reviewers. Editors must to inform authors about publication, ethical policies, manuscript review process and timing. The editor must convey the information and reasons regarding the accepting or rejecting of the manuscript to the author within the specified time. If the authors decide to correct the article, the authors should be informed and given time to make the corrections. Editors must approve authors' requests to withdraw their studies under review process. Editors should evaluate authors' objections to reviewers decisions/reports and, if necessary, initiate a new review process.

Relations with editorial board members;

Editors must provide information and guidelines to the editorial board members about publishing and ethical policies of the journal. Editor should select and update the editorial board members who will contribute to the journal's development. Editors should take into account feedbacks and the opinions of the editorial board in improving the journal. The editor should review and improve the journal publishing and writing rules with the editorial board. The editor should be able to assign responsibilities to members of the editorial board in some tasks in the development of the journal.

Journal Policy

Reviewing and Publishing Policy

kararlarını ve buna yönelik gerekçelerini editöre bildirmeleri gerekmektedir.

IJEDAI 'de görev alan hakemlerinin etik sorumlulukları aşağıdaki gibidir:

Hakemlerden IJEDAI 'nin yayım ilkeleri, amaç ve kapsamını okumaları beklenmektedir. Hakemler uzmanlık alanı ile ilgili çalışmaları değerlendirmeyi kabul etmelidirler. Hakemler çıkar çatışması olmayan çalışmalara hakemlik yapmalıdır. Hakemler tarafından makaleler tarafsızlık ve gizlilik çerçevesinde değerlendirmeler yapılmalıdır. Hakemler değerlendirme raporlarında ve yazışmalarda yapıcı, nazik ve bilimsel bir dil kullanmalıdır. Hakemler, saygısızlık içerebilecek, hakaret, saldırganlık ve iftira olabilecek yorumlar yapmamalıdır. Hakemler makaleyi değerlendirme sürecini kendilerine verilen belirli bir zaman çerçevesinde tamamlamalıdır.

Editörün Etik Sorumlulukları

IJEAI editörü ve alan editörleri, "Yayın Etiği Komitesi" (COPE) nin editörler için yayınlamış olduğu kılavuzlarda yer alan etik sorumluluklara uyması gerekmektedir. Editör, dergiye gönderilen makalelerin yayınlanmasına kadar geçen bütün süreçleri yönetir. Editörlerin genel sorumluluğu şöyledir; derginin genel olarak gelişimini sağlama, dergide yayımlanan çalışmaların kalitesini arttırmaya yönelik süreçleri yönetme, derginin editör kurullarındaki diğer üyelerle birlikte etik politikalarında da güncelleme yapmadır.

Ayrıca editörler aşağıda belirtilen sorumlulukları da yerine getirmelidir.

Okuyucularla İlişkiler:

Editörler, dergide hakem değerlendirmesi gerekli olmayan bölümlerin düzenlenmesini (mektuplar, makaleler, konferans duyuruları vb.) sağlamalıdır. Editörler, derginin amaç ve kapsamına uygun olarak yayınlanan makalelerin okuyucuların bilgi ve becerilerine uygun olması için çaba göstermelidir. Editörler, okuyucunun dergi yayımlama, kapsam ve etik ile ilgili geri bildirimlerini dikkate almalıdır.

Hakemlerle İlişkiler;

Editörler, çalışmanın ilgili alanındaki hakemleri seçmeli ve hakem havuzunu güncellemelidir. Editörler, hakemlerin makale inceleme sürecine ilişkin sorularına gerekli bilgileri sağlamalı ve hakemlere zamanlama konusunda hatırlatmada bulunmalıdır. Editörler, makale inceleme sürecinde hakemlerin ihtiyaç duyduğu yönergeleri sağlamalıdır. Editörler, yazarlar ve hakemler arasındaki çıkar çatışmalarına karşı dikkatli olmalıdır. Editör, hakemleri performans, zamanlama, nezaket ve kalite açısından değerlendirmelidir.

Yazarlarla İlişkiler;

Editörler, makale gönderim sürecinde yazarların ihtiyaç duyduğu yönergeleri ve şablonu sağlamalıdır. Editörler, yazarlar ve hakemler arasındaki çıkar çatışmalarına karşı dikkatli olmalıdır. Editörler yazarları yayın, etik politikalar, makale inceleme süreci ve zamanlaması konusunda bilgilendirmelidir. Editör, yazının kabul veya reddedilmesine ilişkin bilgi ve gerekçeleri belirtilen süre içerisinde yazara iletmelidir. Yazarların makaleyi düzeltmeye karar vermesi durumunda yazarlara bilgi verilmeli ve düzeltmeleri yapmaları için süre tanınmalıdır. Editörler, yazarların inceleme sürecindeki çalışmalarını geri çekme isteklerini onaylamalıdır. Editörler, yazarların hakem kararlarına/raporlarına olan itirazlarını değerlendirmeli ve gerekiyorsa yeni bir inceleme süreci başlatmalıdır.

Editör Kurulu İle ilişkiler;

Editörler, yayın kurulu üyelerine derginin yayıncılığı ve etik politikaları hakkında bilgi ve yönergeler sağlamalıdır. Editör, derginin gelişimine katkıda bulunacak yayın kurulu üyelerini seçmeli ve güncellemelidir. Editörler dergiyi geliştirirken yayın kurulunun geri bildirimlerini ve görüşlerini dikkate almalıdır. Editör, editör kurulu ile dergi yayım ve yazım kurallarınını gözden geçirmeli ve

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All of sources used in the articles must be cited in accordance with the latest published style of the American Psychological Association (APA). Any studies published in any journal or as a book cannot be sent to IJEDAI. It should be stated whether the submitted articles are derived from conferences/thesis/projects. Articles published in full text (proceeding paper) at conferences cannot be submitted for publication for IJEDAI. All of sources used in the articles must be cited in accordance with the latest published style of the American Psychological Association (APA). All responsibility for the published articles/writting belongs to the author(s). Author(s) have the responsibility of all contents in the manuscript/article/writing.

Peer Review Process Policy

For publication, all manuscripts submitted to the IJEDAI are pre-reviewed by the Editor or Editorial Board in terms of scope and writing rules. Editor may reject the submissions which do not comply with the principles of the IJEDAI. The pre-reviewing process is completed in 10 days. After the pre-reviewing, all manuscripts are sent to at least two independent reviewer for blind peer review. The reviewers are asked to judge the scientific, validity, significance, and originality of manuscripts. The reviewer' assessment period is 30 days, this period can be extended if necessary. If the reviewer' assessment period is not completed on time, the editor may send the article to a new reviewers.If different opinions are expressed from the reviewers, the editor may send the article to a third reviewer for assessment. If there are the revisions recommended by the Reviewer/Editor, the time required for the authors to make these is a maximum of 30 days. The publication process begins for articles accepted for publication by the Editor/Editorials board. The final revised of the articles in accordance with the IJEDAI writing format is performed by the author(s). After the proofreading process, volume, issue and page numbers is assigned and the manuscript appears in Online First section. Article withdrawal cannot be made for manuscript that have been peer-reviewed and accepted.

Plagiarism Policy of IJADAI

The publishing rights of the published work belong to the journal. The IJEDAI is strictly against any plagiarism in any form. Authors must submit only entirely original manuscripts and appropriately cite or quote the work and/or words of others. Guidelines published by the “Committe on Publication Ethics” - COPE are taken into account. The COPE guidelines on plagiarism are followed. APA style are used in quoting and citing sources. Manuscripts submitted to the IJEDAI is checked for originality using anti-plagiarism software like Turnitin/ iThenticate. The similarity rate of the accepted manuscript must be not exceeded the rate of 20%. American Psychological Association. (2020). Publication manual of the American Psychological Association(7th ed.). https://apastyle.apa.org , https://publicationethics.org

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iyileştirmelidir. Editör, derginin geliştirilmesinde bazı görevlerde yayın kurulu üyelerine sorumluluklar verebilmelidir.

Dergi Politikaları

Hakemlik ve Yayın Süreci Politikaları

IJEDAI ’ne yayınlanmak için gönderilen makaleler çift-körl hakem süreciyle değerlendirilmekte ve çevrimiçi olarak yayımlanmaktadır. Dergiye gönderilen makaleler için sorumlu yazar tarafından 'Telif Hakkı Devir Formu' doldurulmalı ve dergiye gönderilmelidir. Yazarlar, başka bir dergide henüz değerlendirme aşamasında olan çalışmasını aynı anda IJEDAI ’ye gönderemez. Gönderilen makalenin konferans/tez/proje araştırmalardan türetilme durumu belirtilmelidir. Konferanslarda tam metin olarak yayınlanan makaleler IJEDAI için yayına gönderilemez. Makalelerde yararlanılan tüm kaynaklar American Psychological Association (APA)’nın yayınlanan son sitiline uygun bir şekilde gösterilmelidir. Yayımlanan yazıların/makalelerin her türlü sorumluluğu yazar(lar)a aittir.

Hakem Değerlendirme Süreci Politikaları

Yayınlanmak üzere IJEDAI 'ye gönderilen tüm yazılar, Editör veya Yayın Kurulu tarafından kapsam ve yazım kuralları açısından ön incelemeye tabi tutulur. Editör, IJEDAI ilkelerine uymayan yazıları reddedebilir. Ön inceleme süreci 10 gün içerisinde tamamlanır. Ön incelemeden sonra tüm yazılar kör hakemlik için en az iki bağımsız hakeme gönderilir. Hakemlerden yazıların bilimselliğini, geçerliliğini, önemini ve orijinalliğini değerlendirmeleri istenir. Hakem değerlendirme süresi 30 gündür, gerek görülmesi halinde bu süre uzatılabilir. Hakem değerlendirme süresinin zamanında tamamlanmaması durumunda editör, makaleyi yeni hakemlere gönderebilir. Hakemlerden farklı görüş bildirilmesi halinde editör, makaleyi değerlendirilmek üzere üçüncü hakeme gönderebilir. Hakem/Editör tarafından önerilen düzeltmeler varsa yazarların bunları yapması için gereken süre en fazla 30 gündür. Editör/Editör Kurulu tarafından yayına kabul edilen makaleler için yayın süreci başlar. Makalelerin IJEDAI yazım formatına göre son revizyonu yazar(lar) tarafından gerçekleştirilir. Düzeltme işleminden sonra cilt, sayı ve sayfa numaraları atanır ve makale Önce Online bölümünde görünür. Hakem değerlendirmesi yapılmış ve kabul edilmiş makaleler için makale geri çekme işlemi yapılamaz.

IJEDAI'in İntihal Politikası

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American Psychological Association. (2020). Publication manual of the American Psychological Association(7th ed.). https://apastyle.apa.org/ , https://publicationethics.org/

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Editorial

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Education and artificial intelligence

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Abstract

Research in the field of education has an important place in science and society. In recent years, there has been a significant increase in the number of researches in the field of educational sciences and artificial intelligence, and many journals publish special issues in this field.

The reflections of artificial intelligence, from preschool to graduate education, are revealed by many studies. Academic journals on artificial intelligence and education contribute to this field. The aim of the "International Journal of Educational and Artificial Intelligence" (IJEDAI), the first issue of which was published, is to be beneficial to science and humanity by conveying current developments in the fields of education and artificial intelligence in education, and by sharing original studies.

In this editorial article, the focus is on the discussion of artificial intelligence tools and features in education in terms of creating articles suitable for IJEDAI content.

In the first issue of IJEDAI, science education and artificial intelligence studies were included. In the first issue of IJEDAI, Kösen and Dede's (2024) study on STEM education, Aşçı et al. (2024) study on the reflection of artificial intelligence on science education, Özeler et al. (2024) study on virtual laboratory applications, Şentürk (2024) study on creative comics were presented.

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INTRODUCTION

Educational research is important in order to improve qualifications in the field of education or to find solutions to problems. In terms of scientific and social development, countries value research in the field of education. In recent years, research in the field of educational sciences and artificial intelligence has been given importance, the number of researches in this field has increased significantly, and many journals publish special issues in the field of education and artificial intelligence. The implications of artificial intelligence, from pre-school to postgraduate education, are shown by many studies (Morales-García et al., 2024; Wang et al., 2024). Many AI tools are spreading rapidly because they enable learning through online and open educational resources (Gardner & Yuan, 2021).

Artificial intelligence is the development of machines with a certain level of intelligence and capabilities similar to those of humans (Chen et al., 2020). Artificial intelligence technologies are used in many areas, from the creation of educational materials to measurement and evaluation. Some artificial types in the literature: machine learning, data mining, natural language processing, deep learning, artificial neural networks, expert systems (Mukhamediev et al., 2022; Wang et al., 2024). Artificial intelligence tools such as ChatGPT, Copilot and Gemini are very common and well-known tools and are used in education and many fields by giving voice and written commands. AI-powered tools provide ease of work for teachers in education (Owan, et al., 2023). Publishing research in education and artificial intelligence in open access journals is important for developing the theory-practice relationship in education.

It is important that Artificial Intelligence tools or applications have some characteristics to be considered Artificial Intelligence. Some important features that AI tools should have are: learning ability, problem solving, data analysis and visualisation, autonomous behaviour, natural language processing, perception ability, prediction.

The first issue of IJEDAI included studies on science education and artificial intelligence. Kösen and Dede (2024) published a study entitled "Thematic content analysis of STEM Studies published in the field of science education in Türkiye". The study entitled "Reflections of artificial intelligence on science education in Türkiye" was published by Aşcı et al. (2024). Özeler et al. (2024) published a study entitled "The effect of virtual laboratory applications on the achievement of secondary school students in learning the granular structure of matter". The study entitled "An alternative teaching tool: Creative comics." was published by Şentürk (2024).

RESULTS

The academic journal, which includes artificial intelligence and education, contributes to this field. The "International Journal of Educational and Artificial Intelligence" (IJEDAI), whose first issue has been published, aims to convey the current developments in the fields of education and artificial intelligence in education, and to be beneficial to science and humanity by sharing original studies. This editorial discusses the creation of articles suitable for the content of IJEDAI, its classification in terms of educators, the characteristics of artificial intelligence tools and applications.

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Thematic content analysis of STEM studies published in the field of science education in Türkiye

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Abstract

Purpose: This study aims to thematically analyze STEM studies published in the field of science education in Türkiye from 2013 to 2022.

Design and Methodology: The thematic content analysis research method was used in the study. The identified journals in SSCI and ERIC indexes were searched with the criteria of focusing on science education and conducted in Türkiye. 70 articles were analyzed with parameters such as aims, dependent variables, learning models integrated with STEM, research methods, sample groups, sample sizes, data collection tools, number of data collection tools, duration of instruction, data analysis methods, and results.

Results: The findings revealed that the majority of the studies aimed to determine opinions and the effect on skill development. Moreover, it was determined that achievement, attitudes, scientific creativity, and critical thinking were utilized as dependent variables and STEM was predominantly integrated with project-based learning. Additionally, it was established that the majority of studies employed a case study approach, utilized secondary school students as a sample population, included between 11 and 50 participants, employed interview methods for data collection, utilized a singular data collection instrument, four weeks as instructional duration, and content analysis as data analysis method in STEM studies. Moreover, the findings revealed that the proportion of dependent variables exhibiting positive effects of STEM education was 86.49%, while 13.51% did not demonstrate a positive effect.

Implications & Suggestions: Researchers engaged in studies within the STEM field were provided with recommendations regarding the study.

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1. INTRODUCTION

Nowadays, it is evident that there are rapid and significant changes and developments in science and technology. Competition among countries has increased as a result of these changes. It is essential for countries to have scientifically literate people who can use information effectively, think creatively and critically, solve problems, and have scientific process skills to keep up with and contribute to this rapid change and to compete with other countries in science and technology (Akgündüz et al., 2015; Ceylan, 2014; Çiftçi, 2006). Furthermore, the importance of integrating science, technology, engineering, and mathematics (STEM) across disciplines to promote scientific and technological progress has been recognized by nations around the world (Akgündüz et al., 2015). In this context, countries aim to update and improve their education policies and to develop and renew their curricula (Irkıçatal, 2016).

In 2001, STEM emerged in the United States of America (USA) as an interdisciplinary education model. STEM is an acronym for Science, Technology, Engineering and Mathematics (Bybee, 2010; Sanders, 2009). The acronym STEM has been defined in academic literature as an interdisciplinary approach that does not adhere to the traditional, subject-specific learning that deals with science, technology, engineering, and mathematics disciplines in isolation. Instead, it integrates four or more disciplines with an overarching teaching and learning paradigm (Ejiwale, 2013; Morrison, 2006). STEM education aims to equip students at all levels, from preschool to higher education, with the ability to identify problems using an interdisciplinary approach and to develop appropriate solutions (Altunel, 2018). STEM education aims to develop students' literacy in science, technology, engineering, and mathematics, fostering creativity, collaboration, problem-solving, and competitiveness, while promoting the acquisition of 21st century skills. 21st Century Skills are some skills individuals need to have to keep up with rapid 21st century innovation and succeed. These skills were identified as creativity and innovation, communication and collaboration, critical thinking and problem-solving, and information, communication, and technology literacy (Partnership for 21st Century Learning [P21], 2015). STEM is to equip students with the requisite skills to thrive in the 21st century global economy (English, 2016). According to Thomasian (2011), STEM education has two primary objectives: firstly, to expand the number of students who have professional choices among these disciplines in higher education, and secondly, to improve students' fundamental knowledge levels in STEM disciplines, thereby enabling them to develop innovative solutions to problems related to these disciplines in their daily lives.

The STEM approach, which has gained considerable traction globally, was first introduced in Türkiye in the 2014 report published by the Turkish Industry and Business Association (TÜSİAD). The report states that there is a need for individuals trained in STEM fields and with 21st century skills. It therefore recommends the creation of employment opportunities in STEM fields, an increase in the number of students receiving STEM education, and an enhancement of STEM skills at all levels of education (Akgündüz et al., 2015; TÜSİAD, 2014). Furthermore, Türkiye's consistently low performance in international examinations such as PISA, TIMMS and PIAAC has highlighted the necessity for innovative approaches to educational reform (MoNE, 2016). As a consequence, the STEM approach was incorporated into the 2018 science curriculum as a discrete element, designated as "Science, Engineering, and Entrepreneurship Applications" (MoNE, 2018).

A review of existing literature reveals a considerable body of work analysing the current state of STEM education within Türkiye (Aydın-Günbatar & Tabar, 2019; Bolat & Saltan, 2020; Ceylan, 2021; Çalışkan & Okuşluk, 2021; Daşdemir et al., 2018; Duran & Sarı, 2021; Elmalı & Balkan Kıyıcı, 2017; Eren & Dökme, 2022; Ergün, 2020; Gökçen, 2021; Gülhan, 2022; Kalemkuş, 2020; Kaya & Ayar, 2020; Kızılay, 2018; Mandev & Yavuz, 2022; Ormancı, 2020; Özcan & Karabaş, 2019; Püsküllü, 2019; Sarica, 2020; Ültay et al., 2021; Yaman, 2020; Yıldırım & Gelmez Burakgazi, 2020; Yıldırım, 2016; Yılmaz et al., 2018). Some of these studies seek to identify trends in specific areas of STEM education. For instance STEM studies with students in the fourth and fifth grades (Duran & Sarı, 2021), STEAM studies (Gülhan, 2022), STEM studies about opinions of teachers and teacher candidates (Ültay et al., 2021), postgraduate theses on STEM (Ceylan, 2021; Çalışkan & Okuşluk, 2021; Ergün, 2020; Ormancı, 2020), STEM studies on teacher education (Kızılay, 2018), experimental research on STEM education (Kalemkuş (2020); STEM studies in science education (Eren & Dökme, 2022; Püsküllü, 2019), and STEM studies in science and mathematics education (Gökçen, 2021).

In examining these studies, it became evident that there were fewer instances of studies utilizing the method of meta-synthesis (thematic) content analysis than those employing descriptive content analysis (Kaya & Ayar, 2020, Ormancı, 2020; Sarica, 2020; Yıldırım & Burak Gelmezgazi, 2020; Yılmaz et al, 2018). Upon examination of these studies, Kaya and Ayar (2020) sought to elucidate the patterns of STEM studies by analyzing 50 qualitative articles published in the ULAKBİM database in Türkiye between 2016 and 2019. The study examined the evolution of STEM studies within the context of publication year, research topic, research method, sample group, and research findings. The study primarily utilized teachers as its sample population, with the majority of studies published in 2018. The case study method was the most prevalent research method employed. Additionally, it was determined that opinions on STEM education were the most extensively researched topic, with the findings indicating that STEM education has the potential to enhance students' 21st-century skills. In a related study, Yıldırım and Burak Gelmezgazi (2020) conducted a review of 12 qualitative studies conducted in Türkiye between 2014 and 2019. The studies were identified through an examination of the ERIC, Scopus and Web of Science databases. The analysis revealed that the studies examined focused on the results of STEM applications carried out inside or outside the school, the current situation at the cognitive level regarding STEM education, and prospective teachers' relationships between STEM disciplines. In contrast to the aforementioned studies, Sarica (2020) and Ormancı (2020) conducted thematic content analysis of postgraduate theses in the field of STEM education in Türkiye. Furthermore, Yılmaz et al. (2018) used thematic content analysis and document analysis together and examined 20 articles about STEM education in Türkiye that were placed in the ULAKBİM database between 2010 and 2017. A review of these studies reveals that studies in STEM fields conducted up to 2020 have been the subject of the majority of research. Furthermore, the studies that have been examined are not solely focused on science but also encompass other disciplines, including mathematics and engineering.

In this study, it was aimed to conduct a thematic content analysis of STEM studies conducted in only science field in Türkiye and included in journals with Turkish addresses accessed in Social Sciences Citation Index (SSCI) and Education Resources Information Center (ERIC) databases. SSCI is a reliable source of the most significant journals in the international humanities and social sciences (Chen & Du, 2015). ERIC is one of the international field indexes (Ültay & Ültay, 2018). In thematic content analysis, a limited number of studies are examined to gain a deeper understanding of the general framework of the subject under investigation (Çalık & Sözbilir, 2014). Accordingly, it was deemed appropriate to scan the journals of Türkiye origin included in these SSCI and ERIC indexes and to examine the studies of STEM education published in these journals. The problem of this study is to determine the general trend in STEM education research in Türkiye. The sub-problems related to this problem are as follows:

1. What were the aims of STEM studies?
2. What dependent variables were employed in STEM studies?
3. What learning models were integrated with STEM in these studies?
4. Which methods did STEM studies employ?
5. What sample groups did STEM studies utilize?
6. Which sample sizes did STEM studies exploit?
7. What data collection tools did STEM studies utilize?
8. How many data collection tools did STEM studies utilize?
9. What instructional duration did STEM studies prefer?
10. What data analysis methods did STEM studies employ?
11. What were the results of STEM studies?

2. METHOD

2.1. Method

This study utilized the thematic content analysis (meta-synthesis) method, which is a qualitative research approach. Thematic content analysis involves synthesizing and interpreting research on the same subject from a critical perspective within the framework of themes or templates (Çalık & Sözbilir, 2014; Finfgeld, 2003; Walsh & Downe, 2005). Thematic content analysis enables a comprehensive understanding of the structure of the subject under investigation (Au, 2007). In addition, for researchers, teachers, and policymakers who may not have access to all the studies, the synthesis of the common and similar aspects of

the different studies on the topic through thematic content analysis could be a valuable reference (Çalık et al., 2005; Gül & Sözbilir, 2015). As thematic content analyses are qualitative, it is common for the number of studies analyzed to be limited (Çalık & Sözbilir, 2014; Gül & Sözbilir, 2015).

2.2. Data Collection

This study examined STEM studies in the field of science education, which were published in educational science journals predominantly from Türkiye, indexed in the SSCI and/or ERIC databases, and published between 2013 and 2022. A review of academic journals reveals that there is only one Turkish-addressed and SSCI-indexed journal: Science and Education. A total of 23 journals, predominantly from Türkiye, were examined in the ERIC database. STEM studies were found in 14 of these journals. A total of 98 studies on STEM were identified in Science and Education and 14 journals. Following the research criteria, 70 studies conducted exclusively in the field of science education (including those related to the environment, physics, chemistry, and biology) were included in the study scope (Appendix A). The journals included in the study are listed in Table 1.

The studies were selected using criterion sampling, one of the purposive sampling methods. In criterion sampling, all situations that meet a set of pre-determined criteria are studied (Yıldırım & Şimşek, 2018). The following criteria were used to define the scope of the research:

- The studies were published in a journal included in the SSCI index or ERIC index,
- The studies were only focused on science education (including environment, physics, chemistry, and biology),
- The studies were conducted in Türkiye.

Table 1. *The Journals and Their Indexes*

Journals	Index	f
Education and Science	SSCI	3
Educational Sciences: Theory & Practice	ERIC	3
Eurasia Journal of Mathematics, Science & Technology Education	ERIC	1
Eurasian Journal of Educational Research	ERIC	7
European Journal of Educational Research	ERIC	2
International Journal of Curriculum and Instruction	ERIC	7
International Journal of Education in Mathematics, Science and Technology	ERIC	7
International Journal of Instruction	ERIC	1
International Journal of Research in Education and Science	ERIC	1
International Online Journal of Education and Teaching	ERIC	7
Journal of Education in Science, Environment and Health	ERIC	7
Journal of Pedagogical Research	ERIC	1
Journal of Turkish Science Education	ERIC	15
Participatory Educational Research	ERIC	7
The Turkish Online Journal of Educational Technology	ERIC	1
Total		70

f= frequency

The journals within the scope of the study were searched until 31 May 2022. The index information of the journals is applicable for the 2022 year. The publication years and frequencies of the studies obtained as a result of the screening are listed in Table 2.

Table 2. *Frequency of the STEM Studies According to Years*

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Frequency (f)	1	1	2	16	4	7	6	14	15	4

2.3. Data Analysis

The 70 studies have been numbered from A1 to A70. The matrix prepared by the researchers was used to analyze and interpret the data. Firstly, the codes corresponding to each category were determined and the articles within the scope of the study were coded according to their content characteristics, and the studies with common characteristics were classified under the same code. Then, categories and themes were formed by bringing together the appropriate codes. Frequency and percentage values were calculated for the codes, and categories.

2.4. Validity and Reliability

In order to ensure the reliability of the study, the researchers employed a two-step coding process. First, they separately coded the variables. Second, they compared the resulting codes. The consistency between the codes was quantified using the formula put forth by Miles and Huberman (1994) (Common codes / (total number of common and non-common codes) x 100), resulting in a value of 96.4%. In accordance with the recommendations of Miles and Huberman (1994, p.64), a 70% degree of concordance between two distinct coders is considered a sufficient threshold for the dependability of qualitative data analysis. The 96.4% of similar data indicates the validity of the analysis. Furthermore, a consensus was reached due to the few discrepancies between the coding and exchange of ideas among the coders, thus reinforcing the reliability of the findings.

Sandelowski and Barroso (2006) identified four categories of validity that are essential to guarantee the validity of thematic content analysis studies (p. 228). To ensure the reliability of the study, the research was conducted following the established criteria for each of the four validity types. The following section outlines the criteria and the procedures carried out in the study for each criterion.

1. Descriptive validity refers to the factual accuracy of the data. It implies that all relevant studies have been included in the research and that the information from each study is accurately defined.
2. Interpretive validity refers to the full and fair representation of the understanding and perspectives of the researchers.
3. Theoretical validity refers to the reliability of the researchers' interpretations.
4. Pragmatic validity refers to the usefulness and transferability of knowledge.

Sandelowski and Barroso (2006) delineated the process of optimizing validity in thematic content analysis studies (p.232). The methodology employed to ensure the validity of this study is presented in Table 3. All actions performed are marked with a cross sign (×).

Table 3. *Types of Validity Provided in the Study*

Validity Type	Descriptive	Interpretive	Theoretic	Pragmatic
Utilize all available communication channels for searching	x			
Consultation with experts in research synthesis			x	
Independent search by at least two persons	x			
Independent assessment of each report by at least two persons	x	x		
Exchange ideas about changes in the process and the results achieved, and document the whole process	x	x	x	x

3. RESULTS / FINDINGS

The aims of the STEM studies in the scope were examined. The frequencies and percentages of the aim category and related codes are presented in Table 4. The studies are presented in the table with their respective codes.

Table 4. *Frequencies and Percentage of the Aims of STEM Studies*

Category	Codes	Studies	f	%
Aim	Determining opinions about STEM education	A6, A15, A18, A19, A21, A31, A32, A43, A44, A45, A54, A55, A58, A59, A68, A70	16	16.33
	Determining the effect of teaching on skill development	A4, A12, A14, A16, A17, A24, A28, A34, A37, A39, A47, A50, A56, A57, A58, A69	16	16.33
	Determining the effect of teaching on affective behaviours	A4, A10, A16, A23, A30, A37, A39, A44, A50, A53, A56, A57, A58, A60	14	14.29
	Affective behavior detection	A5, A8, A11, A20, A27, A31, A33, A61, A66	9	9.18
	Curriculum review	A3, A25, A26, A35, A62, A63, A65	7	7.14
	Content analysis of STEM studies	A13, A22, A42, A51, A64	5	5.10
	Determining the effect of teaching on cognitive behaviours	A36, A37, A52, A53, A57	5	5.10
	Socio cultural and gender studies	A5, A7, A48	3	3.06
	Psychomotor behavior/ Scientific process skills determination	A5, A20, A27	3	3.06
	Metaphor detection	A40, A41	2	2.04
	STEM career choice	A2, A48	2	2.04
	Teacher candidate education	A10, A50	2	2.04
	Instructional material design	A29, A32	2	2.04
	Measurement tool development-adaptation	A49, A67	2	2.04
	Education system and policies	A7, A46	2	2.04
	Environmental education	A54	1	1.02
	In-service training	A16	1	1.02
	Mind map detection	A54	1	1.02
	Misconception detection	A52	1	1.02
	STEM prerequisite determination	A9	1	1.02
	STEM cognitive structure detection	A38	1	1.02
	Use of distance education	A55	1	1.02
	The nature of STEM concepts	A1	1	1.02
Total			98	100

** A study may comprise more than one aim*
f=frequency, %= percentage

Table 4 reveals that the majority of publications in the field of STEM in the SSCI and ERIC index from Türkiye focus on equally two aims: the determination of opinions about STEM education (16.33%) determining the effect of teaching on skill development (16.33%). The analysis revealed that the most frequent aims were, in order, determining the effect of teaching on affective behaviors (14.29%), affective behavior detection (9.18%), curriculum review (7.14%), content analysis of STEM studies (5.10%) and determining the effect of teaching on cognitive behaviors (5.10%), respectively. However, Table 3 indicates that one study each was conducted on the following topics: in-service training (A16), misconception detection (A52), mind map detection (A54), nature of STEM concepts (A1), STEM prerequisite detection (A9), STEM cognitive structure detection (A38), use of distance education (A55) and environmental education (A54).

In the meantime, it is understood that some studies researched more than one subject. To illustrate, the study coded A54 investigated the subjects of opinion determination towards STEM, environmental education and mind mapping; the study coded A5 investigated the subjects of affective behavior determination, psychomotor behavior/scientific process skill determination, socio-cultural and gender; and the study coded A4 investigated the subjects of the effect of instruction on affective behavior and the effect of instruction on skill development.

The dependent variables in the STEM studies were analyzed within the scope of the research. The frequencies and percentages of the dependent variables category and related codes are presented in Table 5. The studies are presented in the table with their respective codes.

Table 5. *Frequencies and Percentage of the Dependent Variables of STEM Studies*

Category	Codes	Studies	f	%
Dependent Variables	Achievement	A36, A37, A53	3	8.11
	Attitude towards STEM	A50, A52, A53	3	8.11
	Scientific creativity	A28, A34, A47	3	8.11
	Critical thinking	A4, A39, A51	3	8.11
	STEM perception	A39, A51	2	5.41
	STEM awareness	A10, A58	2	5.41
	Science process skills	A56, A58	2	5.41
	21 century skills	A12, A14	2	5.41
	Ability to prepare lesson plan	A17	1	2.70
	Ability to design STEM learning and teaching processes	A63	1	2.70
	Attitude towards science	A52	1	2.70
	Attitude towards science and technology	A44	1	2.70
	Conceptual change	A52	1	2.70
	Daily life problem solving	A36	1	2.70
	Engineering perception	A60	1	2.70
	Innovative thinking skills	A69	1	2.70
	Intrinsic motivation	A4	1	2.70
	Reflective thinking skills	A37	1	2.70
	Research skills	A69	1	2.70
	Problem solving perception	A4	1	2.70
	Psychomotor skills	A37	1	2.70
	STEM career interest	A30	1	2.70
	STEM profession interest	A56	1	2.70
	STEM semantic perceptions	A50	1	2.70
	STEM teaching tendency	A10	1	2.70
Total			37	100

** A study may include more than one dependent variable. f=frequency, %= percentage*

Table 5 illustrates that the dependent variables on which the impact of STEM education has been most extensively researched were achievement, attitude towards STEM, scientific creativity, and critical thinking, with an equal percentage (8.11%). The subsequent dependent variables used were STEM perception, STEM awareness, science process skills, and 21st-century skills, which have equal percentage (5.41%). Moreover, an analysis of the studies according to the number of independent variables revealed that the studies in which only a single independent variable was examined were the most common, while the studies in which three independent variables were examined were the least common. A single independent variable was examinedin 12 studies (A12, A14, A17, A28, A30, A34, A44, A47, A52, A58, A60, A63). In eight studies, two independent variables were examined. These were A4, A36, A39, A50, A51, A53, A56 and A69. In only two studies, three independent variables were examined. These were A37, A50 and A60.

The learning models integrated with STEM were investigated in the STEM. Table 6 shows the findings related to the teaching methods and practices integrated with STEM in the analyzed studies. The studies are presented in the table with their respective codes.

Table 6 demonstrates that in 20 studies, STEM education was implemented in conjunction with various learning models. Among these learning methods, STEM education was most commonly implemented with the project-based learning method (20.0%). Then it was followed by inquiry-based learning, out-of-school learning, the socio-scientific method, and engineering design-based learning with an equal percentage (10.0%).

Table 6. *Frequencies and Percentage of the Learning Models Integrated with STEM*

Category	Codes	Studies	f	%
Learning Model	Project-based learning	A10, A12, A19, A24	4	20
	Engineering design-based learning	A39, A56	2	10
	Inquiry-based learning	A27, A47	2	10
	Out-of-school learning	A11, A30	2	10
	Socio-scientific method	A14, A15	2	10
	Cooperative learning	A1	1	5
	Argumentation	A37	1	5
	Digital game-technology oriented learning	A29	1	5
	Game-based learning	A4	1	5
	Mathematical modelling	A46	1	5
	Robotic applications	A70	1	5
	Simulation supported learning	A58	1	5
	Virtual reality	A68	1	5
Total			20	100

f=frequency, %= percentage

The research approach, design, and method used in the analyzed studies were investigated. The frequencies and percentages of the methodology/design category a are presented in Table 7. The studies are presented in the table with their respective codes.

Table 7. *Frequencies and Percentage of the Methodology/Design in STEM Studies*

Category	Sub-category	Codes	Studies	f_{code}	$\%_{code}$	f_{sc}	$\%_{sc}$
Methodology/ Design	Quantitative	Quasi-experimental	A28, A37, A47	3	4.29	20	28.57
		Pre-experimental	A10, A12, A52, A60	4	5.71		
		Descriptive	A2, A55, A66	3	4.29		
		Correlational	A20	1	1.43		
		Survey	A5, A8, A18, A29, A33, A49, A61, A67	8	11.43		
		Meta-analysis	A57	1	1.43		
	Qualitative	Culture analysis	A7	1	1.43	37	52.86
		Phenomenology	A1, A19, A38, A40, A41, A43, A70	7	10.00		
		Case-study	A6, A9, A11, A15, A16, A17, A21, A23, A27, A32, A39, A45, A48, A54, A59, A68	16	22.86		
		Action research	A44	1	1.43		
		Individual- self research	A31	1	1.43		
		Document analysis	A35, A62	2	2.86		
		Review	A46, A65	2	2.86		
		Concept analysis	A26	1	1.43		
		Content analysis	A3, A22, A25, A42, A51, A64	6	8.57		
	Mixed	Explanatory	A4, A13, A24, A36, A53, A56, A58	7	10.00	13	18.57
		Exploratory	A34	1	1.43		
		Triangulation	A50, A69	2	2.86		
		Embedded	A14, A30	2	2.86		
		Multiphase	A63	1	1.43		
Total				70	100		

**f_{code}: Frequency of code, $\%_{code}$: Percentage of code, f_{sc}: Frequency of sub-category, $\%_{sc}$: Percentage of sub-category*

In Table 7, the category presents the research approaches, the sub-category presents the research designs, and the codes present the research methods. As evidenced by Table 6, studies within the STEM disciplines are predominantly qualitative in terms of research methodology (52.86%) and interactive in terms of research

design (34.29%). Case study has been identified as the most prevalent research method employed in STEM studies (%22.86). It is observed that phenomenology and explanatory research methods share second place with equal percentages (10.0%). Nevertheless, Table 7 indicates that correlational, meta-analysis, cultural analysis, action research, individual-self research, concept analysis, exploratory, and multiphase research methods are the least favored research approaches in STEM studies.

The sample levels of the STEM studies were examined. The frequencies and percentages of the sample level category is presented in Table 8. The studies are presented in the table with their respective codes.

Table 8. *Frequencies and Percentage of the Sample Levels in STEM Studies*

Category	Codes	Studies	f	%
Sample Level	Pre-school	A19, A27	2	2.86
	Primary school	A4	1	1.43
	Secondary school	A5, A7, A11, A14, A28, A29, A30, A33, A36, A37, A39, A40, A41, A44, A45, A47, A49, A52, A53, A56, A59, A60, A66, A69	24	34.29
	High school	A12, A34, A48	3	4.29
	Undergraduate	A1, A6, A8, A10, A15, A17, A20, A21, A23, A24, A32, A38, A43, A50, A54, A58, A61, A63, A70	19	27.14
	Teacher	A9, A16, A18, A31, A55, A67, A68	7	10.00
	Document	A2, A3, A13, A22, A25, A35, A42, A51, A57, A62, A64	11	15.71
	No sample size	A26, A46, A65	3	4.29
Total			70	100

f=frequency, %= percentage

Table 8 shows that the most preferred sample level used in STEM studies was secondary school (34.29%). It can be seen that the undergraduate level was in second place (24.14%) and the document was in third place (15.71%). Furthermore, Table 6 shows that the least used sample level was pre-school (2.86%) and three studies did not specify the sample level.

The sample sizes of the STEM studies were investigated. The frequencies and percentages of the sample sizes category are illustrated in Table 9. The studies are presented in the table with their respective codes.

Table 9. *Frequencies and Percentage of the Sample Sizes in STEM Studies*

Category	Codes	Studies	f	%
Sample Size	1-10	A3, A9, A31, A35, A55, A62, A68	7	10.00
	11-50	A1, A4, A11, A12, A13, A14, A15, A16, A17, A19, A21, A22, A23, A27, A30, A32, A36, A37, A39, A42, A43, A44, A45, A50, A51, A52, A53, A54, A56, A57, A58, A59, A60, A63	34	48.57
	51-100	A7, A25, A28, A40, A41, A47, A64	7	10.00
	101-200	A6, A10, A20, A24, A33, A34, A38, A61, A69	9	12.86
	201-500	A5, A8, A18, A48, A66, A70	6	8.57
	501-1000	A29, A67	2	2.86
	Over than1000	A2, A49	2	2.86
	No sample size	A26, A46, A65	3	4.29
Total			70	100

f=frequency, %= percentage

Table 9 shows that between 11 and 50 sample size was the most preferred in STEM studies (48.57%). Moreover, it presents that sample sizes between 201 and 500 and between 501 and 1000 were the least preferred sample sizes in STEM studies, with the same percentage (2.86%). In addition, Table 8 also presents that three studies did not specify the sample size.

Data collection tools used in STEM studies were examined. The frequencies and percentages of data collection tools category is illustrated in Table 10. The studies are presented in the table with their respective codes.

Table 10. *Frequencies and Percentage of Data Collection Tools in STEM Studies*

Category	Codes	Studies	f	%
Data Collection Tool	Questionnaire/Form	A9, A10, A11, A16, A18, A22, A23, A24, A32, A33, A36, A40, A41, A48, A50, A51, A63, A64, A70	19	15.83
	Achievement/Concept test	A24, A28, A34, A36, A37, A47, A52, A53, A56, A58	10	8.33
	Scale	A4, A5, A8, A10, A12, A14, A20, A30, A37, A39, A44, A49, A50, A52, A53, A56, A58, A60, A61, A66, A67, A69	22	18.33
	Interview	A4, A6, A7, A9, A12, A14, A15, A19, A21, A27, A30, A31, A38, A39, A43, A44, A45, A53, A54, A55, A56, A58, A59, A63, A68, A69	26	21.67
	Observation	A4, A6, A7, A27, A31, A69	6	5.00
	Field notes	A6, A7, A14, A15, A44, A59, A69	7	5.83
	Alternative tools	A4, A9, A23, A24, A25, A29, A37, A38, A44, A54	10	8.33
	Document	A1, A2, A3, A7, A9, A13, A16, A17, A24, A31, A35, A44, A53, A57, A59, A62	16	13.33
	No data collection	A26, A42, A46, A65	4	3.33
Total			113	100

** A study may include more than one type of data collection tool*
f=frequency, %= percentage

Table 10 indicates that interview was mostly preferred data collection tools in STEM studies (21.67%). It is seen that the scale was in second place (18.33%) and the questionnaire/form was in third place (15.83%). Furthermore, Table 10 indicates that observation was the least preferred data collection tool, and in four studies used any data collection tool.

Table 11. *Frequencies and Percentage of Number of Data Collection Tools in STEM Studies*

Category	Codes	Studies	f	%
Number of Data Collection Tool	1	A1, A2, A3, A11, A13, A17, A18, A19, A21, A22, A25, A28, A29, A32, A33, A34, A35, A40, A41, A43, A45, A47, A48, A51, A55, A57, A60, A61, A62, A64, A67, A68, A70	33	47.14
	2	A5, A8, A10, A15, A16, A20, A23, A27, A36, A38, A49, A54, A63	13	18.57
	3	A6, A12, A31, A37, A39, A50, A52, A56, A58, A59, A66	11	15.71
	4	A7, A30, A53	3	4.29
	5	A14, A24, A44	3	4.29
	6	A4, A69	2	2.86
	7	A9	1	1.43
	No number	A26, A42, A46, A65	4	5.71
Total			70	100

f=frequency, %= percentage

The number of data collection tools employed in STEM studies was examined. The frequencies and percentages of the number of data collection tools category are presented in Table 11. The studies are presented in the table with their respective codes.

Table 11 indicates that the majority of STEM studies employed a single data collection tool (47.14%). Moreover, it is seen that the least of STEM studies used seven data collection tools (1.43%). In addition, the frequency and number of data collections appear to be inversely proportional.

The instructional durations of STEM studies were analyzed. The frequencies and percentages of the instructional duration category are presented in Table 12. The studies are presented in the table with their respective codes.

Table 12 shows that the instructional duration of 29 studies varied between one week to 24 weeks. It seems that the most commonly preferred instructional duration was four weeks (17.24%). Table 11 also shows that 6 weeks, 8 weeks, and 14 weeks with instructional duration shared second place in STEM studies, with equal percentages (13.79%).

Tablo 12. *Frequencies and Percentage of STEM Studies' Instructional Duration*

Category	Codes	Studies	f	%
Instructional duration	1 week	A30	1	3.45
	2.5 week	A52	1	3.45
	3 week	A11, A36	2	6.90
	4 week	A1, A12, A27, A32, A54	5	17.24
	5 week	A39	1	3.45
	6 week	A28, A45, A47, A69	4	13.79
	8 week	A4, A59, A60, A68	4	13.79
	9 week	A23	1	3.45
	10 week	A58	1	3.45
	12 week	A34	1	3.45
	13 week	A9, A17	2	6.90
	14 week	A15, A31, A44, A63	4	13.79
	15 week	A56	1	3.45
	24 week	A14	1	3.45
Total			29	100

f=frequency, %= percentage

Data analysis methods of STEM studies were investigated. The frequencies and percentages of data analysis category are presented in Table 13. The studies are presented in the table with their respective codes.

Table 13. *Frequencies and Percentage of Data Analysis in STEM studies*

Category	Sub-category	Codes	Studies	f_{code}	$\%_{code}$	f_{sc}	$\%_{sc}$
Data Analysis	Quantitative	Descriptive statistics with tables	A2, A4, A5, A8, A10, A14, A18, A25, A28, A29, A30, A34, A37, A39, A48, A50, A52, A53, A60, A61, A66, A69	22	17.19	73	57.03
		Figure/graphic	A2, A13, A57, A67	4	3.13		
		t-test	A4, A5, A8, A14, A25, A28, A30, A34, A39, A50, A52, A53, A61, A69	14	10.94		
		Correlation	A5, A8, A20, A24, A25	5	3.91		
		ANOVA/ANCOVA	A10, A30, A61, A66, A69	5	3.91		
		Factor analysis	A49, A67	2	1.56		
		Regression	A8	1	0.78		
		Non-parametric	A12, A18, A20, A25, A36, A37, A39, A44, A47, A53, A56, A60, A63, A66	14	10.94		
		Effect size	A13, A34, A39, A52, A57, A58	6	4.69		
	Qualitative	Content analysis	A1, A3, A4, A11, A12, A13, A14, A15, A16, A19, A21, A22, A25, A27, A30, A31, A32, A33, A34, A35, A36, A40, A41, A42, A43, A44, A45, A50, A51, A53, A54, A55, A58, A62, A63, A64, A68, A70	38	29.69	55	42.97
		Descriptive analysis	A6, A8, A9, A15, A16, A17, A23, A24, A33, A36, A38, A39, A44, A56, A59, A69	16	12.50		
		Constant- comparative	A7	1	0.78		
Total				128	100		

** A study may include more than one data analysis method*

f_{code}:=frequency of code, $\%_{code}$:= percentage of code, f_{sc}= frequency of sub-category, $\%_{sc}$= percentage of sub-category

Table 13 indicates that quantitative analysis methods were employed with greater frequency than qualitative data analysis methods in STEM studies. However, Table 13 shows that content analysis was the first place, descriptive analysis with tables was the second place, t-test, and non-parametric analysis were the third places with equal percentages. However, regression and constant-comparative were the least used as data analysis methods with equal percentages in STEM studies.

The results related the effects of STEM education on dependent variables were examined. The frequencies and percentages of the result category are presented in Table 14. The studies are presented in the table with their respective codes.

Table 14. *Results on the Effect of STEM Education on Variables*

Category	Sub-category	Codes	Studies	f_{code}	$\%_{code}$	f_{sc}	$\%_{sc}$
Result	A positive effect was found	Attitude towards STEM	A50, A52, A53	3	8.11	32	86.49
		Scientific creativity	A28, A34, A47	3	8.11		
		Achievement	A37, A53	2	5.41		
		Critical thinking	A39, A51	2	5.41		
		Scientific process skills	A56, A58	2	5.41		
		STEM awareness	A10, A58	2	5.41		
		STEM perception	A39, A51	2	5.41		
		21-st century skills	A12, A14	2	5.41		
		Ability to prepare lesson plan	A17	1	2.70		
		Attitude towards science and technology	A44	1	2.70		
		Competence to design the learning-teaching process according to STEM	A63	1	2.70		
		Conceptual change	A52	1	2.70		
		Daily life problem solving	A36	1	2.70		
		Engineering perception	A60	1	2.70		
		Innovative thinking skills	A37	1	2.70		
		Intrinsic motivation	A4	1	2.70		
		Psychomotor skills	A37	1	2.70		
		Reflective thinking	A37	1	2.70		
		Research skills	A69	1	2.70		
		STEM career interest	A30	1	2.70		
		STEM profession interest	A56	1	2.70		
		STEM teaching tendency	A10	1	2.70		
	A positive effect was not found	Achievement	A36	1	2.70	5	13.51
		Attitude towards science	A52	1	2.70		
		Critical thinking	A4	1	2.70		
		Problem-solving perception	A4	1	2.70		
		STEM semantic perception	A50	1	2.70		
Total				37	100		

f=frequency, %= percentage

Table 14 indicates that STEM education had a statistically significant positive effect on the dependent variables, with a percentage of 86.49%. Table 13 also indicates that the dependent variables exhibiting the most positive effects were scientific creativity and attitude towards STEM, with equal percentages (8.11%). Conversely, STEM education did not have a statistically significant positive effect on the dependent variables, with a percentage of 13.51%. As can be seen in a positive effect was not found sub-category, the dependent variables, achievement, attitude toward science, critical thinking, problem-solving perception, and STEM semantic perception had the same percentage (2.70%).

4. DISCUSSION and CONCLUSION

This study sought to ascertain the general trajectory of STEM studies in Türkiye over the past decade. To this end, 70 STEM studies published in 15 educational science journals and indexed in the SSCI or ERIC database between 2013 and 2022 were subjected to analysis. The aforementioned studies were subjected to a

thematic content analysis employing parameters including the studies' stated aims, dependent variables, learning models that integrate with STEM, research methods, the composition of sample groups, sample sizes, data collection tools, number of data collection tools, instructional durations, data analysis methods, and results.

Upon examination of the aims of the study, it was observed that the aims of opinion determination towards STEM education and the effect of teaching on skill development were the most extensively studied, followed by the effect of teaching on affective behaviors. This result is comparable to that obtained by Kaya and Ayar (2020). Kaya and Ayar (2020) identified the most studied topics in STEM education studies in Türkiye as opinions towards STEM education, attitudes towards STEM education, and skills towards STEM education, respectively. Sarica (2020) found that the most studied topic was skill development, followed by opinion formation. The high number of studies whose aim or purpose is to determine opinions is thought to be due, at least in part, to the desire to collect more detailed information from the sample group through interviews or open-ended surveys after STEM education. Moreover, It has been demonstrated that there is a dearth of studies about in-service training, misconception detection, mind mapping detection, the nature of STEM concepts, STEM prerequisite determination, STEM cognitive structure detection, the utilization of distance education in STEM education, and environmental education in STEM education.

The study revealed that the dependent variables in which the effect of STEM education was most extensively examined as an independent variable were achievement, attitude towards STEM, scientific creativity, and critical thinking, with equal percentages. The results appear to be in close alignment with those of several previous studies in the literature, including those by Aydın-Günbatar & Tabar (2019), Çavaş et al. (2020), Ecevit et al. (2022), and Gülhan (2022). For instance, Çavaş et al. (2020) observed that in the postgraduate theses and articles in the field of STEM education in Türkiye between 2010 and 2018, skills were predominantly examined as dependent variables, followed by attitude and achievement. Ecevit et al. (2022) found that the most frequently studied dependent variables in graduate theses and articles in the field of STEM education between 2014 and 2020 in Türkiye were attitude, achievement and problem-solving skills, respectively.

This study revealed that the most integrated approach to STEM education was project-based learning. This result was also found in the study conducted by Zulaikha et al. The reason why the project-based learning model is more integrated with STEM education is that they are similar in many ways. Furthermore, project-based teaching can facilitate the acquisition of numerous 21st-century skills, which is one of the fundamental objectives of STEM education (Katz & Chard, 2000, p.161). Furthermore, the present study revealed that, following project-based learning, STEM education became more integrated with inquiry-based learning, out-of-school learning, socio-scientific learning, and engineering design-based learning.

The case study method was identified as the most frequently employed research method in the publications examined in the current study. Similarly, studies in the literature have indicated that the case study method is the most frequently employed research method in STEM education studies (Aydın-Günbatar & Tabar, 2019; Çavaş et al., 2020; Kızılay, 2018; Özcan & Karabaş, 2019). Furthermore, in the studies examined, it was observed that after the case study method, survey, phenomenology, and explanatory research methods were used more frequently. In addition correlational, meta-analysis, culture analysis, action research, concept analysis, and exploratory research methods were used very rarely in STEM studies.

The sample groups most commonly employed in STEM studies were examined, with the results indicating that studies conducted with secondary school students were found to be the most prevalent. Similar findings were identified in many studies within the literature (Daşdemir et al., 2018; Eren & Dökme, 2022; Ergün, 2020; Gülhan, 2022; Kalemkuş, 2020; Mandev & Yavuz, 2022; Özcan & Karabaş, 2019; Sarica, 2020; Püsküllü, 2019). It is hypothesized that the incorporation of STEM education into the 2018 Science Curriculum, encompassing Science, Engineering, and Entrepreneurship Practices, has been effective in increasing the number of STEM education studies, particularly at the secondary school level. Furthermore, it was determined that the most frequently studied sample group after secondary school students was undergraduate students, while the least frequently studied sample groups were preschool and primary school students.

In addition, the most frequently studied sample sizes were also examined in STEM studies. It was determined that the most commonly used sample size was between 11 and 50. In the study conducted by Ormancı (2020), the most frequently used sample size was found to be in a similar range (between 31 and 50) to the current study.

In this study, the interview was identified as the principal data collection tool in STEM studies. Some studies have reached similar findings in the literature (Çalışkan & Okuşluk, 2021; Kızılay, 2018; Püsküllü, 2019). However, it was concluded that observation was the least used data collection tool in this study. Furthermore, it was found that the majority of studies employed a single data collection tool, with the number of studies decreasing as the number of data collection tools used increased. It is notable that no study in the literature can be related to this data.

This study revealed that the instructional duration employed varied considerably between one and 24 weeks. The most frequently used instructional duration was four weeks, followed by six, eight, and 14 weeks, each of which occurred at equal rates. Kalemkuş (2020) determined that the most common instructional duration was six to 10 weeks. In the study conducted by Aydın-Günbatar and Tabar (2019), the most common instructional duration was observed to be between one and two months (4-8 weeks). The findings of this study indicate that one of the most common aims of STEM studies is to determine the effect of teaching on skill development. It is reasonable to assume that skill development will not be achieved in a relatively short period. Therefore, it is deemed appropriate that the instructional duration should be extended to a minimum of four weeks or more.

Upon examination of the data analysis methods employed in the studies, it was found that quantitative data analysis methods were utilized more frequently than qualitative data analysis methods. However, it appears that the majority of the data was analyzed using content analysis. Ecevit et al. (2022) and Sungur Gül et al. (2022) defined content analysis as the most frequently used data analysis method.

The results of the studies examining the effect of STEM education on the dependent variables were analyzed. The findings demonstrated that STEM education had a statistically significant, positive effect on the dependent variables at a rate of 86.49%, whereas the effect was not statistically significant for the remaining 13.51%. The analysis revealed that the dependent variables exhibiting the most positive effects were scientific creativity and attitude toward STEM. The number of studies examining the results of STEM education in the literature is relatively limited (Duran & Sarı, 2021; Ültay et al., 2021). In Duran and Sarı's (2021) study, it was found that STEM education had the most positive effect on academic achievement. Ültay et al. (2021) categorized the results of all STEM education studies they examined. In this study, it was found that there was a positive tendency according to STEM, with a positive opinion that STEM education increased students' attitudes and interest towards science courses.

Consequently, it has been established that the number of studies on STEM education conducted in Türkiye and published in SSCI or ERIC-indexed journals has gradually increased over the past decade. The majority of studies included in this review were conducted with secondary school students. The qualitative research approach and the case study method were the most frequently employed research methods, while content analysis was the most prevalent method used for data analysis. Furthermore, the results of these studies indicated that STEM education had the most positive effect on attitudes towards STEM and scientific creativity. Furthermore, the effect of STEM education on academic performance, critical thinking, scientific creativity, and attitudes towards STEM was investigated. The findings suggest that STEM education has a predominantly positive effect on scientific creativity and attitudes towards STEM.

4.1. Suggestions

The analysis of the studies revealed that only a small number of studies were focused on specific objectives, including metaphor determination, career choice for STEM disciplines, pre-service teacher education, instructional material design, measurement tool development and improvement, education system and policies, in-service training, misconception determination, mind map determination, prerequisite and cognitive structure determination related to STEM, and distance education and environmental education. It can be concluded that there is a need for further studies to be conducted on these objectives.

It has been observed that variables such as self-efficacy, self-confidence, and scientific literacy etc. are not included as dependent variables in STEM studies. These variables may be included as dependent variables in future STEM studies.

A review of the literature revealed a paucity of studies that integrated STEM education with a range of pedagogical approaches, including cooperative learning, argumentation, technology-supported teaching, mathematical modeling, game-based learning, and simulation-supported research learning methods. However, there is potential for further research in this area, with studies being conducted in this field integrating STEM education with models such as problem-based learning, the 5E model, the REACT model, and others.

The studies observed were predominantly conducted using qualitative research methods, with mixed methods employed in the lowest percentage. Consequently, there is scope to expand the body of literature utilizing this approach. The case study was the method employed in most of the studies, although only a few employed other methods, including correlational, meta-analysis, cultural analysis, action research, concept analysis, and exploratory research. There is a potential for further studies to employ these research methods within the context of STEM education.It has been observed that the number of studies involving primary school, pre-school, and high school students as a sample is very low. It is therefore recommended that studies on STEM education involving students at these educational levels be emphasized. It was observed that the sample size of the analyzed studies was mostly between 11-50. However, studies with sample sizes outside this range can be conducted.

As observation and field notes were seldom employed as data collection instruments in the studies analyzed, further research utilizing these techniques could be conducted. The findings revealed that a significant majority of studies employed a single data collection instrument, with a markedly lower proportion utilizing four or more. Therefore, it is recommended that the number of data collection instruments be augmented in future studies.It has been observed that regression analysis is rarely employed in studies within the STEM disciplines. However, there is potential for the use of regression analysis in the future to inform educational practice within this field.

This study focused on analyzing only those studies published in SSCI or ERIC-indexed journals to determine the status of STEM education in Türkiye. It is recommended that this study be expanded in the future by examining STEM studies conducted in Türkiye and scanned in other international indexes.

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Declaration of Conflicting Interests and Ethics

In terms of the ethical standards that govern research, the approval of an ethics committee is not a prerequisite for this study.

Authorship Contribution Statement

İnanç Kösen: Conceptualization, Investigation, Methodology, Analysis, Writing e original draft.
Hülya Dede: Conceptualization, Supervision, Validation, Writing e review, and editing.

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APPENDIX A. STEM Studies in the Scope of the Research

Codes	STEM Studies
A1	Akaygun, S., & Aslan-Tutak, F. (2016). STEM images revealing stem conceptions of pre-service chemistry and mathematics teachers. *International Journal of Education in Mathematics, Science and Technology, 4*(1), 56-71.
A2	Akgunduz, D. (2016). A Research about the placement of the top thousand students placed in STEM fields in Turkey between the years 2000 and 2014. *EURASIA Journal of Mathematics, Science and Technology Education, 12*(5), 1365-1377.
A3	Aktürk, A. A., Demircan, H. Ö., Şenyurt, E., & Çetin, M. (2017). Turkish early childhood education curriculum from the perspective of STEM education: A document analysis. *Journal of Turkish Science Education, 14*(4), 16-34.
A4	Asigigan, S. I. & Samur, Y. (2021). The effect of gamified STEM practices on students' intrinsic motivation, critical thinking disposition levels, and perception of problem-solving skills. *International Journal of Education in Mathematics, Science, and Technology (IJEMST), 9*(2), 332-352.
A5	Atabey, N. & Topcu, M.S. (2021). The relationship between Turkish middle school students' 21st century skills and STEM career interest: Gender effect. *Journal of Education in Science, Environment and Health (JESEH), 7*(2), 86-103.
A6	Ayar, M. C. (2015). First-hand experience with engineering design and career interest in engineering: An informal STEM education case study. *Educational Sciences: Theory & Practice, 15*(6), 1655-1675.
A7	Ayar, M.C. & Yalvac, B. (2016). Lesson learned: Authenticity, interdisciplinarity, and mentoring for STEM learning environments. *International Journal of Education in Mathematics, Science and Technology, 4*(1), 30-43.
A8	Gürler, S. A. (2021). State of prediction of the critical thinking dispositions of primary school teacher candidates through their self-efficacy for STEM practices. *Participatory Educational Research, 9*(3), 62-81.
A9	Aydin, G. (2020). Prerequisites for elementary school teachers before practicing STEM education with students: A case study. *Eurasian Journal of Educational Research, 20*(88), 1-40.
A10	Aydogan Yenmez, A., Gökce, S., Aydede, M.N. & Çelik, T. (2021). Investigation of pre-service teachers' awareness of STEM and STEM teaching intention. *International Online Journal of Education and Teaching (IOJET), 8*(1). 250-260.
A11	Baran, E., Canbazoglu Bilici, S., Mesutoglu, C. & Ocak, C. (2016). Moving STEM beyond schools: Students' perceptions about an out-of-school STEM education program. *International Journal of Education in Mathematics, Science and Technology, 4*(1), 9-19.
A12	Baran, M., Baran, M., Karakoyun, F., & Maskan, A. (2021). The influence of project-based STEM (PjbL-STEM) applications on the development of 21st century skills. *Journal of Turkish Science Education, 18*(4), 798-815.
A13	Batdi, V., Talan, T., & Semerci, C. (2019). Meta-analytic and meta-thematic analysis of STEM education. *International Journal of Education in Mathematics, Science and Technology (IJEMST), 7*(4), 382-399.
A14	Benek, I., & Akcay, B. (2021). The effects of socio-scientific STEM activities on 21st century skills of middle school students. *Participatory Educational Research*, 9(2), 25-52.
A15	Bozkurt Altan, E., Ozturk, N. & Yenilmez Turkoglu, A. (2018). Socio-scientific issues as a context for STEM education: A case study research with pre-service science teachers. *European Journal of Educational Research, 7*(4), 805-812.
A16	Altan, E. B., & Ercan, S. (2016). STEM education program for science teachers: perceptions and competencies. *Journal of Turkish Science Education, 13*(special), 103-117.
A17	Altan, E. B., & Ucuncuoglu, I. (2019). Examining the development of pre-service science teachers' STEM-focused lesson planning skills. *Eurasian Journal of Educational*

Research, 19(83), 103-124.

A18 Çavaş, B., Çapar, S., Çavaş, L., & Yahşi, Ö. (2021). Turkish STEM Teachers' Opinions about the Scientist-Teacher-Student Partnership. *Journal of Turkish Science Education (TUSED), 18*(4), 622-637.

A19 Çetin, A. (2020). Examining project-based STEM training in a primary school. *International Online Journal of Education and Teaching (IOJET), 7*(3). 811- 825.

A20 Çetin, A. (2021). Investigation of the relationship between the STEM awareness and questioning skills of pre-service teachers. *International Journal of Research in Education and Science (IJRES), 7*(1), 65-81.

A21 Cetin, A., & Balta, N. (2017). Pre-service science teachers views on stem materials and stem competition in instructional technologies and material development course. *European Journal of Educational Research*, *6*(3), 279-288.

A22 Çevik, M. (2017). Content analysis of STEM-focused education research in Turkey. *Journal of Turkish Science Education*, *14*(2), 12-26.

A23 Çınar, S., Pırasa, N., Uzun, N., & Erenler, S. (2016). The Effect of Stem Education on Pre-Service Science Teachers' Perception of Interdisciplinary Education. *Journal of Turkish Science Education (TUSED), 13*(Special Issue), 118-142.

A24 Corlu, M.A. & Aydin, E. (2016). Evaluation of learning gains through integrated STEM projects. *International Journal of Education in Mathematics, Science and Technology, 4*(1), 20-29.

A25 Corlu, M. S. (2013). Insights into STEM education praxis: An assessment scheme for course syllabi. *Educational Sciences: Theory & Practice, 12*(4), 2477-2485.

A26 Corlu, M. S., Capraro, R. M., & Capraro, M. M. (2014). Introducing STEM education: Implications for educating our teachers in the age of innovation. *Science and Education, 39*(171), 74-85.

A27 Dilek, H., Tasdemir, A., Konca, A.S. & Baltaci, S. (2020). Preschool children's science motivation and process skills during inquiry-based STEM activities. *Journal of Education in Science, Environment and Health (JESEH), 6*(2), 92-104.

A28 Dogan, A., & Kahraman, E. (2021). The Effect of STEM Activities on the Scientific Creativity of Middle School Students. *International Journal of Curriculum and Instruction, 13*(2), 1241-1266.

A29 Donmez, I., Tekce, M. & Kirmit, S. (2020). Using digital games in technology oriented STEM education: The examination of the students' game designs. *Journal of Education in Science, Environment and Health (JESEH), 6*(2), 77-91.

A30 Donmez, I. (2021). Impact of out-of-school STEM activities on STEM career choices of female students. *Eurasian Journal of Educational Research, 91*, 173-203.

A31 Dönmez, İ., & Taşar, M. F. (2020). A self-study on the values and beliefs of science teachers and their science, technology, engineering and mathematics (STEM) applications. *Participatory Educational Research, 7*(1), 59-79.

A32 Ercan, S., Bozkurt altan, E., Taştan, B., & Dağ, İ. (2016). Integrating GIS into science classes to handle STEM education. *Journal of Turkish Science Education (TUSED), 13*(Special Issue), 30-43.

A33 Ergun, A., & Balcin, M. D. (2019). The perception of engineers by middle school students through drawings. *Eurasian Journal of Educational Research, 19*(83), 1-28.

A34 Eroglu, S. & Bektas, O. (2022). The effect of STEM applications on the scientific creativity of 9th-grade students. *Journal of Education in Science, Environment and Health (JESEH), 8*(1), 17-36.

A35 Yapıcıoğlu, A. E. (2021). An analysis of the outcomes of the Turkish science curriculum in terms of science process skills, nature of science, socio-scientific issues, and STEM: An analysis of the outcomes of the Turkish science curriculum. *International Journal of Curriculum and Instruction, 13*(2), 925-949.

A36 Gülen, S. (2019). The effect of STEM education roles on the solution of daily life problems. *Participatory Educational Research, 6*(2), 37–50.

A37 Gülen, S. & Yaman, S. (2019). The effect of integration of STEM disciplines into Toulmin's argumentation model on students' academic achievement, reflective thinking, and psychomotor skills. *Journal of Turkish Science Education, 16*(2), 216-230.

A38	Hacıoğlu, Y., Yamak, H., & Kavak, N. (2016). Pre-service science teachers' cognitive structures regarding science, technology, engineering, mathematics (STEM) and science education. *Journal of Turkish Science Education*, *13*(special), 88-102.
A39	Hacioglu, Y. & Gulhan, F. (2021). The effects of STEM education on the students' critical thinking skills and STEM perceptions. *Journal of Education in Science, Environment and Health (JESEH)*, *7*(2), 139-155.
A40	Idin, S. & Donmez, I. (2018). A metaphor analysis study related to STEM subjects based on middle school students' perceptions. *Journal of Education in Science, Environment and Health (JESEH)*, *4*(2), 246-257.
A41	İdin, Ş. (2019). The metaphors of Turkish, Bulgarian and Romanian students on STEM disciplines. *International Journal of Curriculum and Instruction*, *11*(2), 147-162.
A42	Kanadlı, S. (2019). A meta-summary of qualitative findings about STEM education. *International Journal of Instruction*, *12*(1), 959-976.
A43	Karademir, A., & Yıldırım, B. (2021). A Different perspective on preschool STEM education: Preschool STEM education and engineering for preservice teachers. *Journal of Turkish Science Education*, *18*(3), 338-350.
A44	Karahan, E., Canbazoglu-Bilici, S., & Unal, A. (2015). Integration of media design processes in science, technology, engineering, and mathematics (STEM) education. *Eurasian Journal of Educational Research*, *60*, 221-240.
A45	Karakaya, F., Alabaş, Z.E., Akpınar, A., & Yılmaz M. (2020). Determination of middle school students' views about stem activities. *International Online Journal of Education and Teaching (IOJET)*, *7*(2), 537-551.
A46	Kertil, M. & Gurel, C. (2016). Mathematical modeling: A bridge to STEM education. *International Journal of Education in Mathematics, Science and Technology*, *4*(1), 44-55.
A47	Kırıcı, M. G., & Bakırcı, H. (2021). The effect of STEM supported research-inquiry-based learning approach on the scientific creativity of 7th grade students. *Journal of Pedagogical Research*, *5*(2), 19-35.
A48	Kizilay, E., Yamak, H., & Kavak, N. (2020). Analysis of the female student profiles who consider choosing STEM careers. *International Journal of Curriculum and Instruction*, *12*(2), 164-175.
A49	Koyunlu Unlu, Z., Dokme, I., & Unlu, V. (2016). Adaptation of the science, technology, engineering, and mathematics career interest survey (STEM-CIS) into Turkish. *Eurasian Journal of Educational Research*, *63*, 21-36.
A50	Mirici, S., Gencer, İ., & Gündüz, S. (2019). The impact of STEM project writing education on candidate female teachers' attitudes, their semantic perceptions and project writing skills towards STEM education. *International Journal of Curriculum and Instruction*, *11*(2), 255-272.
A51	Ormancı, Ü. (2020). Thematic content analysis of doctoral theses in STEM education: Turkey context. *Journal of Turkish Science Education*, *17*(1), 126-146.
A52	Ozdemir, Benli, E. (2021). The impacts of stem supported Science teaching on 8th grade students' elimination of misconceptions about "solid, fluid and gas pressure", and their attitudes towards Science and STEM. *International Online Journal of Education and Teaching (IOJET)*, *8*(1), 205-228.
A53	Özcan, H., & Koca, E. (2019). The impact of teaching the subject "pressure" with STEM approach on the academic achievements of the secondary school 7th grade students and their attitudes towards STEM. *Science and Education*, *44*(198), 201-227.
A54	Sümen, Ö. Ö., & Çalisici, H. (2016). Pre-service teachers' mind maps and opinions on STEM education implemented in an environmental literacy course. *Educational sciences: Theory and practice*, *16*(2), 459-476.
A55	Ozdemir, E. B. (2021). Views of science teachers about online STEM practices during the COVID-19 period. *International Journal of Curriculum and Instruction*, *13*(1), 854-869.
A56	Özkul, H., & Özden, M. (2020). Investigation of the effects of engineering-oriented STEM integration activities on scientific process skills and STEM career interests: A mixed methods study. *Science and Education*, *45*(204), 41-63.
A57	Saraç, H. (2018). The effect of science, technology, engineering and mathematics-STEM

	educational practices on students' learning outcomes: A meta-analysis study. *Turkish Online Journal of Educational Technology-TOJET*, *17*(2), 125-142.
A58	Sarı, U., Duygu, E., Şen, Ö. F., & Kırındı, T. (2020). The effect of STEM education on scientific process skills and STEM awareness in simulation based inquiry learning environment. *Journal of Turkish Science Education*, *17*(3), 387-405.
A59	Akdağ, F. T., & Güneş, T. (2016). Assessment of STEM applications in terms of students' opinions. *Participatory Educational Research*, *4*(1), 161-169.
A60	Akdağ, F. T., & Güneş, T. (2016). The effect of STEM applications on students' science-engineering perceptions. *Participatory Educational Research*, *4*(1), 195-207.
A61	Tekerek, B., & Karakaya, F. (2018). STEM education awareness of pre-service science teachers. *International Online Journal of Education and Teaching (IOJET)*, *5*(2), 348-359.
A62	Tofur, S., & Gökkaya, Y. (2020). Examining the pre-school curriculum in terms of the STEM approach. *International Online Journal of Education and Teaching (IOJET)*, *7*(3), 1189-1203.
A63	Turk, N., Kalayci, N., Yamak, H. (2021). Evaluation of the effectiveness of science, technology, engineering and mathematics (STEM) curriculum designed and implemented for undergraduate programs of faculty of education. *International Online Journal of Education and Teaching (IOJET)*, *8*(3), 1401-1428.
A64	Ulger, B. B. & Çepni, S. (2020). Gifted education and STEM: A thematic review. *Journal of Turkish Science Education*, *17*(3), 443–466.
A65	Yalçın, N., Kılıç, B., & Atatay, Ç. (2016). A model suggestion for STEM activity design within the scope of the curriculum. *Participatory Educational Research*, *4*(1), 95-107.
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The effect of virtual laboratory applications on the achievement of secondary school students in learning the granular structure of matter

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Abstract

Purpose: The objective of this study is to investigate the impact of virtual laboratory applications on students' performance in the teaching of the subject matter "Particulate Structure of Matter" to middle school students.

Design and Methodology: The study was conducted in two public educational establishments. The study sample comprised 191 seventh-grade students. The study employed a quasi-experimental design, utilising a pre-test-post-test control group. The study employed an achievement test as the primary data collection instrument. The subject of "Particulate Structure of Matter" was taught using the methods prescribed by the current curriculum for the control group and a computer-aided virtual laboratory application for the experimental group. The data were subjected to quantitative analysis using the SPSS data analysis program, and the results were obtained. Independent groups t-test analyses were conducted to examine the differences between the means in the data obtained from the experimental and control groups.

Results: The findings revealed that the results were statistically significant at $p<0.05$. Consequently, it was concluded that there was a significant difference in favour of the experimental group and that virtual laboratory applications were more effective in teaching the subject of particulate structure of matter to middle school students.

Implications & Suggestions: A comparative analysis of the implementation and impact of virtual laboratory applications can be conducted by examining the differences between interactive and non-interactive applications.

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1. INTRODUCTION

One of the topics addressed in science courses at the middle school level is the particulate structure of matter. The subject enables an understanding of the formation of matter, its properties, its transitions between states, the distinction between heat and temperature, the concept of density, the preparation of mixtures and the processes involved in their separation. The particulate structure of matter occupies a significant position in the curriculum of science courses, as it is also pertinent to other scientific disciplines. In Turkey, students commence their study of the "Particulate Structure of Matter" subject in the sixth grade (MEB, 2018). The accurate acquisition of these subjects and concepts serves as a foundation for the subsequent learning of numerous high school chemistry concepts (Adadan, 2013).

As students are unable to perceive the particles of matter with their eyes, they experience difficulty in forming an image or concept of them. This situation presents a challenge for students in learning the concepts of the particulate structure of matter (Ayas et al., 2002; Özmen, 2004). The research conducted by Altay and Balım (2021) focused on an examination of 17 studies conducted between 2002 and 2020 on the subject of "Particulate Structure of Matter". It was found that the majority of the studies examined aimed to determine the prevalence of misconceptions and that there were common misconceptions among students.

In order to surmount these challenges, it is vital to equip students with activities that will facilitate the concretisation, visualisation and simulation of the particulate structure of matter and other scientific disciplines. In the literature, there are studies examining the teaching of more abstract concepts and subjects in science courses. These include the use of animation (Daşdemir, 2016), laboratory practice courses (İlhan et al., 2009), virtual laboratories (Udin et al., 2020), and computer-assisted teaching (Gökulu, 2013; İlyasoğlu & Aydın, 2014; Karaçöp, 2012; Karaduman & Emrahoğlu, 2011; Renshaw & Taylor, 2000).

Experimentation and laboratory work occupy a significant position in the learning and teaching of scientific subjects. Virtual laboratory courses have a variety of applications, including those related to virtual reality, augmented reality, animation, and simulation. The use of virtual laboratories has been demonstrated to enhance student motivation through the provision of visuals and interaction (Estriegana et al., 2019; Guzman et al., 2021). The utilisation of laboratories and experimentation facilitate students' acquisition of scientific concepts (Bozkurt & Sarıkoç, 2008; Ramirez et al., 2020). Conversely, in recent years, virtual laboratories have begun to be utilised in virtual environments, in addition to face-to-face environments, where students can utilise and experiment. This has also been the subject of numerous scientific studies in this field (Udin et al., 2020).

The utilisation of virtual laboratory applications presents a favourable avenue for students to cultivate positive attitudes towards science courses, particularly in relation to their learning success and effectiveness in these courses (Baş, 2022). In the study conducted by Duman and Avcı (2016), the impact of virtual laboratory applications on the identification and eradication of misconceptions encountered in the "States of Matter and Heat" unit was investigated. The study demonstrated that virtual laboratory applications were an effective tool for student success and the retention of knowledge in a teacher-centred learning environment. The findings align with those of Harrison and Treagust (2000), who asserted that the utilisation of visual teaching materials, including visual models, demonstrations, animations and simulations, facilitated the construction of models in students' minds, a process that was observed in the context of textbook-based learning.

Virtual laboratories facilitate interactive learning for a variety of subjects and lessons through the use of animations and simulations (Bozkurt & Sarıkoç, 2008). There are numerous similarities and differences between laboratory applications conducted in actual, physical, face-to-face settings and those performed in virtual laboratories. The utilisation of virtual laboratory applications may present a multitude of advantages and disadvantages for students. Virtual laboratories afford students the opportunity to engage in experiments in a manner that is centred on their individual needs and preferences. Furthermore, students can undertake these experiments repeatedly, and they can also access learning opportunities that are independent of time and place. The EBA education platform was established by the Ministry of National Education (MEB), and the utilisation of animations, simulations and virtual laboratories in educational and training processes has increased further. PhET (http://www.phet.colorado.edu) applications, which provide a plethora of interactive content in online environments as virtual laboratories in science education, are employed by both teachers and numerous researchers (İlyasoğlu & Aydın, 2014).

It is acknowledged that there is a direct correlation between the utilisation of interactive virtual laboratory applications, such as PhET, in the field of science education and the integration of artificial intelligence. The advent of artificial intelligence has led to a proliferation of machines and software that exhibit human-like cognitive abilities within virtual environments. The utilisation of artificial intelligence is becoming increasingly prevalent in the field of science education (Jia et al., 2023). Kiraz (2014) carried out his study on artificial intelligence-supported virtual laboratory design. A review of the literature on the teaching of the subject of "Particulate Structure of Matter" reveals a preponderance of studies on virtual laboratories that incorporate animations without user interaction (Danacı, 2018; Daşdemir, 2016; Okumuş et al., 2016). The present study concerns the development of interactive virtual laboratory applications on the subject of "Particulate Structure of Matter." It is proposed that this study will make a significant contribution to the field by examining the impact of such applications.

The subject of the science course, "Particulate Structure of Matter," presents a significant challenge for traditional laboratory-based instruction due to its abstract nature, microscopic scale, and the dynamic interactions between particles within molecular structures. The issue that this study seeks to address is the necessity for investigating student success in virtual laboratory environments, as opposed to traditional laboratory approaches.

The objective of this study is to investigate the impact of virtual laboratory applications on student performance in the teaching of the subject matter of "Particulate Structure of Matter" to middle school students. The research problem can be stated as follows:

Is there a significant difference in favor or against the course success of the students in the experimental group where virtual laboratory application was used and the control group students in the subject of “Particulate Structure of Matter” in the seventh grade middle school science course?

2. METHOD

2.1. Research Design

This study was conducted in accordance with the standards of quantitative research and with a quasi-experimental research design. In the course of the research, the impact of traditional teaching and virtual laboratory applications conducted in accordance with the prevailing curriculum were contrasted and evaluated in terms of students' performance in the subject of "Particulate Structure of Matter". Quasi-experimental research designs are employed to investigate the impact of pedagogical approaches in the context of educational research. As the experimental group received instruction through the virtual laboratory method, while the control group followed the established curriculum, the study employed a pre-test-post-test design with a control group comprising both experimental and control groups (Fraenkel & Wallen, 2011; McMillan & Schumacher, 2006). Prior to the commencement of the research, ethical approval was sought and obtained from the university ethics committee. Furthermore, the requisite official permissions were obtained from the national education directorates for the secondary school, which is a state school, where the study would be conducted. Table 1 presents an overview of the research design, which compares the use of virtual laboratories and traditional methods in the context of the current curriculum.

Table 1. *Research Design Application*

Groups	Pretest	Application	Posttest
Experimental	Achievement Test (Particular Structure of Matter)	Virtual Laboratory Application	Achievement test (Particle Structure of Matter)
Control	Achievement test (Particle Structure of Matter)	Traditional Education According to the Current Program	Achievement test (Particle Structure of Matter)

2.2. Sample of the Study

The study sample comprises 191 seventh-grade students from two middle schools (A1 and A2) in a district of a province in the eastern region of Türkiye, selected during the 2023-2024 academic year. The seventh grade is divided into four branches at both schools. Two of these branches were randomly selected as the experimental group, while the remaining two were selected as the control group.
In determining the sample and selecting the schools in which the study will be conducted, factors that may affect the success of the students were taken into consideration, and care was taken to ensure that schools with similar characteristics were selected. Furthermore, additional criteria were considered, including similarity in socio-economic and cultural aspects, comparable student knowledge levels, both schools being public institutions, and the researcher's prior experience working in these schools. The same instructor teaches both the experimental and control groups in the two schools where the study is conducted.
The data set comprises the number of students in the experimental and control groups, the number and detailed information in terms of both the experimental and control groups and the schools and classes, as presented in Table 2.

Table 2. *A Numerical Distribution of the Experimental and Control Groups*

School Type	Number of Students	Number of CG Students	Number of EG Students
Public School (A1)	95	48	47
Public School (A2)	96	50	46
Total	191	98	93

2.3. Teaching practices

In order to carry out the applications in the study, the subject of "F.7.4.1 Particulate Structure of Matter" from the "Pure Substances and Mixtures" unit of the seventh grade Science Course was selected. The subject was restricted to four learning outcomes in accordance with the middle school level. The course content was developed in alignment with the specified learning outcomes. The experimental and control groups were engaged in the study for a total of six lesson hours. The achievement test, which was employed as a pretest and posttest in the study, was also developed in accordance with the aforementioned learning outcomes. A comprehensive overview of the subject, including its constituent sub-areas, learning outcomes, recommended teaching times, key concepts and explanations, is provided in Table 3. Despite the existence of analogous learning outcomes and concepts in the experimental and control groups, distinct lesson plans were devised for each. The achievement test for the particulate structure of matter was conducted in accordance with the learning outcomes as set out in the current study.

Table 3. *Framework for the Particulate Structure of Matter*

Section	Learning outcomes	Time for lesson	concepts	Explanation
Structure of the Atom	F.7.4.1.1. It tells the structure of the atom and the fundamental particles in its structure.	2	Atom (nucleus, layer, proton, neutron, electron), property of scientific knowledge, molecule	Details about atomic theories are not given.
Atomic Models	F.7.4.1.2. Questions how ideas about the concept of atom have changed from past to present.	2		It is emphasized that scientific knowledge may change over time.
Molecule	F.7.4.1.3. It indicates that the same or different atoms will come together to form a molecule. F.7.4.1.4. It creates and presents various molecule models.	2		General information about theory, one of the types of scientific knowledge, is given.

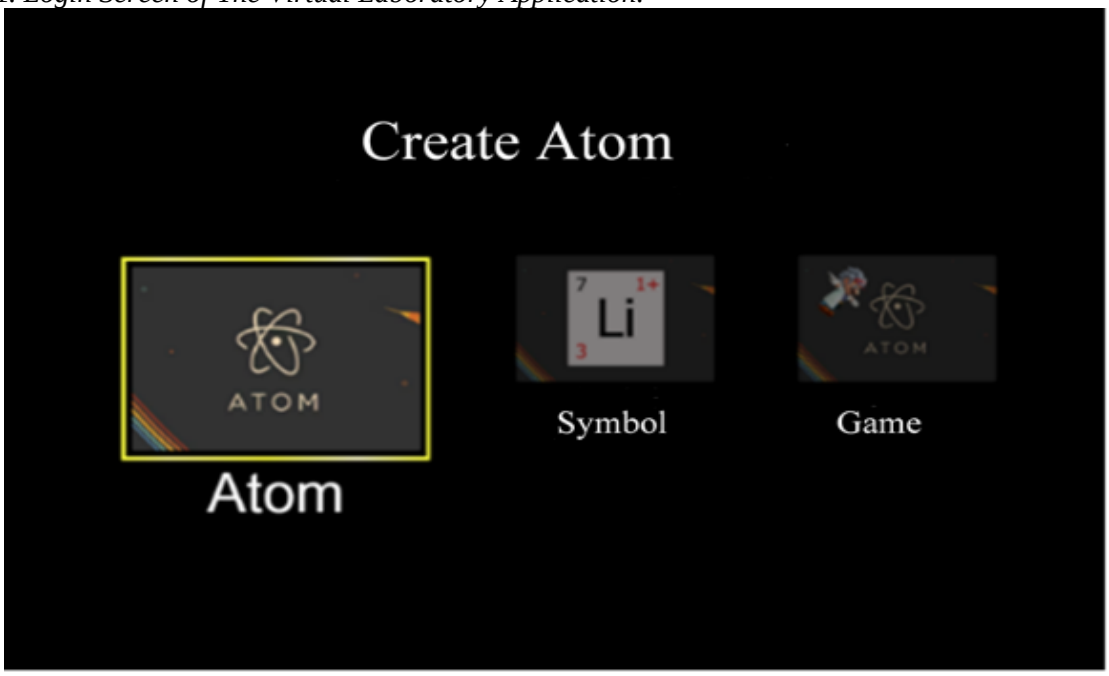
The implementation of the applications was conducted in accordance with the instructions set forth in the textbooks utilized by the Ministry of National Education, in alignment with the prevailing curriculum. The control group received instruction within the aforementioned framework, as delineated in Table 3. To ensure

uniformity in the application of the lessons, the teachers were provided with analogous lesson plans and presentations, enabling them to impart the material in a consistent manner.

2.4. Use of Virtual Laboratory for Experimental Group

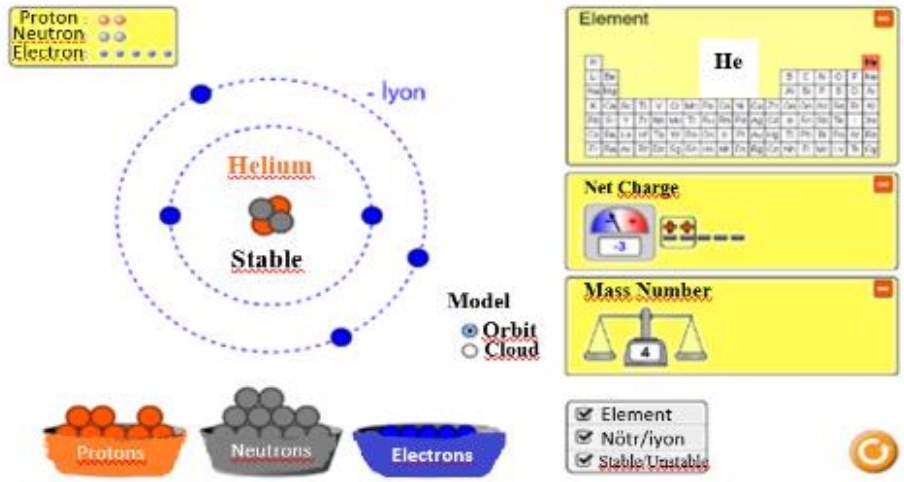
In order to facilitate the processing of the lessons in the experimental group, computer-aided virtual laboratory applications were implemented in lieu of the activities outlined in the textbook, in alignment with the current curriculum's prescribed achievements and concepts. In the experimental group, the computer-aided virtual laboratory applications were based on the open source "Build in Atoms" application, the source code of which is accessible to chemistry teachers. This application was translated into Turkish with the support of experts and accompanied by visual aids. The source code can be accessed via the following link: https://phet.colorado.edu/sims/html/build-an-atom/latest/build-an-atom_en.html.
The user interface is designed for ease of use by educators and students alike. The virtual laboratory application comprises three modules, the visuals of which are displayed in Figure 1.

Figure 1. *Login Screen of The Virtual Laboratory Application.*



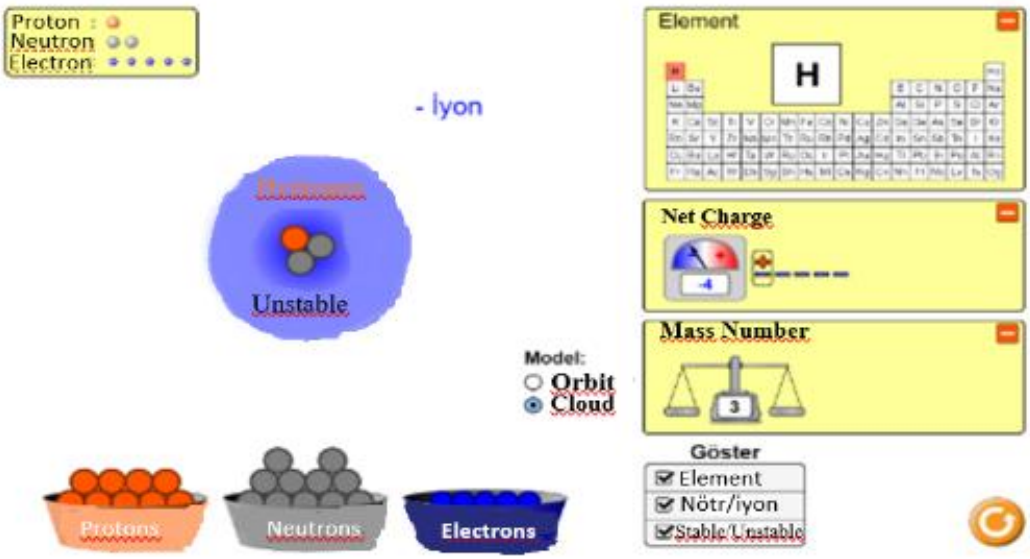
The user is able to place the protons, neutrons and electrons, which are the fundamental particles of the atom, in the atom module according to their relevant layers. Should the user attempt to place them in an incorrect layer, a warning is generated as the layer is not valid and the particle cannot be placed there. The number of particles placed allows the user to ascertain the element, mass number and ion charge. The first ten most common elements can be worked on this screen. The position of these first ten elements in the periodic table according to the number of protons placed in the nucleus is also displayed as an additional feature. The application image showing these features is also shown in Figure 2.

Figure 2. *Atom Generation Module Screenshot.*



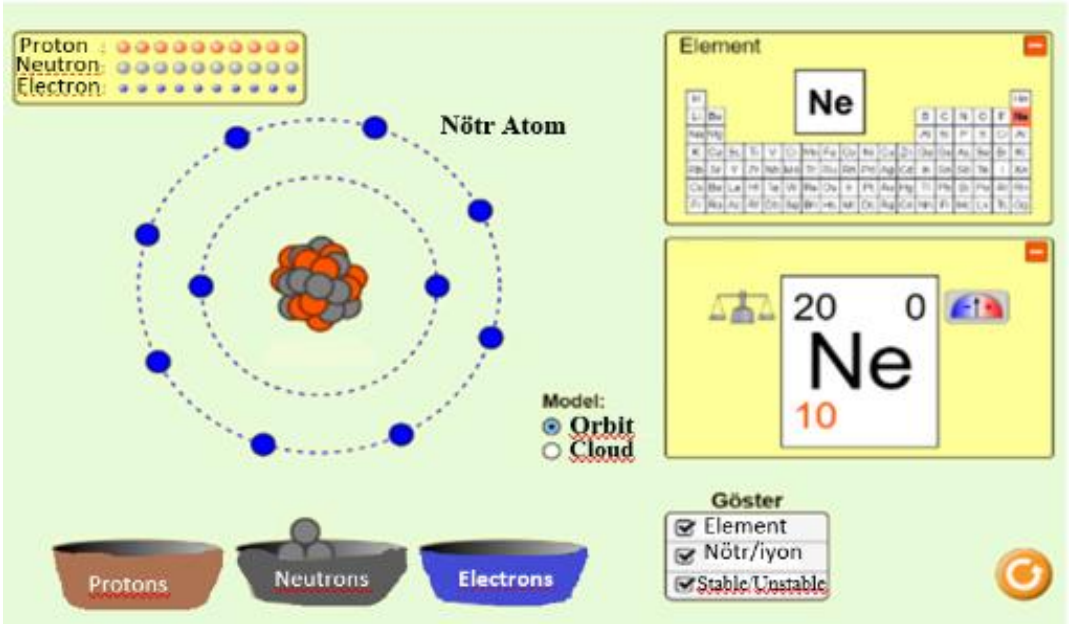
Moreover, the number of protons and neutrons placed in the nucleus determines whether the atom is stable or unstable. These properties can also be observed in motion in the cloud structure. The screenshot illustrating this phenomenon is also shown in Figure 3.

Figure 3: *A Cloud Screenshot of the Stable and Unstable Structure of the Atom.*



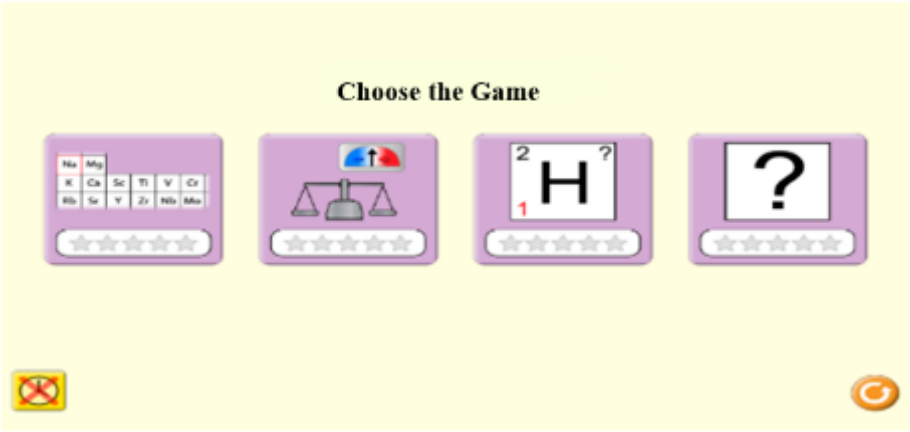
The symbol module allows the user to observe how the symbol of the element, along with the mass number, ion charge and proton number, are displayed in accordance with the numerical status of the particles situated within the core and layers. The screenshot of the symbol module is presented in Figure 4.

Figure 4: *A screenshot of the symbol module.*



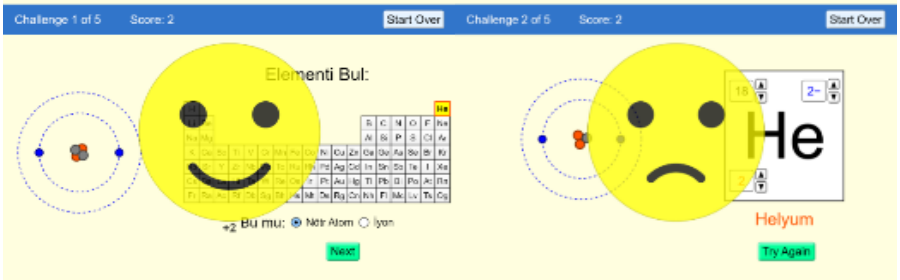
The responses to the queries may be set to a timed or indefinite duration. The user may receive auditory and visual feedback on the correct answers they have provided. The screenshot of this module is presented in Figure 5.

Figure 5. *Screenshot of the virtual laboratory question-and-answer module.*



Furthermore, upon completion of the responses, the outcome can be ascertained. Each question and answer section encompasses a multitude of elements, including the identification of its position in the periodic table based on the specified atomic structure, the generation of symbols, the calculation of ion charge and mass number. Additionally, screenshots illustrating the results of random, correct and incorrect answers in this module are presented in Figure 6.

Figure 6. *Screenshots of Virtual Laboratory Questions and Answers.*



2.5. Data Collection Tool

In this study, the Achievement Test was employed to ascertain the learning levels of students with regard to the subject of Particulate Structure of Matter. The achievement test, which assesses students' knowledge of the subject matter "Particulate Structure of Matter," was developed as part of the research project. The results presented in Table 3 were taken into account during the construction of the test. In the initial stages of the test's development, the researchers constructed an item pool comprising 30 questions. The preparation and development of the questions were conducted by three science teachers and an associate professor of chemistry. The suitability of these questions for the subject of "Particulate Structure of Matter" at the secondary school level was evaluated. In the development of the achievement test, similar processes were employed, with an examination of the literature to gather evidence for reliability and validity (İlhan & Hoşgören, 2017). Following the administration of the test, various corrections were made to the questions. These were based on the opinions of experts on a number of issues, including the suitability of the questions for the stated objectives, their shape and appearance, the clarity of the question wording, and the formats of the questions. The aim was to ensure that the test had the desired scope and face validity.

The following section presents a selection of questions from the examination in order to illustrate the format and content of the assessment.

Question 2: Which of the following statements about the atom is inaccurate?
A) Protons and neutrons are located within the nucleus of the atom.
B) Electrons exhibit rapid movement around the nucleus.
C) The particle that defines the identity of the atom is the electron.
D) Neutrons are uncharged particles.
Question 4: Which of the following are the fundamental particles that constitute the atom?
A) Neutron, Proton, Cation
B) Proton, Neutron, Nucleus
C) Nucleus, Electron
D) Proton, Neutron, Electron
Question 6: Which particle is found in the nucleus of the atom?
A) Electron
B) Proton
C) Cation
D) Nucleus

The 30-question test, which provided content and face validity in line with expert opinions, was administered to 157 eighth-grade students who had previously studied the particulate structure of matter in two state middle schools. The responses to the 30-item test were scored as follows: correct answers were awarded a score of 1, while incorrect or omitted responses were assigned a score of 0. Based on the total scores obtained from the test, the 42 students with the highest scores were identified as the upper group, and the 42 students with the lowest scores were designated as the lower group. In order to select the most appropriate items for the test, item analyses, item difficulty index, item discrimination index, item correlation analyses and Kuder-Richardson–20 (KR-20) reliability coefficient were calculated, taking the aforementioned scores into consideration. The item difficulty index provides a measure of the proportion of students who answer the questions in the test correctly (expressed as a value between "0" and "1"). If this value is close to one, it can be interpreted as indicating that the question is relatively straightforward; conversely, if it is close to zero, it can be interpreted as indicating that the question is more challenging. The item discrimination index examines an item in terms of its capacity to distinguish between students in the lowest and highest 27% percentiles in terms of their total score.For each item on the test, item difficulty indexes and item discrimination indexes were calculated according to the subgroup-upper group method (Table 4). Based on these analyses, it was determined that items 8, 15, and 23 should be removed from the test.

Table 4. *Item Difficulty and Discrimination Indexes*

Question Number	Item Difficulty Index	Item Discrimination Index	Question Number	Item Difficulty Index	Item Discrimination Index
1	0.65	0.45	16	0.54	0.31
2	0.70	0.21	17	0.68	0.21
3	0.61	0.50	18	0.56	0.64
4	0.57	0.57	19	0.37	0.45
5	0.58	0.64	20	0.54	0.50
6	0.64	0.52	21	0.64	0.67
7	0.83	0.33	22	0.54	0.69
8*	**0.73***	**0.12***	23*	**0.51***	**-0.55***
9	0.56	0.31	24	0.50	0.67
10	0.63	0.45	25	0.37	0.45
11	0.58	0.74	26	0.54	0.50
12	0.75	0.50	27	0.67	0.62
13	0.71	0.33	28	0.54	0.69
14	0.68	0.36	29	0.58	0.55
15*	**0.87***	**0.17***	30	0.50	0.67
			Avg. Index	**0.61**	**0.44**

Following the removal of these questions, the average difficulty index of the test was recalculated as 0.54, while the average item discrimination index was recalculated as 0.45. This provided the determined confidence interval. In order to ensure the selection of suitable items for the achievement test, an item-total correlation analysis was conducted. Correlation analysis is employed to ascertain the relationship between the total score obtained from each question and the total score obtained from the test, thereby elucidating the relationship. It is emphasised in the literature that items with a question-total correlation value exceeding 0.30 should be included in the test (İlhan & Hoşgören, 2017; Ferketich, 1991).

A correlation analysis was conducted to ascertain the relationship between the question scores and the total scores. This analysis led to the conclusion that questions 2, 16, and 17 should be removed from the test (Table 5).

Table 5. *Item-Total Correlations of the Items in the Test*

Question Number	Item-Total Correlation Value	Question Number	Item-Total Correlation Value
1	0.378	17*	**0.188***
2*	**0.201***	18	0.496
3	0.432	19	0.472
4	0.439	20	0.426
5	0.464	21	0.557
6	0.405	22	0.543
7	0.339	24	0.598
9	0.308	25	0.472
10	0.339	26	0.426
11	0.549	27	0.537
12	0.462	28	0.543
13	0.318	29	0.362
14	0.338	30	0.598
16*	**0.282***		

Following the completion of the item analyses, six questions that did not meet the requisite values as a result of the analyses were removed from the 30-question test, leaving a 24-question test that was deemed suitable for further analysis. The KR-20 reliability coefficient of this 24-question test was calculated as 0.83, indicating that the test is highly reliable.

2.5. Analysis of Data

In the study, the achievement test on the subject of "Particulate Structure of Matter" was administered to both the experimental and control groups as both a pretest and a posttest. The data obtained from the achievement test were analysed using the SPSS (Statistical Package for the Social Sciences) program. Each question was evaluated as 1 point for the correct answer and 0 points for the wrong answer, and used in the scoring in this way. The data were then examined descriptively. The study employed the independent sample t-test to ascertain whether there were significant differences between the means of the groups. In order to conduct an independent group t-test, it is essential that the selected groups are independent of one another and that the data follows a normal distribution (Büyüköztürk, 2010; Can, 2019). The normality of the data distribution was evaluated by examining the descriptive statistical values, kurtosis, and skewness. The observed values of kurtosis and skewness fell within the range of +1 to -1, indicating that the data did not deviate significantly from the normal distribution. The findings section presents the results of this analysis.

3. RESULTS / FINDINGS

3.1. Pre-Test Values of Experimental and Control Groups

The data collected as a pre-test and post-test with the "Particulate Structure of Matter" achievement test were subjected to analysis. Table 6 presents the distribution of students in the study according to the experimental and control groups prior to the implementation of the intervention, along with the average score values of the groups. It can be observed that the average pre-test score of the 98 students in the control group was 11.8776, while the average pre-test score of the 93 students in the experimental group was 11.8387.
Table 6 presents the descriptive statistical analysis values (median, variance, minimum, maximum scores, kurtosis and skewness values, etc.) of the pre-test scores of the experimental and control group students. An examination of the kurtosis and skewness values indicates that the data also meet the normality assumption.

Table 6. *Descriptive Values of Pre-Test Scores of Experimental and Control Groups*

Descriptive values	Control Group	Experimental Group
Number of Students	98	93
Minimum Score	2	2
Maximum Score	24	24
Average Score	11.88	11.84
Standard Deviation	5.591	5.029
Skewness	.499	.271
Kurtosis	-.854	-.651

In order to ascertain whether there was a statistically significant difference between the group means in terms of the achievement test, an independent groups t-test was conducted. The results of this analysis, which compared the mean scores obtained from the students according to group type, are presented in Table 7. A comparison of the pretest results reveals no statistically significant difference between the experimental and control groups in terms of their achievement test scores ($t(189) = .050$; $p > .05$). Consequently, the achievement status of the students in the experimental and control groups on the subject of "Particulate Structure of Matter" is found to be similar.

Table 7. *Pre-Test Scores of Groups Independent Groups T-Test Analysis*

Group	N	M	Sd	Df	t	p
Control	98	11.88	5.591	189	0.050	.960
Experimental	93	11.84	5.029			

N: Number of Students, M: Average Score, Standard Deviation (sd), Df: Degree of Freedom, p: Significance level

3.1. Post-Test Values of the Experimental and Control Group

In the study, the "Particulate Structure of Matter" achievement test was administered to the experimental and control groups as a posttest following the virtual laboratory applications. The data were analysed using both

descriptive and independent groups t-tests. Table 8 presents the distribution of students in the study according to experimental and control groups, as well as the average score values of these groups. It can be observed that the average posttest score of students in the control group on the subject of "Particulate Structure of Matter" is 13.84, while the average posttest score of students in the experimental group is 16.54.

Table 8 presents the descriptive values (median, variance, minimum, maximum scores, kurtosis and skewness values, etc.) of the scores obtained by the experimental and control group students from the final application of the tests on the subject of "Particulate Structure of Matter". Upon examination of the kurtosis and skewness values, it can be concluded that the data meet the normality assumption.

Table 8. *Post-Test Scores of Groups Independent Groups T-Test Analysis*

Descriptive values	Control Group	Experimental Group
Number of Students	98	93
Minimum Score	2	10
Maximum Score	24	24
Average Score	13.84	16.54
Standard Deviation	4.886	3.105
Skewness	.404	.206
Kurtosis	-.557	-.679

When the independent groups t-test analysis results (Table 9) are examined, a significant difference was found between the achievement test average of the students in the experimental group where the virtual laboratory was used and the achievement test average of the students in the control group in favor of the experimental group, $t(189)=4.583$; $p<0.05$. Therefore, when the pre-test data are considered, it can be said that the virtual laboratory applications have an effect on increasing the students' success.

In order to ascertain whether the discrepancy between the scores attained in the post-tests on the subject of "Particulate Structure of Matter" is statistically significant, the results of the independent groups t-test analysis are presented in Table 9.

Table 9. *Independent Groups T-Test Analysis Results Applied to Post-Test Results According to Group Type*

Group	N	M	SS	Df	t	p
Control	98	13.84	4.886	189	-4.532	.00
Experimental	93	16.54	3.105			

P<.05

4. DISCUSSION and CONCLUSION

The present study examined the impact of virtual laboratory applications on the teaching of particulate structure of matter in 7th grade in middle school, with a particular focus on student success. The present study revealed that there was no statistically significant difference between the pre-tests administered to the experimental and control groups in the selected schools prior to the implementation of virtual laboratory applications. However, following the implementation of the applications, a significant difference emerged in favour of the experimental group with regard to the success status of the students in the experimental and control groups on the subject of "Particulate Structure of Matter". A comparison of the pre-test and post-test results indicates that virtual laboratory applications had a positive impact on students' success in the subject of "Particulate Structure of Matter" in 7th grade. In the present study, activities from the PhET platform (http://www.phet.colorado.edu) were employed as virtual laboratory applications. It can be posited that the PhET activities played a pivotal role in enhancing students' success. The study yielded significant findings pertaining to the identification of methodologies that facilitate students' success in the subject of "Particulate Structure of Matter".

A review of the literature reveals numerous studies conducted in Türkiye that demonstrate the efficacy of virtual laboratory applications in enhancing academic performance in various subjects, including physics, chemistry, and biology, within the context of science education. These studies have consistently shown that virtual laboratory applications lead to higher levels of academic success compared to traditional methods (Çinici et al., 2013; Duman & Avcı, 2016; Özdener, 2005; Yılmaz & Eren, 2014). Conversely, international studies yield comparable findings regarding the impact of virtual laboratories on academic performance (Banda & Nzabahimana, 2022; Ganasen & Shamuganathan, 2017; Smetana & Bell, 2012).
In some studies on the impact of virtual laboratory applications on students' academic performance in science education, similar outcomes have been observed in comparison groups (Aydın, 2018). Rutten et al. (2012) investigated the potential for enhancing traditional science education through the integration of computer simulations. Their findings underscored the significance of student engagement, the manner in which information obtained through simulations is presented and processed, and the role of well-designed simulation-based education in achieving optimal outcomes.

Suggestion

In the implementation of virtual laboratory applications, it can be realised as either animation or simulation in the field of writing. The current study demonstrates that PhED applications are designed more as simulations. In different studies, artificial intelligence tools can be developed and applications can be made for virtual laboratory applications. A comparative analysis of the implementation and impact of virtual laboratory applications can be conducted by examining the differences between interactive and non-interactive applications. In this study, the focus is on the "Particulate Matter Subject." By extending this analysis to other subjects, we can contribute to the advancement of this field.

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Declaration of Conflicting Interests and Ethics

The authors declare no conflict of interest. This research study complies with research publishing ethics. The scientific and legal responsibility for manuscripts published in IJEDAI belongs to the author(s).

Authorship Contribution Statement

Author Esra Özeler: Investigation, Resources, Software, Analysis, Author Yaşar GENEL: : Supervision , Methodology, Software, Analysis, Author Salih GENEL: Analysis, Wrote the article and Validation.

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Reflections of artificial intelligence on science education in Türkiye

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Abstract

Aim: The aim of this study is to analyse the studies of theses and research articles published in Türkiye related to the use of artificial intelligence in science education between 2010-2023 through the databases of "Google Scholar", DergiPark and "National Thesis Center of the Council of Higher Education" by descriptive content analysis method and to examine them in terms of various variables.

Method: A total of 35 publications, of which 17 were theses and 18 were articles, were considered appropriate for the study in question for descriptive content analysis. In this study, the publications retrieved from the relevant databases were examined in terms of their distribution according to keywords, types of research, sampling methods and sizes, data analysis methods, diversity of study groups, publication years, research methods and designs, and data collection instruments within the framework of the specified research questions.

Results: The results of the study indicated that 145 keywords were identified. The analysis revealed that the majority of the studies on artificial intelligence were research articles. However, it was observed that content analysis was the predominant data analysis method employed.

Suggestions: It is suggested that, in addition to the study of 'artificial intelligence' and its application areas, which are the focus of increasing academic research, further studies should be conducted on science education subjects.

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1. INTRODUCTION

Technological development has been rapid in recent centuries, with new inventions and innovations being made at an increasingly frequent rate. Examples of such developments include the printing press, the computer, the internet, and artificial intelligence. These developments have become increasingly prominent in the present century and have begun to be utilised in a variety of fields. From industry to the military, from health to agriculture, education has of course had its share of these developments in many areas that we can think of and continues to do so. In education, which has had its share in the development of technology, the most basic of the new concepts we encounter is undoubtedly the concept of 'educational technology'. Şimşek et al. (2008), while defining this concept, stated that it has moved away from the definition of 'tools and equipment used in education' over time and has become a discipline in itself, developing in the process and covering many subjects. Educational technology is constantly renewing and expanding its scope with the rapid development of technology. Thus, the technological studies used in the field of education are increasing day by day (Zengin et al., 2024).

The increase in industrialisation with the Industrial Revolution and the parallel development of technological studies have increased human adaptation to this development process. As a result of the innovations and changes that started with Industry 1.0 and gradually reached the present with Industry 2.0, 3.0 and finally 4.0, artificial intelligence and cloud storage technologies have started to be used in Industry 4.0. All these can be considered as steps towards the transition from the information society to the super smart society (Saracel & Aksoy, 2020). Artificial Intelligence, which has become popular in the world and in our country in recent years, has increasingly important applications in everyday life and is one of the important fields of study for many disciplines. As AI has started to take place in our education system today, students at various levels of education are taking courses on learning AI.

1.2. Artificial Intelligence Techniques and Application Areas

In 1950, artificial intelligence appeared on the agenda with Alan Turing's machine called 'Information Processing Machines and Intelligence' and was first used as a name at the Dartmount Meeting in 1956. However, it is known that the history of artificial intelligence goes back to a more distant past (Pirim, 2006). The works of the Muslim scholar Al-Khwarizmi (780-850) in the field of algorithms and mathematics form the basis of AI modelling, especially in the field of finance (Yurdagel & Karaca, 2023; p.17). On the other hand, it can be said that the works of another Muslim scholar Al-Jazari (1153-1233) in the field of engineering related to artificial intelligence also played an important role in forming the foundations of artificial intelligence (Yaşın, 2006).

The first machines that formed the basis of artificial intelligence were created in the 17th century by Wilhelm Schickard (1623), Blaise Pascal (1642) and G. W. Leibniz (1671). What these machines have in common is that they were the first mechanical and digital calculating machines of their time. Thus, it can be said that the study of artificial intelligence began with the first mechanical and digital machines (Erümit et al., 2020). In the 18th century, with the beginning of the industrial revolution, automatic machines were invented, and many other inventions paved the way for artificial intelligence (Kapır, 2022). In the 19th century, a step forward was taken, and the first programmable machines were designed (Erümit et al., 2020). The most important developments in the field of artificial intelligence took place in the 20th century. First, in 1943, Warren McCulloch and Walter Pitts introduced the first artificial neural network model based on the computation and analysis of the human brain (Keskenler & Keskenler, 2017). Then, in 1948, Shannon suggested that computers could prove complex mathematical theorems and play chess. In 1950, the British mathematician Alan Turing proposed the idea of the 'Turing test' in his article, in which he attempted to answer the question "Can machines think?" (Arslan, 2020). In response to this test, John SEARLE of the University of California proposed the 'Chinese room experiment' (Pirim, 2006).

Following the advent of artificial intelligence, a plethora of definitions have been proposed (Nabiyev, 2021). The inaugural explanations and definitions of artificial intelligence were provided by McCarthy in 1956. McCarthy's seminal work defined artificial intelligence as the science and engineering of constructing human-like intelligent machines and computer programs (Arslan, 2020). However, many areas of application have developed thanks to the development of artificial intelligence. Important areas include the defence industry,

education, medicine, law and engineering (Karaduman, 2019; Nabiyev & Erümit, 2022).Along with these areas, many sub-branches for artificial intelligence have started to emerge. Some examples of these are artificial neural networks, deep learning, machine learning, fuzzy logic, educational data mining, genetic algorithms and expert systems (Elmas, 2021; İnal, 2021).

With the development of artificial intelligence, many techniques related to artificial intelligence have emerged and application areas have developed (Bozüyük et al., 2005). In many studies in the literature, application areas related to artificial intelligence are classified as data mining, machine learning, natural language processing, speech, expert systems, planning, scheduling and optimisation, robotics and vision (Adalı, 2012; Atlam et al., 2018; Akgöbek & Çakır, 2009; Atalay & Çelik, 2017; Doğan & Türkoğlu, 2018). On the other hand, in the study of Deperlioğlu and Köse (2023), the application areas of artificial intelligence are described under three main headings as cognitive science, robotics and natural interface applications. The 'Artificial Intelligence Applications Course Program for secondary school students was published by MoNE (2023a). The programme incorporates a range of concepts related to artificial intelligence, including 'machine learning and pattern recognition', 'artificial neural networks', 'fuzzy logic', 'developing sample projects in a block-based environment', 'data mining' and 'image processing'.

1.2. Artificial Intelligence Applications, Courses and Science Education

A significant corpus of research in the domain of artificial intelligence, a major innovation in technology, has demonstrated the impact of artificial intelligence on education (Akdeniz & Özdinç, 2021; Bahroun, 2023; Feng & Law, 2021; Ferreira de Menezes et al., 2023; Guan & Jiang, 2020). The importance of artificial intelligence in enhancing the quality of education is well-documented (Nabiyev & Erümit, 2022), and the integration of smart technologies in education has been shown to be beneficial (Ferreira de Menezes et al., 2023). The utilisation of artificial intelligence technologies in education has been demonstrated to facilitate learning and enhance learning environments (Alan & Zengin, 2023).

A considerable number of applications based on artificial intelligence have been developed for use in learning and education. Examples of artificial intelligence systems in education include personalised education systems, curricula, assessment tools based on artificial intelligence and exam management systems (Arslan, 2020). In the study conducted by Gürlek et al. (2023), the effects of artificial intelligence on education were explained under the following titles: personalising education according to the needs of students, automating students' basic educational activities, ensuring students' development, changing the structure of education and the roles of teachers, providing feedback to students and completing students' deficiencies. On the other hand, the integration of smart education technologies into education is important for the use of artificial intelligence technologies in education. Machine learning, data mining and learning analytics are technologies closely related to education (Chen et al., 2020).

It is evident that a multitude of applications can be developed utilising Python as a programming language in the context of artificial intelligence in education. The majority of artificial intelligence software and applications encountered in education are found and used in online environments. Examples of such applications include Gradescope, which facilitates the distribution of homework to students, Hubert, which conducts written interviews with students and provides feedback, SuperSaas, which plans activities for students, and various Google applications (Akgündüz, 2019). In addition, 'Evernote', which translates sound into writing, 'Turnitin', another online application that compares similarities in different documents and reveals similarity rates, and similar applications, are artificial intelligence applications (Nabiyev & Erümit, 2022). Within the national context, the 'EBA Assistant' (2020) is an artificial intelligence-based application offered to students by the Ministry of National Education, designed to respond to queries posed by users of the EBA platform.

In addition to the aforementioned points, the National Artificial Intelligence Strategy (2021-2025) was developed by the Ministry of Industry and Technology and the Presidency of the Presidency Digital Transformation Office. Activities related to artificial intelligence are planned to be realised (UYZS, 2021). The Ministry of National Education (MoNE) has been conducting studies on artificial intelligence education in recent years. As part of this programme, a curriculum and course content has been developed for the instruction of artificial intelligence. In 2023, the Ministry of National Education established an 'Artificial

Intelligence Applications Course Program' for 7th and 8th grades of Secondary School and Imam Hatip Secondary School. The subjects and concepts covered by this curriculum are as follows: 'The concept of artificial intelligence, historical development of artificial intelligence, usage areas of artificial intelligence, sub-dimensions of artificial intelligence, basic concepts of ethics in artificial intelligence applications, ethics in artificial intelligence, privacy and security, the importance of artificial intelligence, the future of artificial intelligence block-based development environments, image processing projects in block-based environments, machine learning, pattern recognition, artificial neural networks, fuzzy logic, writing-to-sound projects, sound-to-writing projects, language perception projects, language translation projects, image and sound processing and security projects. The Artificial Intelligence Applications Course Curriculum also aims to develop scientific process skills, life skills and engineering skills in students (MoNE, 2023a).

The 'Artificial Intelligence Applications Atelier Programme', as proposed by MoNE (2023b) in Türkiye, is a pioneering initiative designed to be implemented in Science and Art Centres (BİLSEM), catering to gifted students. The programme encompasses a range of subjects, including 'fundamentals of artificial intelligence, machine learning, artificial neural networks, natural language processing, fuzzy logic, artificial intelligence and ethics, artificial intelligence and ethics, project development and problem solving'. Within the context of Türkiye, an additional course on artificial intelligence is the artificial intelligence atelier, which was established by BILSEM as part of the BILSEM summer school programme. This initiative is designed to provide benefits to all students, irrespective of their enrolment status with BILSEM, who are engaged in formal education (MoNE, 2023c).

Science education is a pervasive element of the education system, spanning from preschool to higher education levels (Ouyang et al., 2022; Zhai et al., 2021). A considerable proportion of students encounter challenges in science lessons, harbour prejudices against the subject, and exhibit a diminished level of interest in the course. In such cases, the development of various applications is expected to reverse the prejudices and negative feelings that students develop against science lessons (Alan & Zengin, 2023). Çam et al. (2021) posit in their study that the utilisation of virtualised, artificial intelligence-supported applications for experimentation in science lessons will engender convenience in said lessons. It can be posited that the employment of artificial intelligence technologies in science education engenders positive results. Conversely, it has been posited that the integration of various computer and internet networks under the rubric of 'Digital competence' within the 2018 'Science programme for secondary school' is imperative, with this competence being supported by fundamental skills (MoNE, 2018).

Examples of artificial intelligence applications that have the potential to be utilised within the context of science education include the video-sharing platform YouTube, which offers a variety of educational videos and lectures; the DeepDreamGenerator, which generates alternative versions of existing images; and Experiments with Google, an artificial intelligence library. It also contains artificial intelligence applications, such as 'Quick Draw', which is a drawing development tool, 'PoseNet', which teaches and detects motion, and 'Teachable Machine', which teaches artificial neural networks to students (Akgündüz, 2019).

1.3. Rationale

After reviewing the relevant literature, we found five studies on content analysis, as well as various studies on artificial intelligence in education in our country (Akdeniz & Özdinç, 2021; Güzey et al., 2023; Meço & Coştu, 2022; Tekin, 2023). Kavut (2022) is in the general category and is a study that also deals with education.In addition, it was determined that the content analysis studies conducted in Türkiye on artificial intelligence and education were conducted using the term 'artificial intelligence in education' (Güzey et al., 2023; Meço & Coştü, 2022). However, since artificial intelligence includes many techniques, there are studies related to artificial intelligence using different keywords, and this must be considered in the content analysis to be conducted. In this study, in light of this situation, the current study was conducted in the field of science education. In terms of the theoretical framework, this study is important in terms of revealing the reflections of the developments in the field of artificial intelligence in Türkiye on science education.

1.4. Purpose of the Study and Research Questions

The aim of this study is to analyse descriptively and content-wise the theses and research articles published in

Turkey related to artificial intelligence in terms of science education and to examine them in terms of various variables.

Research questions for the current study:
1. How is the distribution of the keywords used in the studies on AI in science education?
2. How is the distribution of the studies on AI in science education in terms of articles and theses?
3. How is the distribution of the studies on AI in science education in terms of research/publication years?
4. How is the distribution of the studies on AI in science education in terms of sampling method and size?
5. How is the distribution of studies on AI in science education in terms of study group diversity?
6. How is the distribution of the studies on AI in science education according to the journals and universities in which they were published?
7. How is the distribution of studies on AI in science education in terms of research method and design?
8. How is the distribution of studies on AI in science education in terms of data collection tools?
9. How is the distribution of studies on AI in science education in terms of data analysis methods?
10. What is the distribution of AI methods, techniques and applications used in artificial intelligence studies in science education?

2. METHODOLOGY

2.1. Research Model

The present study set out to analyse the descriptive content of theses and research articles published in Turkey on the subject of artificial intelligence in terms of science education, examining them in terms of various variables. To this end, the study was conducted using the descriptive content analysis method, a qualitative research method. In descriptive content analysis studies, researchers first determine the topic, then scan the literature within the scope of the topic they have determined and thus obtain a study pool. Subsequently, they conducted a more detailed examination of the studies using keywords in relevant databases (Ültay et al., 2021). Çalık and Sözbilir (2014) categorised the content analysis method into three distinct categories: meta-synthesis, meta-analysis and descriptive content analysis. In this study, the descriptive content analysis method was selected, and the articles and theses on science education and artificial intelligence in Türkiye were identified. The data were classified, grouped systematically, transformed into tables and graphs, their trends were examined, and they were clearly described and interpreted.

2.2. Data Collection Process

In this research, the following keywords were examined: 'artificial intelligence', 'artificial intelligence techniques and applications', 'machine learning', 'natural language processing', 'speech', 'robotics', 'pattern recognition', 'artificial neural networks'. In addition to these, the keywords 'science education', 'science education', 'science education', 'physics', 'chemistry', 'biology ", 'fuzzy logic', 'data mining', 'educational interface', 'image processing', 'expert systems', 'Google Scholar', DergiPark and 'National Thesis Centre of the Presidency of the Council of Higher Education' databases were used to identify relevant studies. The search was limited to studies conducted in Turkey between 2010 and 2023. The most recent date of publication was 01.01.2024. During the review process, it was ensured that the keywords employed in the scanning study were present in the titles or abstracts of the studies. In determining the keywords, the keywords in the studies in the literature and the titles in the Artificial Intelligence Applications Course Curriculum (I-II) (MoNE, 2023a) proposed by the Ministry of National Education were found to be effective.

In the present study, a set of criteria were applied during the scanning process, and articles and theses/dissertations were identified through keyword searches in this direction. The criteria that were determined for the screening study for descriptive content analysis related to artificial intelligence in science education are as follows:

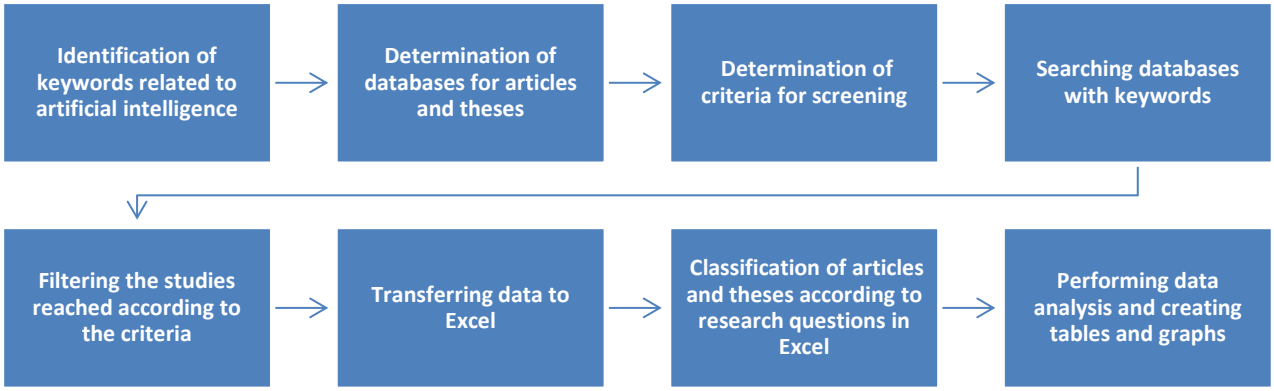
a. The studies to be examined should have been conducted between 2010 and 2023 (December).
b. The studies to be analysed should be conducted in Türkiye.
c. The studies should be published in 'Google Academic', 'DergiPark', 'YÖK National Thesis Centre' databases and should be open to access.

Fourthly, the studies to be analysed should contain the keywords related to 'science education' and 'artificial intelligence' or artificial intelligence.

A search was conducted for the keywords 'artificial intelligence' and 'science education' and 'artificial intelligence in education' in Google Scholar, yielding a total of '285' results. A further '50' results were obtained from the National Thesis Centre. The keywords 'artificial intelligence in education' and 'science education' were searched together in DergiPark, yielding a total of 2043 results. The remaining keywords, including 'artificial neural networks', 'deep learning', 'fuzzy logic', 'educational interface', 'machine learning', 'natural language processing', 'data mining', 'image processing', 'expert systems', 'robotic coding' and 'pattern recognition', were searched individually in the databases, with some limitations, and the articles and theses deemed appropriate were included in the study.

After an initial search of the databases, 77 studies were considered suitable for review. However, 42 studies were excluded because they did not meet the criteria in terms of their relationship to science education and AI. In this study, a total of 35 studies, 17 dissertations and 18 articles, were subjected to descriptive content analysis. The data collection and analysis process of the study is shown in Figure 1.

Figure 1. *Data Collection and Analysis Process of the Study*



2.2. Analysis of Data

In the present study, an analysis of the extant literature on science education and artificial intelligence was conducted through the utilisation of descriptive content analysis. The collected data was systematically and descriptively visualised and explained through the use of various tables and graphs. The objective of descriptive content analysis is to elucidate subsequent studies and to reveal the prevailing subject trends (Ültay et al., 2021).

In this study, the 'Article/Thesis Classification Data Entry Form' developed by the researcher was utilised to categorise the studies obtained from articles and postgraduate theses and to facilitate their entry into Excel for analysis. Within this form, the name, author, year of publication, type, journal/university where they were published, research design and method, data collection tools, sampling method, sample size, distribution of keywords used, and artificial intelligence methods and applications used were examined under 10 titles. The data obtained during the analysis process were classified by transferring them to an Excel file according to the 10 categories determined, and the data close to each other were transformed and handled under common headings in the Excel table. Then, the findings of the study were obtained with tables and graphs via Excel.
In line with this study, the studies on 'artificial intelligence', 'artificial intelligence in education' and related topics together with 'science education' between 2010-2023 were scanned using 'Google Scholar', 'DergiPark' and 'National Thesis Centre' databases and 35 studies (18 research articles and 17 postgraduate theses) were analysed. This study thus sought to analyse the general trends of research in the literature on the subject in question. Authors, publication year and title of the study for the studies analyzed are provided in Table 1 below.

Table 1. *Studies examined for Descriptive Content Analysis*

Author/s	Thesis/ Article	Year	Thesis/Article Name
Yılmaz	MT	2010	The effect of different educational interface agents that are used in educational software on the 8th grade primary school students? achievement, attitude and learning permanency for the science and technology course
Durmuş	PhD	2012	The effects of educational interface agent usage in virtual science and technology museum on the interests and successes of students
Koç Şenol	MT	2012	Science and technology laboratory applications supported by robotic: Robolab
Koç & Böyük	RA	2013	Technology based learning in science and technology education: robotic applications
Özdoğru	MT	2013	The effect of lego programme based science and technology education on the students' academic achievement, science process skills and their attitudes toward science and technology course for physical facts learning field
Ercan	MT	2016	Modelling factors affecting attitudes of 6,7 and 8th grade students towards science via artificial neural network method: Mus province sample
Akgün	PhD	2017	Modeling of Science and Technology Teaching Course Achievements of Elementary Teacher Candidates with Artificial Neural Networks
Schreglmann & Karakuş	RA	2017	The effect of educational interfaces on the critical thinking and the academic achievement
Aksu & Doğan	RA	2018	Comparison of learning methods used in data mining under different conditions
Yorgancı	MT	2018	Analysis of the relationship between attitudes towards teaching profession and academic achievement with artificial neural networks
Atasayar	MT	2019	The prediction of science success at High School Entrance Exam with artificial neural network
Benzer & Benzer	RA	2019	Determination of tendency of cyber bullying with artificial intelligence
Filiz	PhD	2019	Machine learning methods and an application on educational data: the trends in international mathematics and science study 2015 Turkey case
Irak Kürkan	MT	2019	Effects on the learning outcomes of science instruction based on socioscientific issues to the 7th grade students
Şimşek	MT	2019	Investigation of the effects of robotic coding application on science achievement and scientific process skills of 6th grade students in science course matter and heat unit
Yorgancı & Işık	RA	2019	The use of artificial neural networks in classifying the average grade of science teachers' candidates
Göktepe Yıldız & Göktepe Körpeoğlu	RA	2020	Examination of middle school students' interests in stem professions using educational data mining
Sağlam et al.	RA	2020	Investigation of emotional factors affecting PISA 2018 research with data mining methods
Sarı & Karaşahin	RA	2020	Computational thinking in science education: evaluating a teaching activity
Sanca et. al.	RA	2020	Why should fuzzy logic applications be used in science education?
Çam et al.	RA	2021	Determining teacher candidates' awareness of artificial intelligence technologies
İnal	MT	2021	Determining the perceptions of school administrators against artificial intelligence, data mining and big data concepts
Karataş & Ocak	RA	2021	Investigation of 5th grade students' achievement levels of mathematics, science and Turkish courses learning outcomes: a data mining study
Kesler	MT	2021	The effect of artificial intelligence system on the academic success of students in the unit of interaction of light with matter
Özen	MT	2021	Planning, implementing and evaluation of machine learning teaching for preservice teachers in STEM field
Uğuz et al.	RA	2021	The use of educational data mining in the evaluation of PISA 2018 scores of science
Ateş	PhD	2022	Planning internet of things (IoT) aided nano-STEM-GLASS activities and studying the implementation process
Bağır	MT	2022	Opinions of science teachers on the use of artificial intelligence in education
Çetintav et al.	RA	2022	Data mining analysis of the effect of technology use in the course on TIMMS 2019 results
Alan	PhD	2023	The analysis of e-learning settings, which are prepared on the basis of multiple intelligence domains determined by artificial intelligence in science instruction, as per different variables
Bayram & Çelik	RA	2023	A socio-science activity integrated with reasoning and entrepreneurial skills on artificial intelligence: pre-service science teachers' views
Çolak Yazıcı & Erkoç	RA	2023	Analysis of science group teachers' use of artificial intelligence in the distance education process
Güven & Sülün	RA	2023	Using of arduino assisted robotics coding activities in science teaching at the 5th grade of a secondary school
Soypak & Eskici	RA	2023	Examining research on robotic coding applications in high secondary school mathematics and science courses: a content analysis study
Yalçın Çelik & Çoban	RA	2023	Investigating the performance of AI-based chatbots in answering chemistry questions

PHD: PhD Thesis, MT: Master's Thesis, RA: Research Article

3. FINDINGS

In this study, the findings obtained from the relevant databases were examined in terms of the distribution of keywords in the publications obtained within the specified research questions, their types, sampling methods and sizes, data analysis methods, study group diversity, publication years, research methods and patterns, and data collection tools.

3.1 Distribution of Keywords Used in Studies on AI in Science Education

In the present study, the keywords employed in the obtained publications were initially examined and their frequencies were subsequently determined. The type and number of keywords vary in the examined studies. As a result of the content analysis, a total of 145 keywords were obtained in the examined publications. While organizing the keywords, one of the synonymous and near-synonymous keywords was determined and the others were converted to the determined word.

Following these coding procedures, the number of keywords examined was reduced to 82. The most frequently used word among the keywords in the study (f=10) was "science education". The keywords "artificial intelligence" (f=9) and "artificial neural network" (f=7) were the next most prevalent, followed by "data mining" (f=6), "science" (f=5), "robotics" (f=4), "academic success" (f=4) and "STEM" (f=4).

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After these codings, the number of keywords examined decreased to 82. The most frequently used word among the keywords in the study (f=10) was “science education”. It was followed by the keywords “artificial intelligence” (f=9) and “artificial neural network” (f=7), “data mining” (f=6), “science” (f=5), “robotics” (f=4), “academic success” (f=4) and “STEM” (f=4).

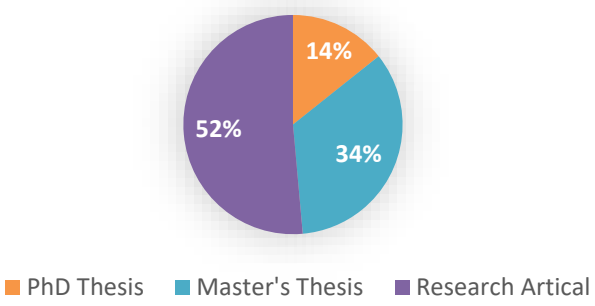
Other keywords used are; “WEKA, data analysis, three-stage model, distance education, attitude, TIMSS, technology-based learning, technology use, STEM-GLASS, interest in STEM professions, socio-scientific issues, socio-scientific reasoning, inquiry-based learning, chatbot, cyberbullying, classification algorithms, classification, classroom education, virtual museum, virtual science and technology museum, robotic coding, program development, PISA, attitude towards the teaching profession, teacher candidate, technology in education, learning method, middle school, focus group interview, internet of things (IoT), nanotechnology, nanoscience, happiness and success, motivation, mathematics and science success, mathematics education, mathematics success, machine learning, high school entrance exam, lego mindstorms NXT 2.0, laboratory, coding, chemistry education, decision trees, permanent learning, human-computer interaction, content analysis, interaction of light with matter, entrepreneurial skills, general grade point averages, awareness, e-learning, Industry 4.0, critical thinking, educational interface agent, education technology integration, artificial intelligence in education, big data in education, educational software, education, interdisciplinary science education, course outcomes, multiple intelligence theory, multi-layered perceptron model, study habits, fuzzy logic, Bloom's cognitive domain taxonomy, scientific process skills, scientific reasoning, computational thinking, fifth grade, sense of meaning, survey, 5E learning model.”

3.2. Distribution of Articles and Theses by Type

The second title of the study is the distribution of publications on artificial intelligence in science education according to research types (Figure 2). These studies are classified under three separate titles: "research article", "master's thesis" and "doctoral thesis". According to the data in Figure 3, the distribution and numbers of 35 studies published between 2010 and 2023 on science education and artificial intelligence according to research types are as follows; “research article” (f=18), “doctoral dissertation” (f=5) and “master’s theses” (f=12). These studies are mostly listed as “research article” (52%), followed by “master’s theses” (34%) and

"doctoral dissertation" (14%).

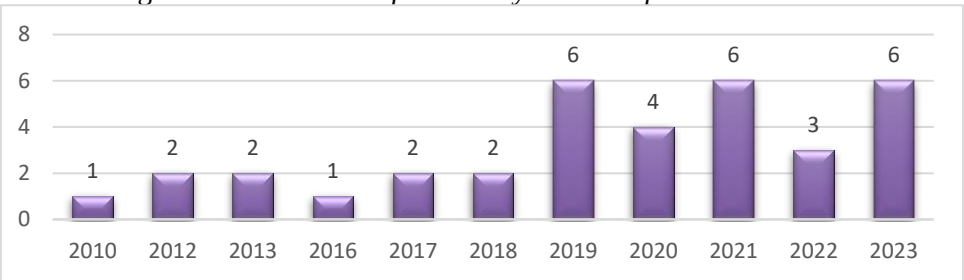
Figure 2. *Distribution of Studies in Terms of Article and Theses*



3.3. Distribution of Studies in Terms of Research/Publication Years

The figure showing the distribution of the studies on artificial intelligence in science education by year of publication and presentation is given in Figure 3.

Figure 3. *Distribution of Studies by research/publication Years*

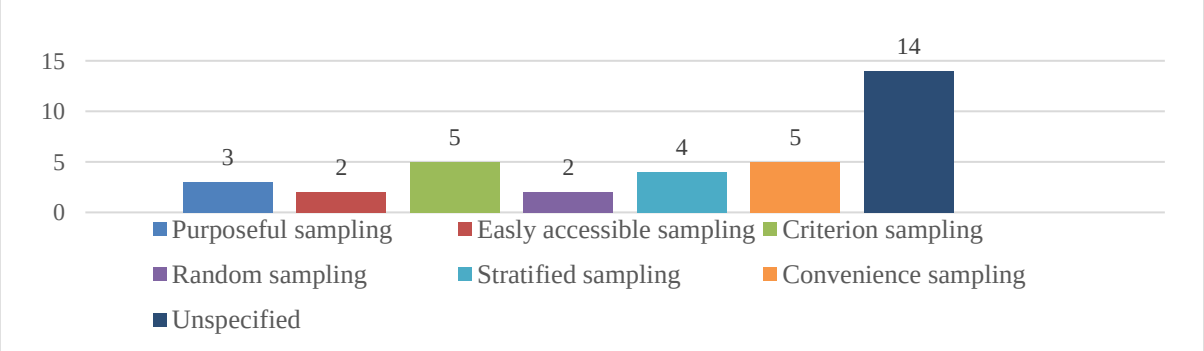


As illustrated in Figure 3, the distribution of publication years is as follows: the lowest number of studies was recorded in 2010 and 2016 (n = 1 each), followed by two studies in 2012, 2013, 201 In 2018, there was a notable increase to seven studies, followed by a decline in 2019 and 2021 to four and six studies, respectively. However, there was a resurgence in 2020 with seven studies, and a significant increase to eight studies in 2023. When the study rates of these 35 studies are examined by year, an increase is observed after 2018. Although this increase decreased in some years, it still maintained its upward trend in 2023. It is also seen that the difference is significant between 2010 and 2023, suggesting that the subject of artificial intelligence in science education is gradually becoming more prevalent.

3.4. Distribution of Studies in Terms of Sampling Method and Size

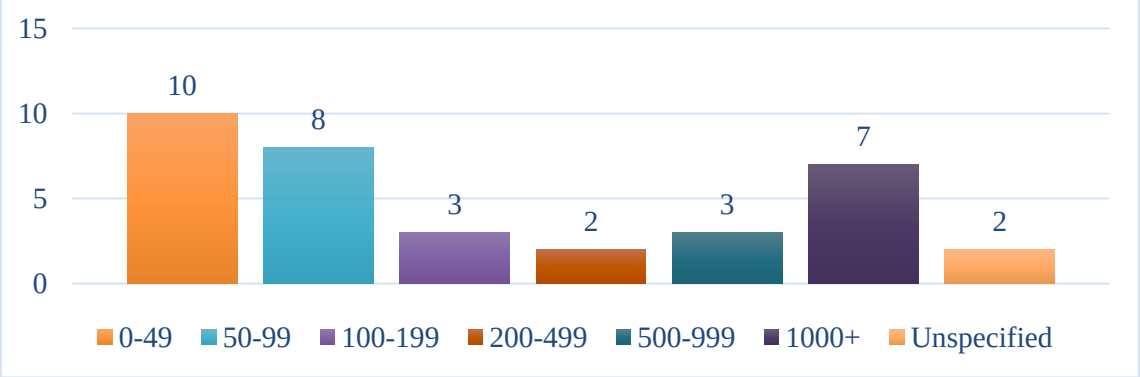
The findings regarding the sampling methods and sample sizes used in studies on Artificial Intelligence in Science Education were examined. The results of these examinations are presented in Figure 4 below.

Figure 4. *Distribution of Studies Conducted in Terms of Sampling Method*



As illustrated in Figure 4, the highest rate is observed in unspecified studies (f=14). While data on sample size and study groups is typically available in these studies, the sampling methods employed remain undetermined. When the studies are then ranked from high to low according to the number of times each sampling method was used, the most frequently used methods were "criterion sampling" (f=5), "convenience sampling" (f=5), "stratified sampling" (f=4), "purposeful sampling" (f=3), "easily accessible sampling" (f=2), and "random sampling" (f=2). This analysis indicates that "criterion sampling" emerges as the most favoured sampling method.

Figure 5. *Distribution of Studies in terms of Sample Sizes*

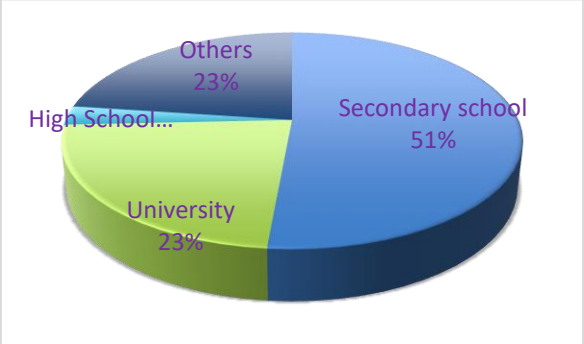


As illustrated in Figure 5, the data indicates that the majority of studies are concentrated within the "0-49" person range (f=10). When descending from the highest to the lowest, the following categories are observed: studies in the "50-99" person range (f=8), studies in the "1000+" person range (f=7), studies in the "100-199" person range (f=3), studies in the "500-999" person range (f=3), studies in the "200-499" person range (f=2). The number of samples is not specified, and the studies are limited to two. However, an analysis of these data suggests that the preferred sample size is in the range of 0-49 persons.

3.5. Distribution of Studies in Terms of Study Group

Within the scope of the study on AI in Science Education, 35 publications were examined by taking into account the teaching levels and the findings regarding the study groups are given in Figure 6.

Figure 6. *Distribution of Studies in Terms of Study Group*

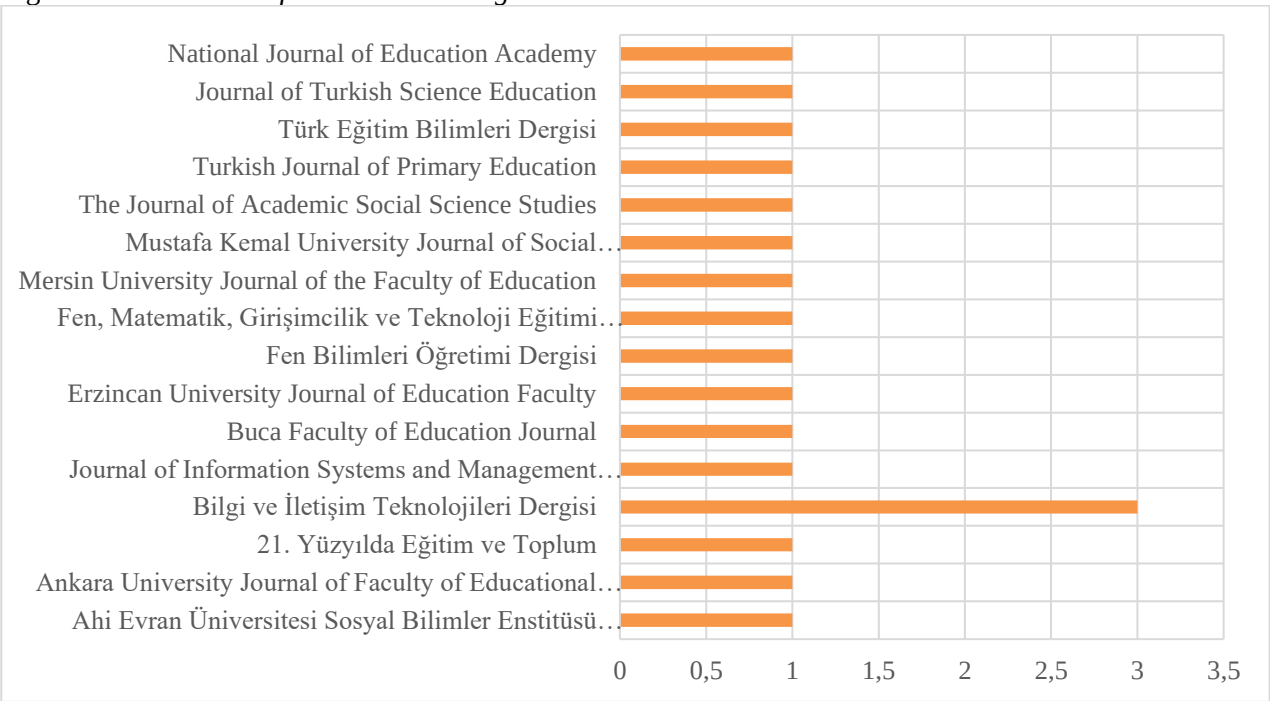


As illustrated in Figure 6, the majority of study groups are observed to be at the secondary school level (51%), with a smaller proportion at the university level (23%). The high school level is the least represented, accounting for 3% of the study groups. The remaining 23% of the study findings are distributed across various categories. The numerical equivalent of these rates is as follows: secondary school (f: 18), university (8), high school (1), and other (8). The remaining 23% (f = 8) encompasses occupational categories such as teachers and school administrators specialising in science and select other disciplines, in addition to content analysis studies. It can be posited that science education and studies of artificial intelligence are more favoured at the secondary school level.

3.6. Distribution of Studies According to Journals and Universities

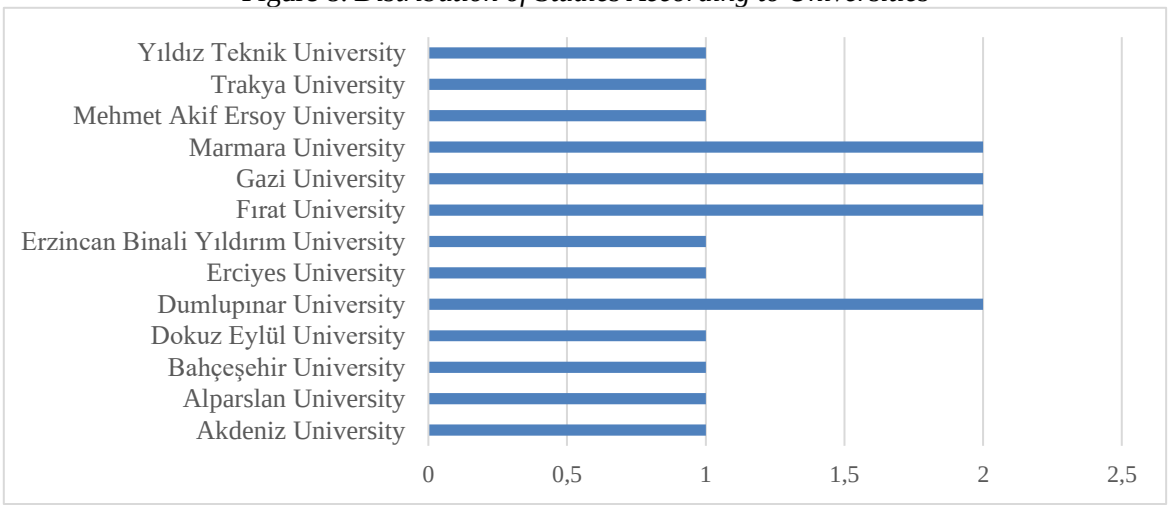
The findings regarding the journals in which studies on AI in science education were published are given in Figure 7, and the findings regarding universities are given in Figure 8.

Figure 7. *Distribution of Studies According to the Journals*



In the research conducted, a total of 35 studies were examined. Of these, 18 were research articles. The names of the journals in which these 18 studies were published, and their frequency of appearance, are given in Figure 13. According to this graph, the most studies were published in the Journal of Information and Communication Technologies (f=3). Of the remaining 15 studies, one was published in each of the journals specified in the graph.

Figure 8. *Distribution of Studies According to Universities*

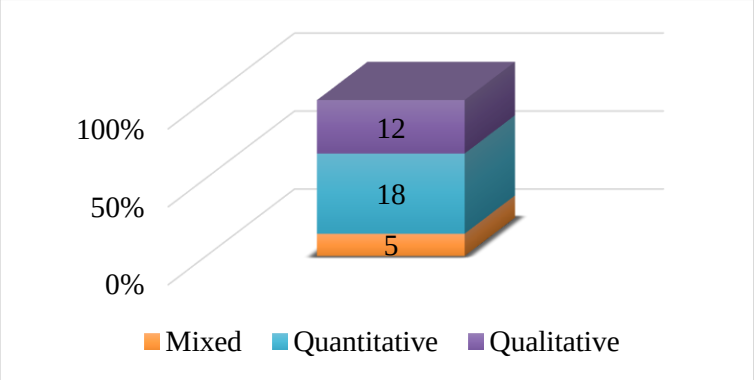


As illustrated in Figure 8, the data indicates the universities in which theses on artificial intelligence in science education were published. Of the 35 studies that were examined in the conducted research, 17 were master's (f=12) and doctoral (f=5) theses. The figure 9 shows a total of 13 different universities. The universities that have published the most studies are "Dumlupınar University", "Fırat University", "Gazi University" and "Marmara University" (each with two studies), while the remaining nine postgraduate theses are located at the aforementioned universities.

3.7. Distribution of Studies in Terms of Research Method and Design

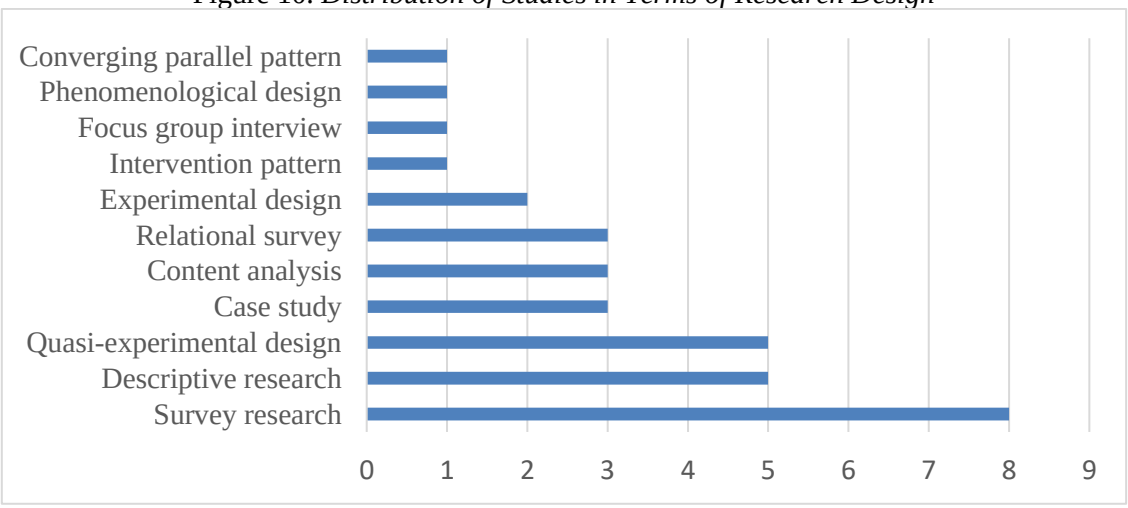
In consequence of the findings pertaining to the research methodologies employed in the analysed studies, it was ascertained that the most prevalent method was the quantitative research method. Moreover, the findings obtained from the studies demonstrated that the most favoured research design was survey research.

Figure 9. *Distribution of Studies in Terms of Research Method*



In the context of research conducted on the utilisation of artificial intelligence in the domain of science education, the graph in Figure 9 provides a comprehensive representation of the research methodologies employed in the studies. The graph reveals a total of 35 study methods, including 12 qualitative studies, namely descriptive research (f=4), case study (f=3), content analysis (f=3), focus group interview (f=1), and phenomenological design (f=1), and 18 quantitative studies, encompassing survey research (f=1), experimental design (f=2), relational survey design (f=3), regression analysis (f=1), survey research (f=6), quasi-experimental design (f=5)" and 5 mixed studies "explanatory design (f=1), triangulation design (f=1), multi-stage design (f=1), intervention design (f=1), convergent parallel design (f=1)".The studies with the highest rate among these studies are quantitative studies. This finding lends further credence to the notion that the quantitative research method is the most favoured approach in this field of enquiry.

Figure 10. *Distribution of Studies in Terms of Research Design*

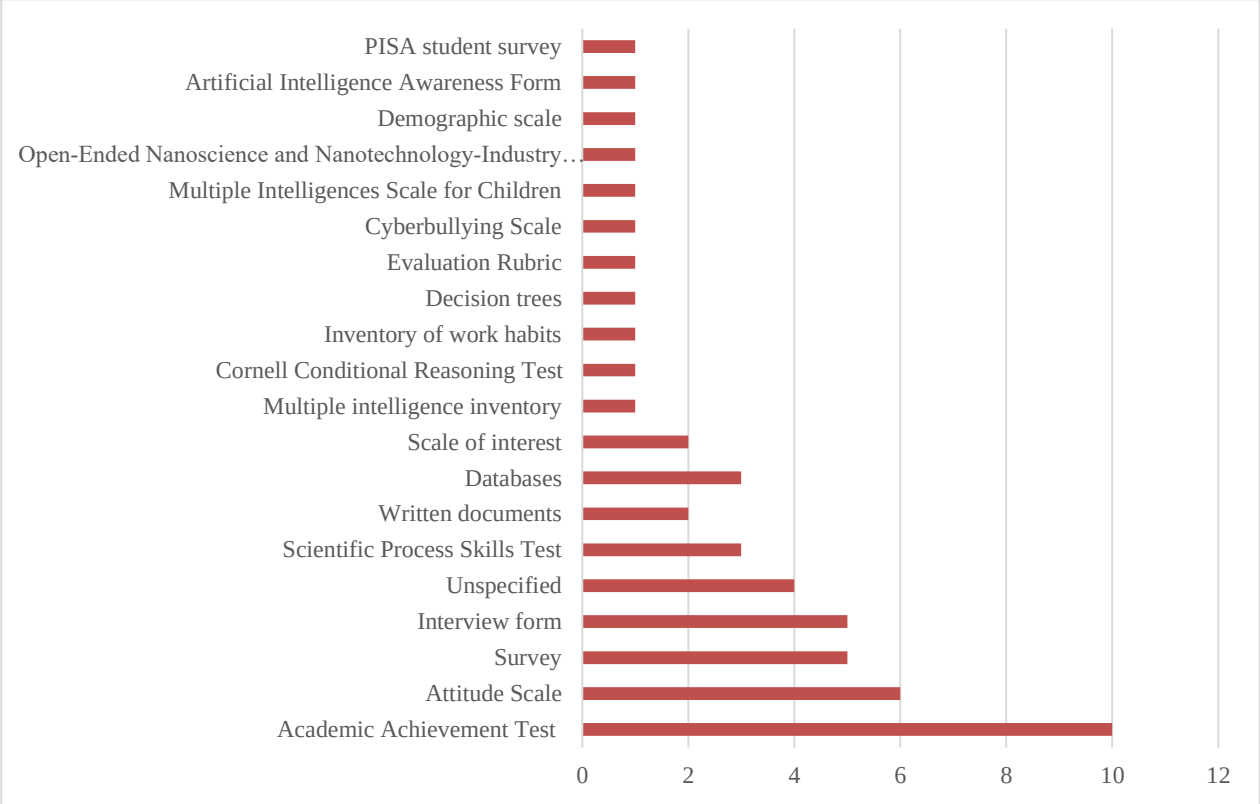


In the context of research conducted on the utilisation of artificial intelligence in the domain of science education, the graph in Figure 10 provides a comprehensive representation of the research designs and quantities employed in the studies. It is evident from the graph that the most prevalent design (f=8) is "survey research", followed by "descriptive design" and "quasi-experimental design" with five studies. The third most popular design in the initial three categories is "relational survey design", "content analysis" and "case study", with three studies each. Two studies each were conducted on "experimental design" and "descriptive research", while one study each was conducted on the remaining nine least preferred research designs.

3.8. Distribution of Studies in terms of Data Collection Tools

A thorough examination of Figure 11 reveals that the most frequently employed data collection instrument in the studies is the "academic achievement test" (f=10). Additionally, it is observed that the "attitude scale", "questionnaire", "written documents", "interview form", "databases", "scientific process skills test" and tools are among the most widely used data collection tools. The category of "not specified" (f=4) encompasses studies that do not specify a particular data collection tool, while studies employing tools from the "written documents, semi-structured interview form, interest scale" categories are also identified.

Figure 11. *Distribution of Studies in Terms of Study Group*

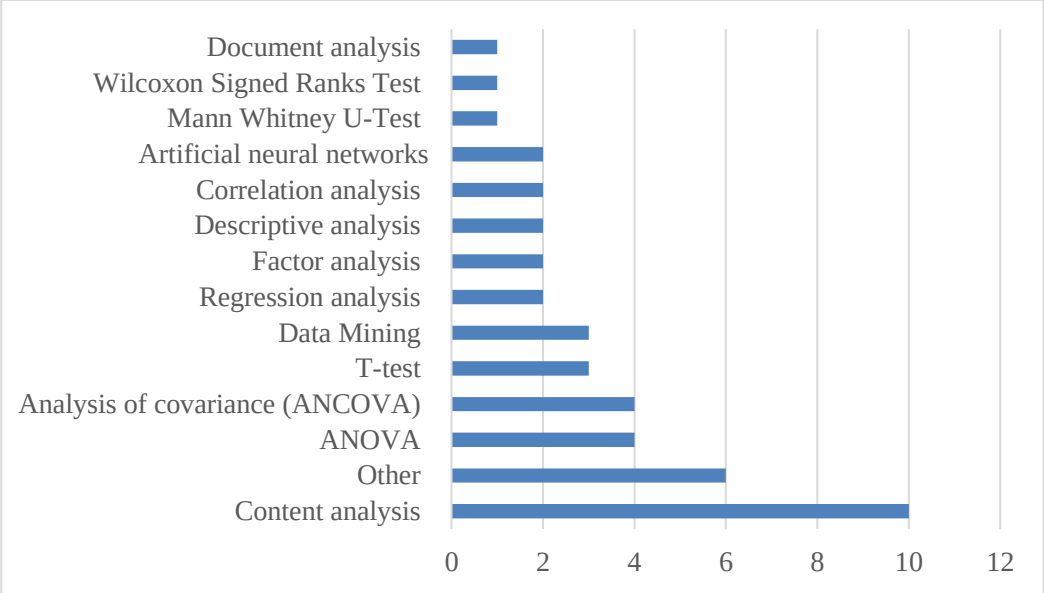


The least preferred data collection tools are said to be "decision trees, PISA student survey, artificial intelligence awareness form, multiple intelligence scale for children, demographic scale, open-ended nanoscience and nanotechnology-industry 4.0 form, Cornell conditional reasoning test, cyberbullying scale, Evaluation rubric", with one instance of each tool being used in the studies examined. Consequently, the total number of data collection tools utilised in the examined studies exceeds 50 (f=51). It is evident that the number and variety of data collection tools employed vary significantly.

3.9. Distribution of Studies in terms of Data Analysis Methods

As demonstrated in Figure 12, upon examination of the studies according to their data analysis methods, it was found that a variety of approaches were employed, with the number and variety of analysis methods used varying. The most frequently utilised data analysis method in the studies was identified as 'content analysis' (f=10), followed by 'ANOVA' (f=4) and 'ANCOVA' (f=4) methods, with four studies each. The least frequently employed data analysis techniques were identified as the 'Man Whitney U-Test', 'Wilcoxon Signed Ranks Test' and 'Document Analysis', each employed in a single study. The 'Other' category, encompassing six distinct methods, was also analysed. These results indicate that the 'content analysis' method is the most prevalent in the field of artificial intelligence in science education.

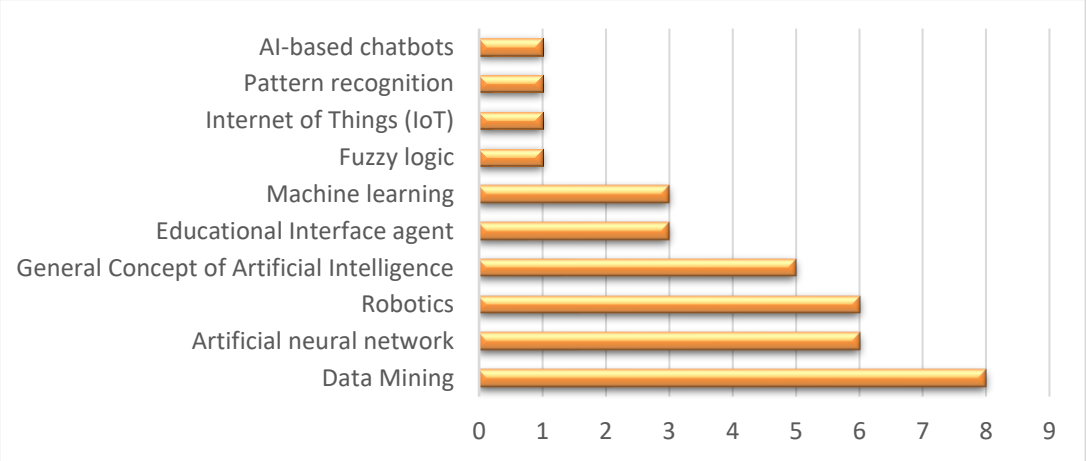
Figure 12. *Distribution of Studies in terms of Data Analysis Methods*



3.10. Distribution of Artificial Intelligence Methods, Techniques and Applications Used in Studies

Figure 13 provides a visual representation of the findings concerning the artificial intelligence methods, techniques and applications utilised in the studies and regarded as subjects. The graph illustrates the frequency with which artificial intelligence techniques and applications are preferred in the studies examined. It is evident that the most frequently employed method is "data mining" (f=8). The "artificial neural network" method (f=6) and "robotics" (f=6) were the next most prevalent methods, followed by "general artificial intelligence concept" (f=5), "machine learning" (f=3) and "educational interface agent" (f=3). Conversely, "fuzzy logic" (f=1), "internet of things" (f=1), "pattern recognition" (f=1) and "artificial intelligence-based chatbots" (f=1) were identified as the least preferred techniques and applications.

Figure 13. *Distribution of Artificial Intelligence in Terms of Methods, Techniques and Applications*



4. CONCLUSION, DISCUSSION AND RECOMMENDATIONS

This descriptive content analysis study examined existing postgraduate theses and articles in the fields of artificial intelligence and science education in Turkey between 2010 and 2023. The aim of the review was to reveal the general trends of research on specific issues. A total of 35 studies were analysed, including 12 master's theses, 5 doctoral theses and 18 research articles.

The keywords "artificial intelligence" and "science education", "artificial neural networks", "deep learning", "fuzzy logic", "educational interface", "machine learning", "natural language processing", "data mining", "image processing", "expert systems", "robotic coding" and "pattern recognition" were identified. The "Google Academic", "National Thesis Center" and "DergiPark" databases were searched for studies addressing the subject in Türkiye between the years 2010-2023.

The Artificial Intelligence Applications Course Curriculum for secondary school students, published by the Ministry of National Education (2023a), encompasses seven distinct artificial intelligence concepts: machine learning and pattern recognition, artificial neural networks, fuzzy logic, developing sample projects in a block-based environment, data mining, image processing. These concepts are incorporated into the curriculum and are subject to instruction. The keywords examined and presented in line with our study are numerous and appear to include all of these concepts. In addition, different artificial intelligence concepts such as "educational interface agent", "robotics" and "decision trees" were also encountered. Based on this, it can be said that our study includes concepts taught at the secondary school level.

A study was conducted by Akdeniz and Özdinç (2021) in which the literature was examined with a view to identifying artificial intelligence techniques in the context of the keywords "fuzzy logic, artificial neural networks, intelligent agents, expert systems and intelligent tut oring systems (IFS) and artificial intelligence (General)" in the "National Thesis Center", "DergiPark" and "Google Scholar" databases between the years 1999-2018 and descriptive content analysis was performed. In the study conducted by Kavut (2022), the focus was on examining authorised postgraduate theses on artificial intelligence that had been published in the National Thesis Center of the Council of Higher Education in Turkey between the years 2019-2021. This was achieved by employing the content analysis method. Concurrently, Meço and Coştu (2022) undertook a separate study, which involved scanning the studies on the same subject with the keyword "artificial intelligence in education" conducted in Turkey between 2017-2021 from the "Google Academic" and "Higher Education Council (YÖK) National Thesis Center" databases. In a similar vein, Tekin (2023) examined the articles and postgraduate theses conducted in Türkiye in 2023 and prior to that on the subject of "artificial intelligence in education". A total of 39 articles and theses were determined and examined from the "ULAKBİM TR Index" and "YÖK National Thesis Center" databases. Güzey et al. (2023) examined the articles using the terms "artificial intelligence in education" in the "education & education research" category of the Web of Science website between 2019-2021 by utilizing artificial intelligence techniques in education.

As demonstrated by these results, the majority of Turkish studies utilised conventional keywords and databases. Nevertheless, there are distinctive elements that set this study apart from others. Primarily, our study is situated within the domain of "science education", and we have concurrently addressed the keywords "artificial intelligence" in education, in addition to artificial intelligence methods, techniques and applications.

While there is an absence of analogous studies in our country concerning the literature review in the domain of science education and artificial intelligence, studies conducted on this subject are identified when examining the literature outside Turkey. In the research conducted by Jia, Sun & Looi (2023) in the domain of science education between 2013 and 2023, 76 studies were accessed via the "Web of Science" and "Scopus" databases using keywords such as " artificial intelligence in science education", "artificial intelligence", "data mining", "machine learning", "algorithm", "expert system", "intelligent education system", "robot", "personalized learning", "recommended system" and bibliometric and content analyses of these data were performed. It should be noted that the choice of databases, inclusion of studies from Turkey, selection of keywords in Turkish, incorporation of different keywords and utilisation of varied analysis methods have contributed to the diversity of this study. The findings have provided insights into the trends in studies examining artificial intelligence in the context of science education in Türkiye.

A subsequent examination of the findings has revealed that the majority of studies conducted on artificial intelligence were of a quantitative nature. Güzey et al. (2023) also stated that their research, which examined the content analyses of studies on artificial intelligence in education, focused predominantly on quantitative studies.

A review of studies on artificial intelligence and science education reveals a balanced prevalence of research articles and graduate theses. This suggests a high level of interest in the field, which is reflected in its extensive publication across various academic disciplines. The analysis methods employed in these studies encompass conventional approaches such as content analysis and ANOVA, along with more advanced techniques like data mining and artificial neural networks. This finding suggests that the field of artificial intelligence is both innovative and open to diverse methodological approaches. The analysis of extant literature reveals a plethora of applications and studies in the domain of artificial intelligence, with implications for science education. The present study employed a descriptive content analysis of graduate theses and articles from the scientific literature on artificial intelligence and science education. The study's findings are expected to contribute to the extant literature and to researchers who wish to conduct studies in this field.

4.1. Recommendations

This study, and similar content analysis studies, can be conducted in different areas of education instead of "science education" based on existing studies in the literature. The subject can also be studied using different keywords that include artificial intelligence applications, methods or techniques. In addition, different studies can be put forward that include science education topics as well as "artificial intelligence" and its application areas, which are increasingly being studied. A review of studies conducted in Turkey indicates a paucity of research on the application of AI in the domain of science education. However, experimental studies in this area are possible. Furthermore, it is recommended that researchers explore the potential of artificial intelligence in science education programmes.

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An alternative teaching tool: Creative comics

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Abstract

In order for educational activities to be more effective, teachers use various teaching tools in the teaching process. This situation puts the stakeholders of education in search of various teaching tools to increase the efficiency of educational activities. One of the teaching tools that this search has revealed is the creative comic. The aim of this study is to discuss and introduce creative comics with their general characteristics. The current study is a reviev type of research. By examining the studies on comics in the existing literature, the characteristics of creative comics were revealed.

Creative comics attention as an effective alternative teaching tool for educational activities with four different uses. Creative comics can be used on the basis of completing the unfinished script, changing the existing script, writing a script for unscripted drawings, and adding facial expressions that reflect emotions.

Creative comics, which represent the combination of comics and creative writing, have many positive effects on educational processes. At the beginning of these positive effects are to make students active, to create a fun lesson environment, to attract attention, to facilitate teaching and understanding, to increase retention, to develop imagination and empathy. As a result, in this study, it has been revealed that creative comics are an alternative teaching tool that can be used for educational purposes.

Considering the theoretical framework of the creative comics put forward in this study, the use of artificial intelligence tools to create creative raw novels that can be used for educational purposes will make significant contributions to the research and the field.

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1. INTRODUCTION

Education is an effective tool for individuals to have the characteristics that can meet the needs of the age they live in (Tıkman, 2021). Teachers also have an important responsibility in providing individuals with the characteristics they will need in social life (Şimşek et al., 2017). In line with this responsibility, teachers are obliged to determine the most appropriate methods and materials to use in their lessons (Bayrakçeken, Doğan & Doymuş, 2015). Preparing teaching materials in order to carry out educational activities in accordance with today's understanding of education also increases the responsibility of teachers.

Comics have been used as an effective teaching material in educational activities for many years. However, in recent years, comics have been making a place for themselves in learning-teaching processes with a different way of using them. This new form as a creative comic represents the combination of comics, a literary art form, with creative writing, which is a form of writing (Şentürk & Topkaya, 2020; Senturk, 2023). This merger combines the strengths of comics and creative writing into one teaching material. Creative comics consist of two basic components. These are comics and creative writing. Comics, which are considered as a type of art, are based on the support of a picture created through lines with a story (Alsaç, 1994). Drawings supported by writing turn into a narrative tool. Platin (1985) emphasizes this aspect of the comics and expresses the comics as a form of narration created by pictures that integrate and create continuity under a certain theme. Inge (1997) also sees the comics as a narrative in which the text is blended in a balanced way with the perception of visual and movement, and the dialogues are shown with speech bubbles.

In simple terms, a comics is a visual with a written narrative blended with humor. This merger has taken on a new form by expanding the boundaries of painting and writing. On the basis of this form, it has an artistic infrastructure. However, over time, comics overflowed from the field of art and turned into a teaching material (Senturk, 2022). Leaving artistic concerns behind and finding a place in the field of education, comics are referred to as educational comics. Educational comics are designed for educational purposes and primarily aim to support teaching. The combination of visuals and text in educational comics can alter students' perspectives on their learning processes (Astuti et al., 2014). Educational comics; It is an effective teaching tool in skills education, on the facilitation and permanence of learning, and in increasing student motivation and active participation in the lesson (Akanca, 2020; Çiçek Şentürk & Selvi, 2024; İlhan & Oruç, 2019; İlhan & Shin, 2024; McNicol, 2017; Şentürk & Şimşek, 2021; Şentürk and Şimşek, 2022; Topkaya & Yilar, 2015; Yildirim, 2016). Şentürk and Şimşek (2021) explain the effect of comics on the speed of learning with a remote control metaphor. This phrase emphasizes the aspect of comics that appeals to individual learning speed. In addition to all these, educational comics support a fun learning environment with their humorous structure. Considering such features of educational comics, it can be said that the effect of comics goes beyond the frames drawn and positively affects the learning-teaching processes. In this respect, it is possible to state that educational comics have a wider impact area than the characters created with unique costumes and superpowers identified with comics on paper with a script (Şentürk, 2022a).

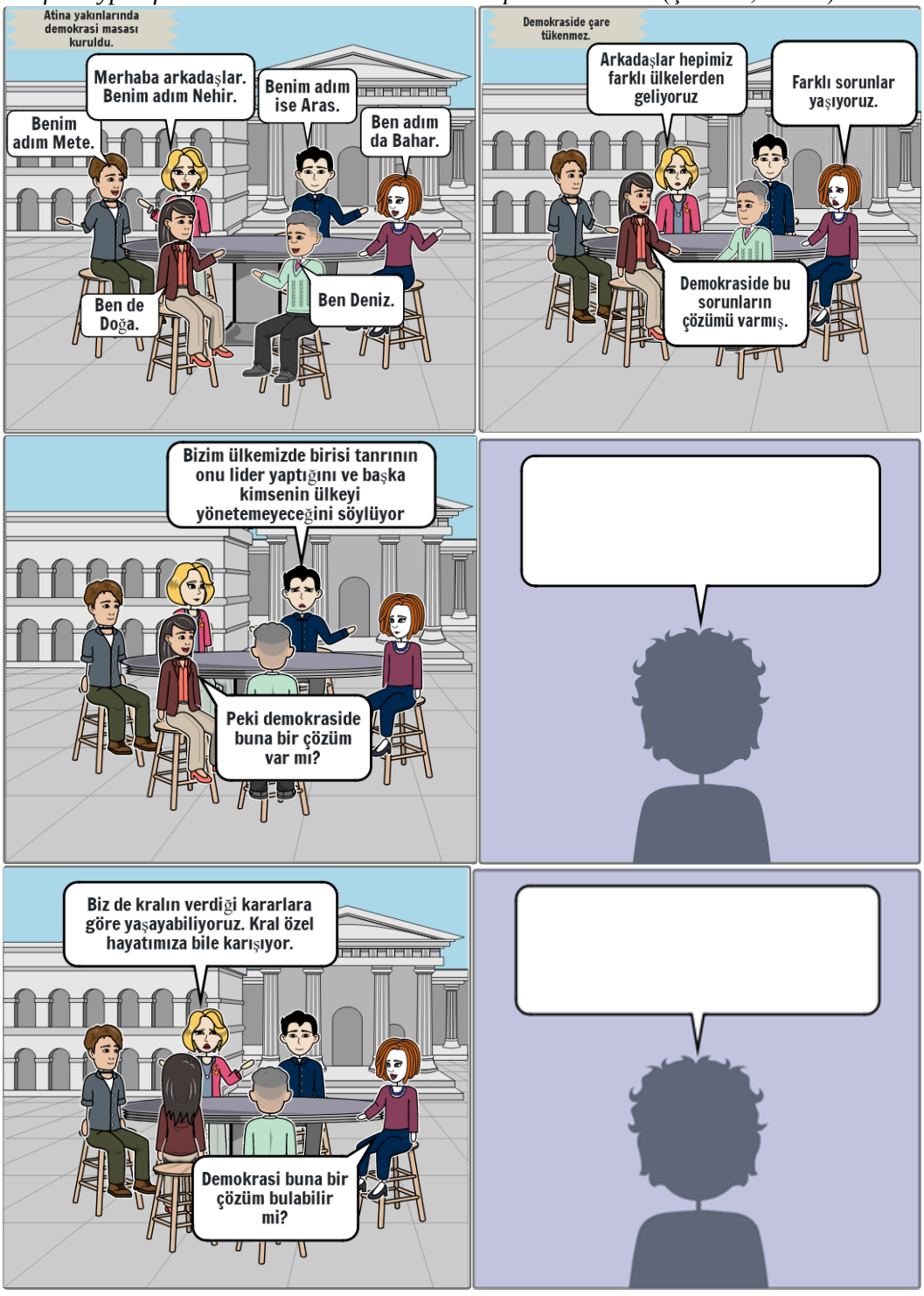
Creative writing refers to different types of original writings in which one can express in a unique way, as opposed to the objective transmission of information (Konuk, 2021). This type of writing requires people to create a new and original fiction by blending their impressions with their knowledge and imagination (Şahin, 2020). This fiction is based on the establishment of bonds that have not been established before, different and fluid relationships (Temizkan, 2010). Creative writing allows one to express one's thoughts freely (Susar Kırmızı, 2015). Such features of creative writing help people understand their inner world and express it freely (Yılmaz, 2013).

Orhon (2020) states that creative writing improves creativity and personality. Because creative writing starts with creative thinking (Şahin, 2020). In fact, creative thinking is among the basic requirements for creative writing (Yılmaz, 2013). Putting imaginative or existing texts into different patterns from a different perspective with the help of various activities (Yılmaz, 2013) shows the need for creative thinking skills in creative writing. In addition, creative writing activities also improve creative thinking skills (Şentürk, 2022a). Creative writing activities encourage students to stimulate their thinking and imagination on the determined topic with active participation in a fun learning process (Göçen, 2018; Susar Red, 2008). In creative writing, the focus is not on written expression with correct grammar. In creative writing, the focus is on effectively putting feelings and thoughts on paper (Orhon, 2020).

Creative comics combine the ability of comics to convey both visual and written messages, and creative writing allows one to express one's feelings and thoughts freely. When the literature is examined, it is seen that creative comics can be integrated into teaching processes in four different ways (Şentürk, 2022a; Şentürk, 2022b; Şentürk & Çiçek Şentürk, 2023).

In creative comics, it is aimed to reveal the knowledge, feelings, thoughts and values of the students on a subject with the first use (Figure 1), where the script is cut at some point or gaps are left in the script. Students fill in the gaps left in the creative comics in line with their own knowledge, feelings, thoughts and values. Thus, teachers can get an idea about their students' knowledge levels, feelings and thoughts on that subject.

Figure 1. *The first type of creative comics in which the script is continued* (Şentürk, 2022b).



In the second type of use (Figure 2), it is expected that some or all of the script of the creative comics will be changed. The teacher places incorrect information or examples of misbehavior at certain points in the scenario.

Students are asked to identify and replace them. With this type of use, creative comics can be effective in determining the learning levels of students. Misconceptions or misinformation that students have can be detected. An idea can be obtained about how students will behave in a situation example.

Figure 2. *The second type is creative comics in which the script is changed* (Şentürk, 2022a).

The third use of the creative comics (Figure 3) is similar to mute maps. In such creative comics, the visual backdrop and characters are created. Speech bubbles are added for characters. However, these bubbles are left hollow. This use requires students to create a script for the creative comics. Students interpret the visual parts of the creative comics with their own knowledge, feelings and thoughts and write dialogues for the characters within the framework of the subject of the course.

Figure 3. *The third type of creative comics for which a script is written* (Şentürk & Çiçek Şentürk, 2023).

In the fourth use of the creative comics (Figure 4), the script is created and the characters are illustrated. However, the facial expressions of the characters are deleted. According to the plot in the creative comic, students draw the emotions of the characters (such as happy, sad, angry, surprised) in a way that reflects their facial expressions. With this usage, it aims to reveal students' feelings towards a certain event. This type of use is especially effective for affective learning.

Figure 4. *The fourth type of comics in which facial expressions are drawn*

The main feature that distinguishes creative comics from educational comics is that creative comics allow people to transfer their own feelings and thoughts to the comic. Students are able to shape creative comics in line with their knowledge, attitudes, values and thoughts. This makes the creative comics an interactive teaching material.

2. CONCLUSION

The stakeholders of education are constantly in search of more efficient educational processes. This search mediates the discovery of many methods, techniques or materials that will have a positive impact on educational processes. Creative comics are one of them.

Creative comics offer powerful alternatives to teachers with four different uses. Creative comics, which combine the power of comics and creative writing on educational processes, turn into an effective teaching tool. Since creative comics are an interactive teaching tool, the use of this genre in educational activities can ensure that students participate more actively in the course process. Students can participate in the lesson with a higher motivation in a more enjoyable classroom environment. Creative comics develop students' empathy and imagination and create opportunities for more permanent learning. Creative comics also make it easier to learn because they have a simple and plain written expression and support this expression with visuals.

In addition to these positive features, the fact that preparing and using creative comics requires education and the use of creative comics in the classroom is time-consuming can be shown among the main limitations of this teaching material. However, creative comics require experience and time to prepare. For this limitation of creative comics, it is recommended to reproduce creative comics prepared in digital environments and use them repeatedly in different classes and in different years. By taking into account the theoretical framework of creative comics presented in this study, artificial intelligence-supported creative comics that can be used for educational purposes can be created. Artificial intelligence-supported creative comics will make significant contributions to the research and the field.

Conflict of Interest and Ethical Statement

The author does not declare any conflict of interest. This study complies with research and publication ethics. The scientific and legal responsibility of the articles published in IJEDAI belongs to the author(s).

Author Contribution Statement

Since the study was a single author, all parts of the study were undertaken by the author of the study.

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Alternatif bir öğretim aracı: Yaratıcı çizgi roman

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Özet

Eğitim faaliyetlerinin daha etkili olabilmesi için öğretmenler öğretim süreci içerisinde çeşitli öğretim araçları kullanmaktadırlar. Bu durum eğitimin paydaşlarını eğitsel faaliyetlerin verimini artırmak için çeşitli öğretim aracı arayışı içerine sokmaktadır. Bu arayışın ortaya çıkardığı öğretim araçlarından biri de yaratıcı çizgi romandır. Bu çalışmanın amacı, yaratıcı çizgi romanları genel özellikleriyle ele almak ve tanıtmaktır. Mevcut çalışma derleme türünde bir araştırmadır. Mevcut literatürdeki çizgi romanlara yönelik çalışmalar incelenerek yaratıcı çizgi romanın özellikleri ortaya çıkarılmıştır.

Yaratıcı çizgi romanlar dört farklı kullanım şekliyle eğitsel faaliyetler için etkili bir alternatif öğretim aracı olarak dikkat çekmektedir. Yaratıcı çizgi romanlar yarım kalan senaryonun tamamlanması, mevcut senaryonun değiştirilmesi, senaryosuz çizimlere senaryo yazılması, duyguları yansıtan yüz ifadeleri eklenmesi esasına dayalı şekilde kullanılabilmektedir.

Çizgi roman ve yaratıcı yazmanın birleşimini temsil eden yaratıcı çizgi roman, eğitsel süreçler üzerinde birçok olumlu etki oluşturmaktadır. Bu olumlu etkilerin başında öğrencileri aktif kılma, eğlenceli bir ders ortamı oluşturma, dikkat çekme, öğretimi ve anlamayı kolaylaştırma ve kalıcılığı artırma, hayal gücünü ve empatiyi geliştirme gelmektedir. Sonuç olarak bu çalışmada yaratıcı çizgi romanların eğitsel amaçlarla kullanılabilecek alternatif bir öğretim aracı olduğu ortaya konulmuştur.

Bu çalışmada ortaya konulan yaratıcı çizmi romanların kuramsal çerçevesi düşünülerek, eğitsel amaçlarla kullanılabilecek yaratıcı çigi roman oluşturmaya yönelik yapay zeka araçlarının kullanımıyla, yapılacak araştırmalara ve alana önemli katkılar sağlayacaktır.

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1. GIRIŞ

Bireylerin yaşadıkları çağın gereksinimlerine cevap verebilecek özelliklere sahip olmasında eğitim etkili bir araçtır (Tıkman, 2021). Bireylerin toplumsal yaşamda ihtiyaç duyacakları özelliklerin onlara kazandırılmasında da öğretmenler önemli bir sorumluluk yüklenmektedir (Şimşek vd., 2017). Öğretmenler bu sorumluluk doğrultusunda derslerinde kullanacakları en uygun yöntem ve materyalleri belirlemekle yükümlüdür (Bayrakçeken vd., 2015). Günümüz eğitim anlayışına uygun eğitsel faaliyetler sürdürmek için öğretim materyali hazırlamak da öğretmenlerin sorumluluğunu artırmaktadır.

Çizgi romanlar uzun yıllardır eğitsel faaliyetlerde etkili bir öğretim materyali olarak kullanılmıştır. Bununla birlikte çizgi roman son yıllarda öğrenme-öğretme süreçlerinde farklı bir kullanım şekliyle daha kendine yer açmaktadır: Yaratıcı çizgi roman. Bu yeni form, edebi bir sanat türü olan çizgi romanın bir yazma biçimi olan yaratıcı yazma ile birleşimini temsil etmektedir (Şentürk & Topkaya, 2020; Şentürk, 2023). Bu birleşme çizgi romanın ve yaratıcı yazmanın güçlü yönlerini bir öğretim materyali üzerinde toplamaktadır. Yaratıcı çizgi roman iki temel bileşenden oluşmaktadır. Bunlar çizgi roman ve yaratıcı yazmadır. Bir sanat türü olarak kabul edilen çizgi romanlar, çizgiler aracılığıyla oluşturulan bir resmin bir öyküyle desteklenmesi temelinde dayanır (Alsaç, 1994). Yazıyla desteklenen çizimler bir anlatım aracına dönüşür. Platin (1985) çizgi romanın bu yönünü vurgulayarak çizgi romanı, belirli bir tema altında bütünleşen ve süreklilik oluşturan resimlerle oluşturulan bir anlatım biçimi olarak ifade etmektedir. Inge (1997) de çizgi romanı metnin, görsel ve hareket algısı ile dengeli bir şekilde harmanlandığı ve diyalogların konuşma balonlarıyla gösterildiği bir anlatı olarak görmektedir.

Basit bir anlatımla çizgi roman, yazılı anlatıma sahip bir görselin mizahla harmanlanmış şeklidir. Bu birleşme resmin ve yazının sınırlarını genişleterek yeni bir forma bürünmüştür. Bu form temelinde sanatsal bir alt yapı barındırmaktadır. Ancak zamanla çizgi roman sanat alanından taşmış ve bir öğretim materyaline dönüşmüştür (Şentürk, 2022a). Sanatsal kaygıları arkada bırakıp eğitim alanında kendine yer bulan çizgi romanlar, eğitici çizgi roman olarak ifade edilmektedir. Eğitici çizgi romanlar, eğitsel amaçlar için tasarlanır ve temelde öğretimi desteklemeyi amaçlarlar. Eğitici çizgi romanların görsel ve metni buluşturması, öğrencilerin öğrenme süreçlerine ilişkin bakış açılarını değiştirebilir (Astuti et al., 2014). Eğitici çizgi romanlar; beceri eğitiminde, öğrenmelerin kolaylaşması ve kalıcılığı üzerinde, öğrenci motivasyonunun ve derse aktif katılımının artırılmasında etkili bir öğretim aracıdır (Akanca, 2020; Çiçek Şentürk & Selvi, 2024; İlhan & Oruç, 2019; İlhan & Şin, 2024; McNicol, 2017; Şentürk & Şimşek, 2021; Şentürk & Şimşek, 2022; Topkaya & Yılar, 2015; Yıldırım, 2016). Şentürk ve Şimşek (2021) çizgi romanların öğrenme hızı üzerindeki etkisini bir uzaktan kumanda metaforu ile açıklamaktadır. Bu ifade çizgi romanların bireysel öğrenme hızına hitap eden yönünü ön plana çıkarmaktadır. Tüm bunların yanında eğitici çizgi romanlar, taşıdıkları mizahi yapı ile eğlenceli bir öğrenme ortamını desteklemektedir. Eğitici çizgi romanların bu gibi özellikleri düşünüldüğünde çizgi romanların etkisinin çizim yapılan karelerin dışına taştığı ve öğrenme-öğretme süreçlerine olumlu etkilediği söylenebilir. Bu yönüyle eğitici çizgi romanların, çizgi romanla özdeşleşen kendine has kostüm ve süper güçlerle yaratılan karakterlerin bir senaryoyla birlikte kâğıt üzerine resmedilmesinden daha geniş etki alanına sahip olduğunu ifade etmek mümkündür (Şentürk, 2022a).

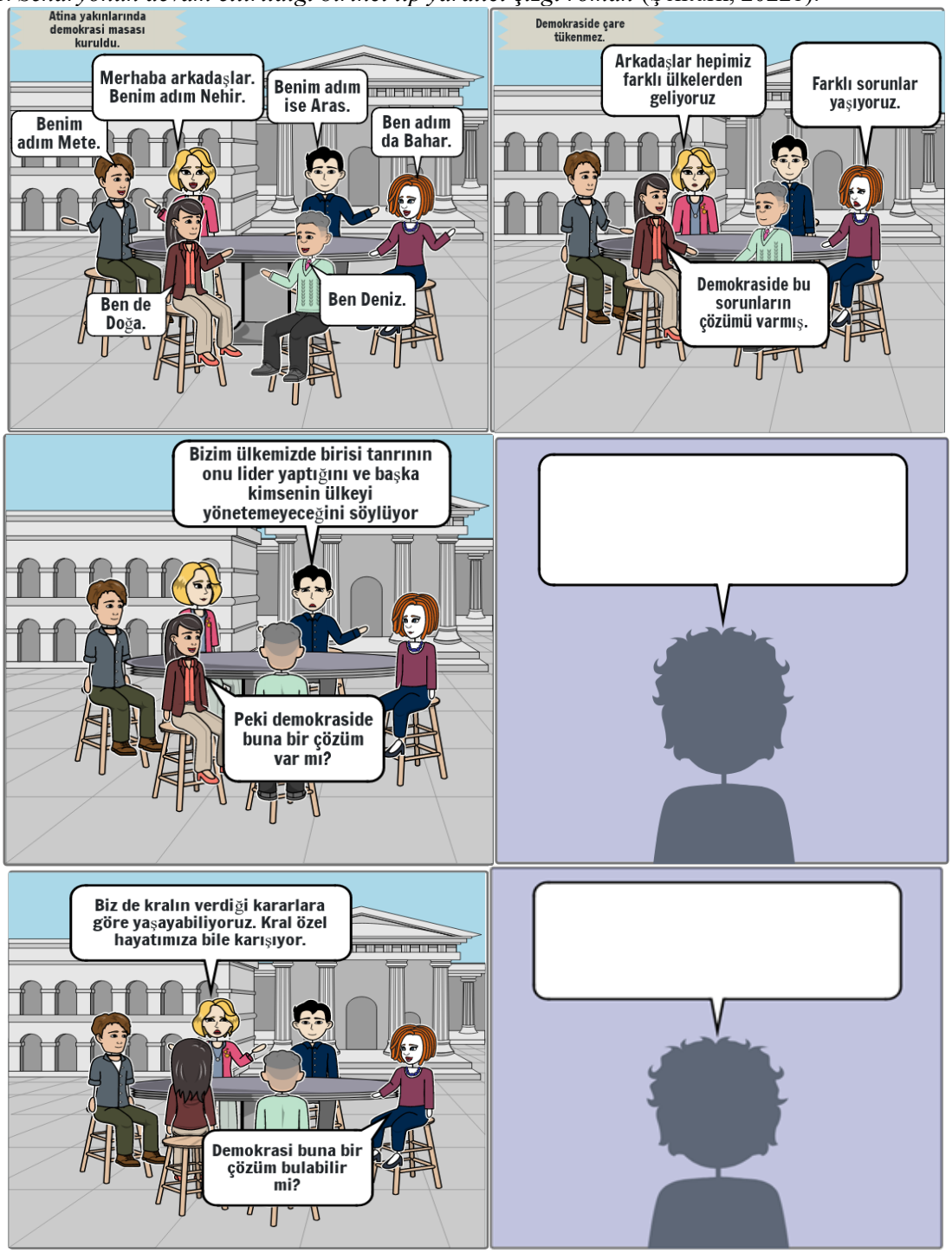
Yaratıcı yazma, bir bilginin nesne bir şekilde iletilmesinin aksine kişinin kendine özgü bir şekilde anlatım gerçekleştirebildiği farklı türde orijinal yazıları ifade eder (Konuk, 2021). Bu yazma türü kişilerin izlenimlerini, bilgi birikimi ve hayal dünyasıyla harmanlayıp yeni ve özgün bir kurgu oluşturmasını gerektirir (Şahin, 2020). Bu kurgu, daha önce kurulmamış bağlar, farklı ve akıcı ilişkiler kurulmasına dayanır (Temizkan, 2010). Yaratıcı yazma kişinin düşüncesini özgürce ifade etmesine olanak tanır (Susar Kırmızı, 2015). Yaratıcı yazmanın bu gibi özellikleri kişilerin iç dünyalarını anlamalarına ve özgürce ifade etmelerine yardımcı olur (Yılmaz, 2013).

Orhon (2020) yaratıcı yazmanın yaratıcılığı ve kişiliği geliştirdiğini ifade eder. Çünkü yaratıcı yazma, yaratıcı düşünmeyle başlar (Şahin, 2020). Hatta yaratıcı düşünme yaratıcı yazma için temel gereklilikler arasındadır. Hayal gücüyle oluşturulan veya mevcut metinlerin çeşitli etkinlikler yardımıyla farklı bir bakış açısıyla farklı kalıplara sokulması (Yılmaz, 2013) yaratıcı yazmada yaratıcı düşünme becerisine duyulan ihtiyacı göstermektedir. Bununla birlikte yaratıcı yazma etkinlikleri de yaratıcı düşünme becerisini geliştirmektedir (Şentürk, 2022a). Yaratıcı yazma etkinlikleri, öğrencilerin eğlenceli bir öğrenme süreci içerisinde aktif bir katılımla belirlenen konu üzerine düşünme ve hayal gücünü harekete geçirmesini teşvik eder (Göçen, 2018;

Susar Kırmızı, 2008). Yaratıcı yazmada odak, doğru dilbilgisi ile yazılı anlatım değildir. Yaratıcı yazmada duygu ve düşüncelerin etkili biçimde kâğıda dökülmesine odaklanılır (Orhon, 2020).

Yaratıcı çizgi roman, çizgi romanların hem görsel hem de yazılı mesaj iletme özelliğini, yaratıcı yazmanın da kişinin duygu ve düşüncelerini özgürce ifade edebilmesine imkân tanımasını bir araya getirir. Literatür incelendiğinde yaratıcı çizgi romanların öğretim süreçlerine dört farklı şekilde entegre edilebileceği görülmektedir (Şentürk, 2022a; Şentürk, 2022b; Şentürk & Çiçek Şentürk, 2023). Yaratıcı çizgi romanda senaryonun bir noktada kesildiği ya da senaryoda boşluklar bırakılan ilk kullanım şekli (Görsel 1) ile öğrencilerin bir konudaki bilgi, duygu, düşünce ve değerlerinin ortaya çıkarılması amaçlanır. Öğrenciler yaratıcı çizgi romanda bırakılan boşlukları kendi bilgi, duygu, düşünce ve değerleri doğrultusunda tamamlarlar. Böylece öğretmenler öğrencilerinin o konuya dair bilgi düzeyleri, duygu ve düşünceleri hakkında fikir edinebilirler.

Görsel 1. *Senaryonun devam ettirildiği birinci tip yaratıcı çizgi roman* (Şentürk, 2022b).



İkinci kullanım şeklinde ise (Görsel 2) yaratıcı çizgi romanın senaryosunun bir kısmının ya da tümünün değiştirilmesi beklenir. Öğretmen, senaryoda belirli noktalara yanlış bilgiler ya da hatalı davranış örnekleri yerleştirir. Öğrencilerden bunların tespit edilmesi ve değiştirilmesi istenir. Bu kullanım şekliyle yaratıcı çizgi romanlar, öğrencilerin öğrenme düzeylerini tespit etmede etkili olabilirler. Öğrencilerin sahip oldukları kavram yanılgıları veya yanlış bilgiler tespit edilebilir. Öğrencilerin bir durum örneğinde nasıl bir davranış sergileyecekleri hakkında fikir edinilebilir.

Görsel 2. *Senaryonun değiştirildiği ikinci tip yaratıcı çizgi roman* (Şentürk, 2022a).

Yaratıcı çizgi romanın üçüncü kullanım şekli (Görsel 3) dilsiz haritalara benzemektedir. Bu tür yaratıcı çizgi romanlarda görsel zemin ve karakterler oluşturulur. Karakterler için konuşma baloncukları eklenir. Ancak bu baloncukların içi boş bırakılır. Bu kullanım şekli, öğrencilerin yaratıcı çizgi roman için bir senaryo oluşturmasını gerektirir. Öğrenciler yaratıcı çizgi romanın görsel kısımlarını kendi bilgi, duygu ve düşünceleriyle yorumlayarak dersin konusu çerçevesinde karakterler için diyaloglar yazarlar.

Görsel 3. *Senaryo yazılan üçüncü tip yaratıcı çizgi roman* (Şentürk & Çiçek Şentürk, 2023).

Yaratıcı çizgi romanın dördüncü kullanım şeklinde (Görsel 4) senaryo oluşturulur, karakterler resmedilir. Ancak karakterlerin yüz ifadeleri silinmiş olur. Öğrenciler, yaratıcı çizgi romanda yer alan olay örgüsüne göre karakterlerin duygularını (mutlu, üzgün, kızgın, şaşırmış gibi) yüz ifadesi ile yansıtacak şekilde çizerler. Bu

kullanım şekli ile öğrencilerin belli bir olay karşısındaki duygularını açığa çıkarmayı amaçlar. Bu kullanım şekli özellikle duyuşsal öğrenmeler için etkilidir.

Görsel 4. *Yüz ifadelerinin çizildiği dördüncü tip çizgi roman*

Yaratıcı çizgi romanı eğitici çizgi romandan ayıran temel özellik, yaratıcı çizgi romanların kişinin kendi duygu ve düşüncelerini çizgi romana aktarmasına imkân vermesidir. Öğrenciler bilgileri, tutumları, değerleri ve düşünceleri doğrultusunda yaratıcı çizgi romanı şekillendirebilmektedir. Bu da yaratıcı çizgi romanı etkileşimli bir öğretim materyali yapmaktadır.

2. SONUÇ

Eğitimin paydaşları süreğen bir şekilde eğitsel süreçlerin daha verimli geçmesi için arayış içerisindedirler. Bu arayış eğitsel süreçler üzerinde olumlu etki oluşturacak birçok yöntem, teknik veya materyalin keşfedilmesine aracılık etmektedir. Yaratıcı çizgi romanlar da bunlardan biri olarak dikkat çekmektedir.

Yaratıcı çizgi romanlar dört farklı kullanım şekliyle öğretmenlere güçlü alternatifler sunmaktadır. Çizgi romanın ve yaratıcı yazmanın eğitsel süreçler üzerindeki gücünü birleştiren yaratıcı çizgi romanlar etkili bir öğretim aracına dönüşmektedir. Yaratıcı çizgi romanlar etkileşimli bir öğretim aracı olduğu için bu türün eğitsel faaliyetlerde kullanılması ile öğrencilerin ders sürecine daha aktif şekilde katılımı sağlanabilir. Öğrencilerin daha eğlenceli bir ders ortamında daha yüksek bir motivasyonla derse katılımı sağlanabilir. Yaratıcı çizgi romanlar öğrencilerin empati becerisini ve hayal gücünü geliştirir, daha kalıcı öğrenmeler için fırsat oluşturur. Yaratıcı çizgi romanlar basit ve sade yazılı anlatıma sahip olması ve bu anlatımı görselle desteklemesinden dolayı öğrenmeyi de kolaylaştırır. Bu olumlu özelliklerin yanında yaratıcı çizgi roman hazırlamanın ve bunları kullanmanın eğitim gerektirmesi, yaratıcı çizgi romanların sınıfta kullanımının zaman alıcı olması bu öğretim materyalinin temel sınırlılıkları arasında gösterilebilir. Bununla birlikte yaratıcı çizgi romanların hazırlanması tecrübe ve zaman gerektirir. Yaratıcı çizgi romanın bu sınırlılığı için dijital ortamlarda hazırlanan yaratıcı çizgi romanların çoğaltılarak farklı sınıflarda ve farklı yıllarda tekrar tekrar kullanılması önerilmektedir. Bu çalışmada ortaya konulan yaratıcı çizgi romanların kuramsal çerçevesi dikkate alınarak eğitsel amaçlarla kullanılabilecek yapay zeka destekli yaratıcı çizgi romanlar oluşturulabilir. Yapay zeka destekli yaratıcı çizgi romanlar yapılacak araştırmalara ve alana önemli katkılar sağlayacaktır.

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