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Editors

Osman CARDAK

Seyit Ahmet KIRAY

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Osman CARDAK
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Contact
Istanbul C. Cengaver S. No 2 Karatay/Konya/TÜRKİYE
isresoffice@gmail.com
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PREFACE

In today's world where science and technology are rapidly developing and changing, individuals' interests and needs are also changing. Keeping up with this rapid change, following the developments of the age, and being able to predict the future can now be described as skills that every individual should have. It is also expected from education, which will provide these skills, to raise individuals with the knowledge, skills, and qualifications required for the age we live in.It is more accessible to follow the developments and innovations in the field of education by publishing works that bring together the studies in the field. This book, which deals with multidisciplinary and scientific topics in education, is prepared to guide researchers, teachers, teacher candidates, and readers working in the field of educational sciences. I would like to thank all the team who contributed to the preparation and publication of the book.

This book covering current research in education consists of four chapters. The first chapter primarily delves into inclusive curriculum-related information. It then compares Turkey's position in Global sustainable development goals. The second chapter addresses concepts, misconceptions, causes of misconceptions, methods used to identify and eliminate misconceptions, the significance of misconceptions in science education, and examples. Another study focuses on the current state and expectations related to Placed-Based Socio-Scientific Issues Teaching. The third chapter discusses realistic mathematics education and mathematical literacy. In the fourth chapter, firstly, it introduces Web-Based Instruction and a Sample Portal Design for Web-Based Instruction. Second study deals with integration steps for STEM education in school curricula and third study deals with the effects of Computer Simulation on Chemistry Learning.

December, 2023

Editors

Prof. Dr. Osman CARDAK

Professor, Necmettin Erbakan University

Ahmet Kelesoglu Faculty of Education, Konya, Türkiye
E-mail: oscardak@gmail.com

Prof. Dr. Seyit Ahmet KIRAY

Professor, Necmettin Erbakan University

Ahmet Kelesoglu Faculty of Education, Konya, Türkiye

E-mail: ahmetkiray@gmail.com

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Include All Not Few: Towards An Inclusıve Curriculum

Dr Fatima Rehan DAR
Oak Consulting, Pakistan

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Defining Inclusive Curriculum

Education is a basic human right and the foundation for a more just society (Ainscow, 2005). The aim of education is to give a transformational experience that enables each learner to attain academic and social standing based on his or her potential. Learning gains are forthcoming only when education is brought to the level of students and through a process of scaffolding, the knowledge margins are broadened and increased. This is termed as an inclusive approach towards the attainment of educational gains. Effective inclusive education transpires mainly through wholehearted acceptance of student differences and diversity, which may comprise physical, cognitive, academic, social, and emotional variations.

An inclusive approach towards curriculum design is therefore preferred as an all-encompassing approach that takes into its fold all levels of learners. Hector-Alexander (2019) opines that an inclusive curriculum design acknowledges that students have multiple identities that are shaped by their previous experiences and that a diverse range of personal circumstances influence how they learn. Inclusive education is championed as a means to remove barriers, improve outcomes and remove discrimination. Hockings defines inclusive curriculum design as "involv[ing] the design, planning and evaluation of programmes, courses and modules not only in terms of their learning outcomes, content, pedagogy and assessment but also in ways in which they engage and include the needs, interests and aspirations of all students" (Hockings, 2010, p. 15)

Grace and Gravestock (2009) point out that, "inclusive curriculum ... refers to the process of developing, designing and refining programmes of study to minimize the barriers that students may face in accessing the curriculum." (p. 1). The barriers that learners face during the course of their education may have diverse ranges. There may be cultural, social and linguistic differences that may necessitate an inclusive approach. Hector-Alexander (2019) states that an inclusive curriculum design acknowledges that students have multiple identities that are shaped by their previous experiences and that a diverse range of personal circumstances influence how they learn. Chen, Mashadi, Ang, and Harkrider (1999) too argue that learning resources for learners should be consistent with their values, beliefs, and styles of learning. This not only ensures an equitable access but makes learning more meaningful, profound and exciting.

Curriculum Development Principles

Morgan & Houghton (2011) state that inclusive curriculum design is beneficial for students, staff and the institution because it places the student at the heart of the design process. This can involve recognizing students' multiple identities, avoiding compartmentalizing solutions based on specific 'need' and adopting a holistic approach to meeting students' entitlements. Kerr and baker (2013) further emphasize that while designing key principles for inclusive curriculum there are a few elements that must be considered. For example, all inherent requirements for the course need to be clearly articulated and available to students prior to enrolment. Also, it is vital to regularly evaluate the accessibility and inclusiveness of courses and modify accordingly. Further, all learning materials and learning technologies used in the course enrolment, delivery, and assessment should be accessible by students using assistive technologies. In terms of the provision of course materials to students studying in online, distance or blended modes this means that the learning management system itself and all materials placed in the learning management system should be accessible to assistive technologies. The assessments in inclusive curriculum should be flexible to accommodate all learners including time lines, assessment tasks, and course requirements. Finally, the teaching staff should adopt a flexible and inclusive attitude with regard to making alternative arrangements for learners with special needs. (p.78-82). Morgan & Houghton (2011) further outline that the principles of an inclusive curriculum design should be based on anticipatory, flexible, collaborative, transparent and equitable mechanisms that factor in all needs of learners. Thomas and May (2010) advocate that stocktaking of the following must be done if the intention is to teach an inclusive curriculum:

- Educational Level/type of entry qualifications; skills; ability; knowledge; educational experience; life and work experience; learning approaches.
- Dispositional Identity; self-esteem; confidence; motivation; aspirations; expectations; preferences; attitudes; assumptions; beliefs; emotional intelligence; maturity; learning styles perspectives; interests; self-awareness; gender; sexuality.
- Circumstantial Age; disability; paid/voluntary employment; caring responsibilities; geographical location; access to IT and transport services; flexibility; time available; entitlements; financial background and means; marital status.
- Cultural Language; values; cultural capital; religion and belief; country of origin/residence; ethnicity/race; social background. Figure 1: Four-pronged typology from student diversity
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The above principles aid in building rich profiles of learners which in turn help to formulate a curriculum based on principles of equity and social justice. Every institution therefore should be alert enough to recognize and celebrate student diversity, make learning and educational resources accessible to all kinds of learners, practice diversity in teaching and learning including assessment, promote flexible and multi modal learning environments, create community of equitable practices, and practice reflection to inform decision making.

The Attention Markers in Inclusive Curriculum

While developing an inclusive curriculum there are a few areas that must become its fundamental mainstays. The following section outlines the possible areas for inclusion:

Students with Special Needs

There are an estimated 240 million children with disabilities worldwide.1 Usually children with special needs are overlooked during educational policymaking which in turn limits their access to socio-economic participation. Such children are most likely to drop out of school. Inclusive education is one of the most effective ways to make education accessible to children with special needs and provide them the opportunity to continue their education and develop the desired skills they need to flourish in society. Morgan & Houghton (2011) state that an inclusive curriculum design approach is one that takes into account students' educational, cultural and social background and experience as well as the presence of any physical or sensory impairment and their mental well-being. They reiterate that an inclusive curriculum design approach is one that takes into account students' educational, cultural, and social background and experience as well as the presence of any physical or sensory impairment, and their mental well-being. Alquraini and Gut (2012) are of the view that unless otherwise instructed, learners with disabilities should be placed with peers with no disability for fruitful learning gains for the former. The main principle is to make such learners acceptable and welcome rather than marginalized and unwanted. Tafa and Manolitsis (2003) opine that those learners attending inclusive programs develop increased respect, awareness, and acceptance of their peers who have special needs, develop less prejudices, and learn to be more helpful and supportive toward them. This in turn enables learners with special needs to develop confidence and reaffirm faith in their own cognitive abilities. Dupuis, Barclay, Holmes, Platt, Shaha, and Lewis (2006) reaffirm that students with disabilities have higher achievement and improved skills through inclusive education, and their peers without challenges benefit, too. Parekh and Brown (2019) state that children with disabilities and special needs in inclusive settings are less likely to experience limited academic opportunities and be negatively affected in their future academic opportunities, compared to those in self-contained special education classrooms. A meta-analytic study conducted by Oh-Young and Filler (2015) compared the outcomes of students with disabilities between placement settings and found that students in more integrated settings outperformed those in more segregated settings, both in the academic and social domains. Moreover, Paul, Di Rezze, Rosenbaum, Cahill, Jiang, Kim, and Campbell (2022) cite a study in which children and youth with disabilities and special needs, when provided opportunities, demonstrated profound personal understandings of their strengths and needs, their conditions and how these impacted their lives. In addition, the study indicated a need for strong leadership at the school level to support implementation of inclusive education, the necessity of professional development for teachers and collaboration with other professionals and a need for flexibility in curriculum and instruction, for which educators require training and experience. An inclusive curriculum also encourages learners without disability to develop positive and caring attitudes towards peers with disabilities. There is a strong possibility of the former becoming peer coaches and developing caring and nurturing attitudes. During the process, they improve

[1] https://www.unicef.org/education/inclusive-education

their own competencies in selected subject areas through peer coaching. Such a curriculum not only addressees the academic needs of learners but also makes concrete efforts to prepare mindful and concerning youth who are cognizant and conscious of the differentiated realities of their peers and learn to respect their varied identities. An inclusive curriculum thus fulfils the equity gaps in education and makes a concerted effort to address the academic needs of all.

Social and Cultural Inclusion

McLoughlin and Oliver (2000) note that one of the limitations in current instructional design models is that they do not fully contextualize the learning experience, and are themselves the product of particular cultures. Fitz and Nikolaidis (2020) are of the view that standardized (not to be mistaken for standards-based curriculum materials) and widely disseminated curriculum materials, although sometimes promoted as democratizing access to learning, may undermine equity. Such curricula favour '*one size fits all'* philosophy which may prove unproductive for learners from diverse socio-cultural backgrounds.

Higbee, Katz and Schultz (2010) opine that, "being part of a diverse educational community can enhance growth and development in important skills like leadership, critical thinking, and cross-cultural communication." (p.1). Alozie, Lundh, Yang and Parker (2021) pronounce the same and state that the voices of diverse students and the educators working with them are often missing from standardized curricula. Also, missing are connections to students' diverse sociocultural and ethnic backgrounds and their communities and the flexibility to adapt instructional materials to these diverse contexts. Developing accessible curricula therefore is a fundamental equal opportunity and human rights issue, and it is our challenge to address this. (Kerr & Baker, 2013)

Considering that there is more intercultural plurality in the world, it is therefore essential that educational curricula attends equitably to the social and cultural realities of learners. In 2014, U.S. public schools hit a minority majority milestone with Latino, African-American, and Asian students having surpassed the number of white students. In 2044, the U.S. Census predicts that over half of the nation's population will be people of color.[2] Cohn (2016) reports that in 2015, for the first time in U.S. history, over half of all babies born were Culturally and Linguistically Diverse. Cultural diversity therefore is unmistakably on the rise. There is a need to practice a culturally inclusive curriculum which reflects the cultural, linguistic and religious diversity of every society. A culturally diverse curriculum is when students learn in a supportive environment free from prejudice and discrimination[3]. A responsive curriculum based on the socio-cultural needs of learners may include: acknowledgment of the presence of individuals and/or groups that do not have social power, prestige, or institutionalized privilege; development of an understanding of their marginalization, active work towards creating equitable and inclusive experiences and opportunities for them and giving due diligence to the socio-linguistic identities of learners.

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[2] https://drexel.edu/soe/resources/student-teaching/advice/importance-of-cultural-diversity-in-classroom/

[3] https://education.nsw.gov.au/teaching-and-learning/curriculum/multicultural-education/culture-and-diversity/cultural-inclusion#Culturally1

The guiding principle for the practice of a socio-cultural rich curriculum is a thorough needs assessment of the learners and their context. Abodey and Ansah (2017) opine that a needs assessment provides the information to determine outcomes (educational objectives) based on a factual foundation and learners' needs. Nugraha, Suwandi, Nurkamto, and Saddhono (2018) consider needs assessment as one of the main investigative tools used by institutions for the identification of actual needs, gaps, and hidden parts of the system and other activities. The needs assessment therefore outlines the various identity markers with which learners come to classrooms and help in formulating efficient governing policies, selection of syllabi, teaching practices, assessment methods and learning environments that are purposeful, active, and meaningful for every learner.

In designing a socio-cultural sensitive curriculum attention can be given to the following areas:

Mother Tongue Based Instruction

One of the approaches to enculturate learners and immerse them in an environment that they are familiar with is through mother tongue-based education, especially in the early years. The said approach emphasizes the use of learners' home languages as the medium of instruction in the early years of schooling, alongside the introduction of regional or national familiar languages. This approach has been recognized for its potential to enhance social justice and equity in education. Nishanthi (2020) states that cognitive development as well as intellectual improvement is relatively faster in those who are fluent in their mother tongue. Pflespsen (2011) cites a study in which an evaluation of mother tongue instruction in northwest Cameroon reveals that first grade children taught in their mother tongue, Kom, perform significantly better across a range of subjects, including English and maths, than those taught only in English. Instruction in the most familiar language is seen to improve learning outcomes as mother tongue based instruction provides a familiar backdrop and rich context which eases the learning process. A curriculum is considered inclusive when it factors in the linguistic heritage that learners bring in classrooms. If commencement of formal education begins in the mother tongue, it reaps in far more cognitive rewards than education given in an unfamiliar language. Avineri, Graham, Johnson, Riner and Rosa (2018) claim that obstructing linguistically minoritized groups from participating in civic and community practices in their home languages limit their access to broader social institutions, diminishes their cultural and linguistic identity, prevents them from having equal opportunities and privileges;… thereby constraining their learning opportunities. An inclusive curriculum based on multilingual education, especially in the early years, provides a level playing to learners who possess varied socio-linguistic identities.

The Case of Tharparkar, Sindh-Pakistan

The case of Pakistan differs considerably when it comes to language of instruction. Pakistan is a diversely networked country with a rich linguistic and cultural heritage. It is home to 69 indigenous languages, some of them are on way to extinction though, and is imbued with a rich and ethnically diverse cultural landscapes.[4] However, the language of instruction has remained a controversy since

[4] https://www.ethnologue.com/country/PK/

independence in 1947 from the British Raj. The imperialistic past of the country has continued to strengthen the significance of English as a language of status, power and upward social mobility. Since independence, the position of English as an official language has stayed. Urdu, though a national language, has failed to compete with English as an equalizer or a chief identity marker. Regional languages too have failed to gain traction and have not been considerably given attention in the formal curriculum both in the private and public sectors of education. The matter however has been seriously taken up by The Citizen Foundation (TCF), which is one the biggest Non-Governmental Organization in the country operating with 1833 schools across Pakistan with 280,000 registered students[5]. In an effort to raise educational quality standards and learning outcomes TCF has intervened and introduced a contextually rich, Mother Tongue Based-Multilingual Language Education (MTB-MLE) in district Tharparkar of Sindh province in 2020 after a thorough needs assessment and research into benefits of mother tongue based instructional curriculum.[6] Tharparkar is a district located in the province of Sindh in Pakistan. It is a linguistically diverse region with over 13 languages and dialects being spoken (Ethnologue, 2020). Sindhi is the provincial language for the region and there are several sub-regional languages used on a daily basis, including Dhatki, Marwari, Koli, Oadki, and Parkari. The mother-tongue based multilingual program, functional in 9 TCF schools, entails a curriculum which is rich in bilingual teaching content, context rich thematic stories, inclusive school practices, and informed pedagogical exercises. A cursory analysis of the program has found learners to be more motivated and happy in schools. The teachers have reported better cognitive outcomes, less behavioral issues and improved connectivity with schools. The model, likely to be scaled up, is a firm example of inclusive educational practices based on the language endowments of learners.

Differentiated Curriculum

Differentiated curriculum is one that is individualized to meet the diverse needs of all of the students in one class. (Abodey and Ansah, 2017). It is a way of teaching that adjusts instruction to meet the learning requirements of all students. In a typically differentiated instruction class a teacher improvises the teaching keeping in mind the various cognitive levels that learners are at. It practices the notion of no learner left being behind. Tomlinson (1999) advocates four classroom elements that can fall in the differentiated curriculum category based on student readiness, interest, or learning profile. The first one is the content—what the student needs to learn or how the student will get access to the information; the second one is the process—activities in which the student engages in order to make sense of or master the content; the third category outlines the products: culminating projects that ask the student to rehearse, apply, and extend what he or she has learned in a unit; and the fourth one is the learning environment—the way the classroom works and feels. To exemplify differentiated instruction in a classroom, learners can be grouped according to the cognitive levels and lessons can be designed at various levels of understanding. These efforts can help all learners to improve and master the content. Further, the practice of differentiated instruction can be applied in the assessment domain as well. While some learners take a test, others can demonstrate their

[5] https://www.tcf.org.pk/

[6] https://view.publitas.com/the-citizens-foundation/mtb-mle-research-report/page/1?utm_medium=email&utm_source=newsletter&utm_campaign=mtbmle&utm_content=mtb-mle-report-download

understating of a concept through project work, report or any other activity. Thus by offering various assessment modes, all learners can engage with the content at their own level of understanding. For example, a reading text based on a story can be used for differentiated instruction in the following manner:

- Learners with low language abilities can be asked to identify difficult words and look for their meanings
- Learners with average comprehension skills are asked to create a story-web.
- Students with advanced comprehension skills are asked to re-tell a story from the point of view of the main character.

A few other examples that be useful to practice a differentiated curriculum are:

- **Creating flexible learning spaces**. Creating flexible learning spaces would mean creating an enabling environment where learners can choose the type of work involvement. For example, some students may benefit from self-directed, independent work while others may need to work in larger groups or require teacher and peer support.
- **Making materials available in a variety of formats**. Materials can be made broad based and wide ranging. Moreover, they can be made available to learners in different layouts. For example, they can be sent to learners in the form of online links, online and printable worksheets, audiobooks and traditional books, you tube links and more. Technology can thus become a strong tool to practice differentiated instruction. Dickenson and Gronseth (2020) are of the view that, "Technology may act as a direct tool substitute, augment the learning experience by providing functional improvements, modify the task design within the learning experience significantly, or redefine the learning experience through the creation of new tasks" (p. 1011)
- **Setting goals**. Setting goals can greatly help learners to stay focused and motivated. While learners work at their pace, goal setting shows them path on which to tread on in an organized and systematic manner. The task enables them to stay meaningfully connected and engaged with learning with desired outcomes in mind.

Differentiated curriculum thus puts the learner at an advantage of progressing at a personalized pace, removing the constrains posed by some standardized curricula. Bursztyn (2007) states that differentiated instruction supports the inclusion of all students, as teachers consider differences in student ability and learning styles to be attributes of diversity rather than identified characteristics used to sort and segregate students. The phenomenon of differentiated curriculum may well be equated with Universal Design for Learning (UDL) which emphasizes that barriers to learning are often caused by inflexible curriculum, teaching materials and methods, rather than by an inherent problem located in an individual student. It focuses on eliminating barriers to learning by considering the diverse needs of students in the design and planning stages of curriculum rather than addressing the barriers later on through individual accommodation (Rose, Meyer & Hitchcock, 2006). UDL strives to create engaged learners who are interested and feel personally connected to the relevance and value of the learning at hand. These students persist in the face of challenges and use resources such as collaboration, coping skills, and self-reflective thinking.[7] The focus of all such interventions is thus to present a framework that

[7] https://www.goodwin.edu/enews/how-to-use-universal-design-for-learning-in-the-classroom/

gives an equitable and level playing field to all learners and affords them the opportunity to intellectually progress at a pace that matches with their abilities

Contextually Rich Teaching Content

While designing and selecting teaching content, due consideration must be given to the socio-cultural contexts of the learners. Inclusivity demands that the teaching content is relatable and gives an authentic learning experience. Hector-Alexander (2019) states that students who are engaged in learning do not exist as a homogenous group. They come into the learning environment with experiences reflective of their social location and culture. Since culture, language and immediate environment bear strong influence on learning, texts and learning materials should reflect the same in order to meet the needs of culturally diverse learners. Kelly, Caires-Hurley, Kganetso, Moses and Baca (2021) also claim that characters, settings, and authors should be diverse as well as reflective of students' community.

An example of a context based learning content can be derived from mother tongue based-multilingual program in practice at Tharparkar, Sindh-Pakistan. It entails a curriculum that carries contextually and linguistically appropriate learning content. The early grade mother tongue based-multilingual instructional program has prepared story books which are bilingual. The stories are developed in learners' mother tongue (Sindhi or Dhatki) and Urdu which is the language to be acquired. The mother tongue provides a familiar ground to learners and aids comprehension. Conceptual understanding becomes better and the concept is then easily transferred to the new language.

Putting learning in context can make the learning experience more engaging and internally motivating for the student. This in turn can connect the learning experience more closely to life outside the classroom, thus making it relevant and memorable and reducing difficulty when applying new concepts to unfamiliar situations. Moreover, Hector-Alexander (2019) also advise that learners should have access to varied resources to ensure multiple perspectives. This can be achieved by moving away from instructivist approaches where all information is prescribed by the teacher to constructive and connectivist approaches where learners actively add to learning resources, suggest additional materials of interest, and discuss alternatives. This can truly ensure an inclusive curriculum where the context and cultural identities all learners are valued and treasured.

Importance of Learning Styles

Learners have various preferences for ways of thinking and approaches to learning. They have preferences for certain methods of learning and find such methods effective. For example, active learners like physical activity in their learning. Reflective people prefer introspection. Achieving an inclusive design involves curriculum planning that: … forge[s] … strong links between educational intentions, course content, teaching and learning methods, and the assessment of student learning while taking full account of student characteristics. (Uniability, 2008, cited by Craig and Zinkiewicz, 2010: 11). One of the strong proponents of inclusive education and learning styles is Howard Gardner, an American Psychologist and a professor at Harvard University. He states clearly that the educational programme should be made as specific as possible to each individual (Gardner, 1993). Gardner's multiple intelligences theory rejects linearity in curriculum design and implies that learners are intelligent in different dimensions and their smartness in a particular field of study suggests a particular learning style and learning preference. The intelligences proposed by Gardner include linguistic intelligence, logical-mathematical intelligence, bodily-kinesthetic intelligence, musical intelligence, naturalistic intelligence, spatial intelligence, and the personal intelligences (interpersonal and intrapersonal intelligence). Gardner suggests that teaching and learning styles should match and new topics should be approached in at least five different ways so that all learners can access the information. (Gardner, 1991). Mcleod (2013) is of the view that educators should ensure that activities are designed and carried out in ways that offer each learner the chance to engage in the manner that suits them best. Among the various factors that influence learning styles social environment, educational experiences and basic cognitive structure of the individual are fundamental. The theory of learning preferences and styles draws a lot of influence from Kolb's (1984) learning theory. Kolb opines that learners naturally prefer a certain single different learning style. Moreover, there are various factors that influence a person's preferred style including social environment, educational experiences, or the basic cognitive structure of the individual. An inclusive curriculum must give regard to the learning preferences in order to make learning reachable and of a greater consequence.

Integration of Social and Emotional Skills in Curriculum

An inclusive curriculum factors in social emotional learning (SEL) and supports its systematic development through integrating the said skills in the curriculum. There are five core competencies within the SEL framework: self-management, self-awareness, social awareness, relationship skills, and responsible decision-making [8] that can safely be integrated in the curriculum for effective learning outcomes. Social emotional skill development therefore when made part of the curriculum makes acceptance of diversity easy, builds intercultural communication and collaboration easy and promotes a healthy and conducive learning environment where all learners are valued. SEL skills improve educational equity and create a positive inclusive school environment. Kart and Kart (2021) in a study finds that learners in inclusive settings have more of an inclination to play with learners with disabilities and have fewer prejudices towards them. Such initiatives prepare learners for life and sow the seeds for more equitable societies. Moreover, Smogorzewska, Szumski and Grygiel (2020) opine that including SEL principles in the curriculum result in a greater understanding of diversity, tolerance, acceptance of others and the use of prosocial behaviors in inclusive classrooms which in turn promote Theory of Mind (ToM). ToM is an important social – cognitive skill that involves the ability to think about mental states, both of self and others and lead to more altruistic human development. Sokal, and Katz (2017) opine that Social Emotional Learning (SEL) is aimed at developing these skills and is generally defined to involve processes by which individuals learn to understand and moderate their own feelings, understand the feelings of others, communicate, resolve conflicts effectively, respect others, and develop healthy relationships.

[8] https://www.globalcitizenshipfoundation.org/article/social-emotional-learning-for-all-a-call-for-inclusion#:~:text=Social%2Demotional%20learning%20supports%20inclusion,%2C%20and%20responsible%20decision%2Dmaking.

One of the ways to merge SEL in the curriculum is by creating interactive learning spaces, especially when they are mediated by dialogue. Such interventions seem to permit collective thinking and learning, enhance academic achievement, social skills, and social cohesion, and are especially beneficial for vulnerable groups of students (Fernández-Villardón , Alvarez, Ugalde, and Tellado, 2020)

Roldán, Marauri, Aubert and Flecha (2021) have conducted a study titled, "Interactive learning environments for the inclusion of students with and without disabilities: Improving learning, development and relationships". This research was a qualitative study of schools that promoted and applied interactive learning environments, especially interactive groups (IGs) and dialogic literary gatherings (DLGs) for students with and without special needs. The results showed that students without SEN benefitted from participating in interactive learning activities with peers with SEN in different ways: (1) they learnt to respect others, accepted differences, and acknowledged different abilities, thereby creating opportunities for new friendships to develop; (2) they learnt about abilities related to helping others participate and learn, to be patient and to gain the satisfaction in helping others learn and behave better; and (3) they benefitted from the cognitive effort required to explain themselves and from the contributions of peers with SEN from which they could learn. Dar (2016) in a study on the integration of cognitive-affective curriculum concluded that cognitive-affective lessons led to more enlivened classrooms. "The classrooms manifested more group and pair work activities, teacher student discussions, role plays, presentations and other collaborative work. The physical environment turned from teacher-centered to learner centered.". (p.2400). An SEL curriculum thus ensures inclusivity and works on the humanistic side of learner personality for effective fusion in the institutional setting as well as in society later on.

Conclusion

Morgan and Houghton (2011) state that an, "inclusive curriculum design is beneficial for students, staff and the institution because it places the student at the heart of the design process." (p.11). This is the same constructivist approach that has been the mainstay of various educational theories with knowledge as an active construction rather than a passive absorption. Elliott, Kratochwill, Cook and Travers (2000) explain constructivism as, "an approach to learning that holds that people actively construct or make their own knowledge and that reality is determined by the experiences of the learner." (p. 256). The same thought process becomes the backdrop of inclusive education that maintains that learners play a fundamental role in the development of cognitive structures in their schemas and the curriculum design process must draw knowledge from the rich contexts from where learners come. A thorough needs assessment that studies the cognitive and physical embodiments, the socio-cultural and linguistic legacies, and learning styles should form the basis of an inclusive curriculum design. Needs assessment will lead to a fair understanding of the natural endowments of learners and a curriculum can be framed accordingly. An inclusive curriculum design can have the following diagrammatic flow:

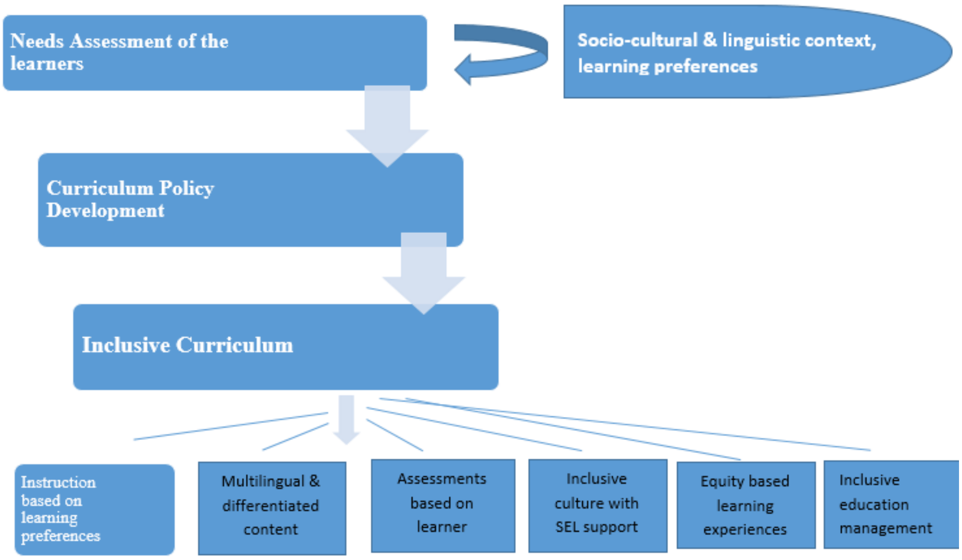

Figure 1. *Inclusive Curriculum Diagram*

A curriculum that reaches out to all through acts of differentiation gives an enriching and all-encompassing educational experience that ensures an equitable and evenhanded cognitive growth and development. Kyriacou (1997) opine that differentiating instruction is said to be the essential ingredient necessary for inclusion. Olibie (2013) also emphasises on the need for teachers to use differentiated curriculum, multiple learning styles and engage in transformational teaching. Inclusion therefore democratizes the concept of education as against set standardized procedures and opens the avenue for equitable access to all kinds of learners. İt reinforces the concept that education is a basic human right and efforts must be made for its provision to all forms of learners for equitable adjustment in society.

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About the Author

Dr. Fatima Rehan Dar has earned her Phd from the School of Education and Cognitive Science, Asia e University, Malaysia. She also has an MA in Curriculum and Teaching from Teachers College, Columbia University (USA) and an MA in English Language and Literature from Government College University (Lahore, Pakistan). She has worked as an educator and consultant with various universities and organizations in Pakistan and abroad including Aga Khan University, SZABIST, Karachi, BeaconHouse National University, Virtual University, Iqra University and Ali Institute of Education, Lahore. She has also been a visiting faculty at University of Warwick (UK) and Institute of Education (UK). She has also been a Charles Wallace Trust scholar at the Institute of Education (UK) in the year 2000. She has also worked with international agencies like USAID, DFID, Mckinzey, UNICEF, JICA, World Bank and Adam Smith International on education projects. Her publications, both national and international, address issues related to curriculum development, teacher education and English language teaching. Dr Dar works as an Independent Evaluator for schools managed under the Public Private Partnership model in Sindh and has developed the Quality Assurance Framework for Peoples' School Program (PSP) schools managed by Sindh Education Foundation. At present she works as CEO, Oak Consulting.

E-mail: fatimadar@oakconsultingedu.com, **ORCID ID:** 0009-0002-0542-2256

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of paper titled "**Include all not few: Towards an inclusive curriculum**" belongs to the author.

Türkiye's Position in the Global Sustainable Development Goals: A Comparison on Quality Education

Sinan ERTEN
Hacettepe University

Pelin KOSEOGLU
Süleyman Demirel University

Zubeyde GUNES
Hacettepe University

Muge OZKANBAS
Hacettepe University

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Sustainability and Sustainable Development

Since its existence, humanity has benefited from the environment in order to meet its endless needs. All the developments that exist for the progress of humanity have emerged as a result of the unconscious use of natural resources. However, natural resources are not unlimited, which causes damage to the basic elements of the environment. Currently, the whole world is faced with environmental problems resulting from the deterioration of the ecological balance. The main reason for the rapidly growing environmental problems that lead to the deterioration of human-environment interaction is the industrialization phenomenon that started in the 19th century and continues to develop (Deniz, 2009). Industrialization is a turning point for human history, as it enables large-scale production and developments in industrialization offer numerous benefits to the world. However, alongside these benefits, industrialization is also known to create challenges in economic, social, and cultural domains because it has also increased the consumption desire of humanity. The world has undergone significant and rapid changes, encompassing a wide range of issues. Presently, change and development have made international competition crucial. Nevertheless, addressing the global challenges that societies face requires nations to collaborate towards common goals rather than engaging in competition. Development can be defined as the process of improving a country's economic and social structure to align it with modern nations. Although the concept of development is primarily associated with the economy, it is evolving to include new dimensions. Nowadays, development is often referred to as "sustainable development," which entails meeting the present generation's needs without compromising the ability of future generations to meet their own needs (Ada, 2015). In other words, sustainable development involves repairing past resource destruction, preserving the environment's carrying capacity, safeguarding the renewable characteristics of existing resources, and ensuring their continuity into the future (Aydın, 2016; Ertan, 2018; The World Commission on Environment and Development, 1987).

The transition to an industrial society has brought many benefits on a global scale. In addition, it has created many social, environmental and economic problems. These are global problems that every society, not just a single society, must solve. However, the intensity of these problems differs depending on the structure of the society. In addition to environmental problems, inequality, terrorism, violence, gender discrimination, unhealthy living conditions, population growth, poverty, inequality of opportunity in education have become the common problem of the whole world. The search for solutions to these problems has increased the importance of the concept of sustainable development on an international scale (Korkmaz, 2020).

It was seen that the use of the concept of sustainable development has increased in the 1980s and this concept has been discussed in the context of solving environmental problems (Ralph & Stubbs, 2014; Spindler, 2013). In these years, the conscious use of natural resources and the prevention of damage to nature constitute the framework of sustainable development. Later, the concept of economy was included in the basis of sustainable development. In this context, the concept of sustainable development; It has begun to be explained as providing economic developments by protecting environmental values and taking into account the rights and benefits of future generations (Bozloğan, 2010). International meetings such as the Stockholm Conference and the Rio Summit, which were held after 1970, revealed the sociological and social aspects of sustainable development as well as the environment and economy. One of the most important steps regarding sustainable development is the determination of the global targets to be achieved by 2030 at the United Nations Sustainable Development Summit.

The Global Sustainable Development Goals

All societies worldwide exhibit the characteristics of a consumer society. With the population projected to reach eight billion in the near future, determining the extent to which resources can sustain the needs and desires of constantly consuming individuals is not as simple as forecasting population growth. Hence, it is crucial to consider the sustainability of limited resources. Efficient resource utilization and future planning become imperative at this juncture. In 2015, the United Nations General Assembly established 17 goals aimed at protecting the planet, eradicating poverty, combating inequality and injustice, among others. These goals, known as the Sustainable Development Goals, are expected to be achieved by 2030. They have been designed to be inclusive of all nations. However, attaining these goals necessitates the cooperation and collaboration of various stakeholders such as technology, business world, innovations, and new approaches to conducting business. The member states of the United Nations adopted the Sustainable Development Goals at the United Nations General Assembly in September 2015, and they came into effect on January 1, 2016. The goals involve 193 countries and are presented through descriptive phrases and illustrations, as shown in Table 1.

Table 1. *Sustainable Development Goals*

Objective Number	Objective Name
1	No Poverty
2	Zero Hunger
3	Good Health and Well-being
4	Quality Education
5	Gender Equality
6	Clean Water and Sanitation
7	Affordable and Clean Energy
8	Decent Work and Economic Growth
9	Industry, Innovation and Infrastructure
10	Reducing Inequality
11	Sustainable Cities and Communities
12	Responsible Consumption and Production
13	Climate Action
14	Life Below Water
15	Life on Land
16	Peace, Justice and Strong Institutions
17	Partnerships for Goals

Türkiye's Position in the Global Sustainable Development Goals

By the end of 2030, the member countries of the United Nations are expected to find solutions to both social, cultural and environmental problems gathered under 17 headings such as food insecurity and hunger, climate crisis, poverty, gender equality, providing quality education. These issues are grouped under the sustainable development goals. These goals are a universal call to action that includes the targets that UN member states are expected to achieve by the end of 2030. The 17 sub-headings and the number and names of countries that have achieved these goals are given in the table below.

Table 2. *Countries achieving the sustainable development goals*

Objective Number	Objective Name	Number of Countries Reached	Reachable Country Names
1	No Poverty	31	Dominica, Czechia, Denmark, Sweden, Kazakhstan, Germany, France, Poland, Russia, Finland, China, Malaysia, Thailand, Iceland, Austria, United Arab Emirates, Jordan, Azerbaijan, Malaysia, Norway, Bosnia and Herzegovina, Ukraine, Croatia, Hungary , Slovenia, Belarus, Ireland, Belgium, Netherlands, Bulgaria, MoldovaGermany, Germany, Hungary, Hungary, Hungary, Hungary, Slovenia, Norway, Moldova, Ireland, Ireland, Jordan, United Arab Emirates, Ukraine, Ukraine, Slovenia, Poland, Russia, Thailand, United Arab Emirates, United Kingdom, Netherlands, Netherlands, Moldova
2	Zero Hunger	0	-
3	Good Health and Well-being	0	-
4	Quality Education	16	Argentina, Peru, Uruguay, **Russia**, **Canada**, Canada, **Serbia**, Croatia, China, Cyprus, Serilanka, Moldova, **Finland**, Belarus, Japan, Japan, Mongolia, Serbia, United Arab Emirates, Vietnam
5	Gender Equality	5	Argentina, Norway, Nabimya, New Zealand, Sweden
6	Clean Water and Sanitation	0	-
7	Affordable and Clean Energy	11	Brazil, Costa Rica, Austria, Denmark, Georgia, Iceland, New Zealand, Portugal, Switzerland, Switzerland, Andorra
8	Decent Work and Economic Growth	2	Cuba, Slovenia
9	Industry, Innovation and Infrastructure	1	Japan
10	Reducing Inequality	9	Denmark, Algeria, Iceland, Norway, Belarus, Azerbaijan, Kazakhstan, Lithuania, Mali, Ukraine, Ukraine
11	Sustainable Cities and Communities	0	-
12	Responsible Consumption and Production	26	Guatemala, Hunduras, Haiti, Morocco, Senegal, Guinea, Congo, Congo, Zambia, Madagascar, Uganda, Kenya, Tanzania, Yemen, Nigeria, Cameroon, Ethiopia, Somalia, Turkmenistan, Uzbekistan, Afghanistan, India, Kombocia, Miyemmar, Philippines, Papua New Guinea,

			Korea
13	Climate Action	20	Nicaragua, Cuba, Bolivia, Morocco, Mauritania, Mauritania, Senegal, Mali, Mali, Guinea, Guinea, Burkinafaso, Madagascar, Sudan, Chad, Syria, Yemen, Afghanistan, Pakistan, India, Papua New Guinea, Kombocia, Korea
14	Life Below Water	0	-
15	Life on Land	4	Germany, Latvia, Lithuania, Estonia
16	Peace, Justice and Strong Institutions	2	Iceland, Japan
17	Partnerships for Goals	1	Norway

When the data for 2023 in the table above are analyzed, it is seen that the Poverty Reduction goal has been achieved the most. The number of countries achieving this goal is 31. The second goal is Responsible Consumption and Production. This goal was achieved by 26 countries. The third goal is Climate Action. The number of countries achieving this goal is 20. Zero Hunger, Good Health and Well-being, Clean Water and Sanitation, Sustainable Cities and Communities, and Life Below Water were not achieved by any country. Another striking data in the relevant table is that Türkiye is not mentioned in all 17 goals. Therefore, Türkiye's level of achievement of these goals is analyzed in detail.

There are some codes according to the level of realization of the United Nations Sustainable Development Goals. Thanks to these codes, the level of realization of the 17 goals can be easily understood on a country basis. There are five codes: blue, green, yellow, orange and red. The blue code indicates that the information has not been achieved, the green code indicates that the information has been achieved, the yellow code indicates that challenges remain, the orange code indicates that significant challenges remain, and the red code indicates that major challenges remain. Türkiye's current situation as of 2023 is summarized in the table below.

Table 3. *Türkiye's position on Sustainable Development Goals*

Objective Number	Objective Name	Türkiye's Situation	Description
1	No Poverty	Code Yellow	The challenges continue.
2	Zero Hunger	Code Orange	Significant challenges remain.
3	Good Health and Well-being	Code Red	Great challenges remain.
4	**Quality Education**	**Code Orange**	**Significant challenges remain.**
5	Gender Equality	Code Red	Great challenges remain.
6	Clean Water and Sanitation	Code Orange	Significant challenges remain.
7	Affordable and Clean Energy	Code Yellow	The challenges continue.

8	Decent Work and Economic Growth	Code Red	Great challenges remain.
9	Industry, Innovation and Infrastructure	Code Red	Great challenges remain.
10	Reducing Inequality	Code Red	Great challenges remain.
11	Sustainable Cities and Communities	Code Orange	Significant challenges remain.
12	Responsible Consumption and Production	Code Yellow	The challenges continue.
13	Climate Action	Code Red	Great challenges remain.
14	Life Below Water	Code Red	Great challenges remain.
15	Life on Land	Code Red	Great challenges remain.
16	Peace, Justice and Strong Institutions	Code Red	Great challenges remain.
17	Partnerships for Goals	Code Orange	Significant challenges remain.

When the relevant table is analyzed, it is seen that Türkiye has not achieved the green code in any of the 17 goals by 2023. Again, none of the 17 goals is marked with a blue code. This is an indication that the data is open for all 17 goals. When the relevant table is analyzed, it is seen that Türkiye is marked with a yellow code in three goals. This shows that there are still significant challenges in poverty reduction, Affordable and Clean Energy and responsible consumption and production. There are five goals where Türkiye is struggling with great difficulties to achieve the goal. These goals are zero hunger, quality education, clean water and sanitation, sustainable cities and communities, and partnerships for the goals. These goals are marked with an orange code. Current data shows that Türkiye is still struggling with major challenges in 9 of the 17 goals. All these goals are marked with code red. Gender equality, decent work and economic growth, industry, innovation and infrastructure, reducing inequality, climate action, Life Below Water, life on land, peace, justice and strong institutions are the goals marked with code red.

Goal 4: Quality Education

Countries must act together to achieve the goals set out in the Sustainable Development Goals. The current goals emphasize making the planet more habitable, using resources efficiently and carefully, and leaving future generations a world they can live in. Undoubtedly, environmental education has its place and importance in this context. Ultimately, it is through education that individuals recognize, understand and take action to protect the environment. The fourth Sustainable Development Goal is Quality Education. Quality Education requires countries to develop and change their education systems, policies and curricula with an awareness of sustainable development. At this point, inclusive and equitable quality education is explained in the context of lifelong learning and equal opportunity in education for all. The sub-goals expected to be achieved in order to realize the goal of Quality Education are determined as follows:

Table 4. *Goal 4 Quality Education 2030 targets*

No.	Targets
1	By 2030, ensure that all girls and boys complete free, equitable and quality primary and secondary education, leading to relevant and effective learning outcomes
2	By 2030, ensure that all girls and boys have access to quality pre-primary education that prepares them for primary education
3	By 2030, ensure that all women and men have equal access to accessible and quality technical education, vocational training and higher education, including university
4	By 2030, significantly increase the number of youth and adults with relevant skills, including technical and vocational skills for employment, decent work and entrepreneurship
5	By 2030, eliminate gender inequalities in education and ensure that vulnerable people, including persons with disabilities, indigenous peoples and children in vulnerable situations, have equal access to education and vocational training at all levels
6	Ensure that all young people and a large proportion of adults, both women and men, are literate and acquire numeracy skills by 2030
7	By 2030, ensure that all students acquire the knowledge and skills needed to advance sustainable development through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, world citizenship and appreciation of cultural diversity and the contribution of culture to sustainable development
8	Creating and improving education opportunities that are sensitive to children, persons with disabilities and gender equality, and creating safe, non-violent, inclusive and effective learning environments for all
9	By 2020, significantly increase the number of scholarships globally that offer developing countries, in particular least developed countries, small island developing states and African countries, the opportunity to enrol in higher education programs in developed and other developing countries, including vocational training programs and information and communication technology programs, technical programs, engineering programs and scientific programs
10	By 2030, significantly increase the supply of qualified teachers through international cooperation for teacher training in developing countries, in particular least developed countries and small island developing States

In order to better understand the purpose of Quality Education, it is necessary to explain the concept of education for sustainable development. Education for sustainable development is an approach that enables individuals to acquire the awareness of sustainable development and transform this awareness into action, develop their critical thinking and decision-making skills. Sustainable education and sustainable development are two concepts that support each other (Öztürk, 2017). Sustainable development education, which aims to raise generations with environmental awareness and sustainable behaviors, is seen as a very important tool to provide the necessary knowledge, skills, values, attitudes and behaviors to protect the environment (Erten, 2002; 2004). Another important feature of sustainable development education is that it is a transdisciplinary process that includes all disciplines. Therefore, it addresses both cognitive, affective and psychomotor domains (Erten, 2004; 2020). In a study explaining education and competencies for sustainable development from the perspective of science teachers; teachers stated that it is important to raise awareness of sustainable development in formal and informal environments and to include it in the curriculum and to articulate it in the curriculum in an integrated manner from pre-school to higher education (Şeker & Aydınlı, 2021). At the same time, when education is considered as a general concept, it is known that the concepts of freedom, human rights, law and justice are highly emphasized. It is possible for all these elements to meet with individuals through quality education (Aksoy, 2016). Another emphasis in quality education is the right to education. The Constitution of the Republic of Türkiye states that "No one shall be deprived of the right to education and learning. The scope of the right to education is determined and regulated by law. Education and training shall be carried out in line with Atatürk's principles and reforms, according to the principles of modern science and education, under the supervision and control of the State." Individuals cannot be prevented from benefiting from basic education regardless of their religion, language, sect, race, ethnic origin, political opinion or gender. In other words, education is a phenomenon that cannot be prevented, cannot be stopped and cannot be compensated for its absence.

Comparison of Countries in the Context of Quality Education

In the context of Quality Education, there are a total of 16 countries (Argentina, Peru, Uruguay, Russia, Canada, Serbia, Croatia, United Arab Emirates, Serilanka, Moldava, Finland, Belarus, Japan, Vietnam, Mongolia, China, Cyprus). Since making a comparison by examining the data of all countries within the scope of the research would increase the data density, the comparison was limited to three countries (Finland, Canada and Serbia). Another reason for selecting these countries is the difficulty in accessing the original documents. Except for Finland, Canada and Serbia, the original documents on the education systems of the other countries are in their own languages. The documents analyzed for the education systems of Finland, Canada and Serbia are both original and in English. The sources selected for Türkiye were the 2018 Science Curriculum and the Turkish National Education Law of 1971. In the 2018 Science Curriculum, since the Turkish National Education Law of 1971 was given as a source in the explanations about the structure of the curriculum, this law was also included.

In this chapter, the Sustainable Development Report for 2022 prepared by the University of Cambridge was accessed from the official web address specially prepared for this report (https://dashboards.sdgindex.org/). Türkiye 2018 Science Curriculum and 1971 Turkish National Education Law were accessed from the official website of the Board of Education (https://ttkb.meb.gov.tr/). For Canada 2022 Science and Technology Curriculum, the official website of the Ministry of

National Education of Canada (Ontarino) (https://www.dcp.edu.gov.on.ca/en/curriculum/science-technology) was used.

Documents related to the Finnish Education System were accessed from the official websites of the national education agency and the Ministry of National Education (https://www.oph.fi/en/education-system, https://www.oph.fi/en/statistics-and-publications/publications/finnish-education-nutshell). The 2020 Russian curricula were accessed from the original documents on the official web pages of the National Education Departments of the relevant country (https://prosv.ru/_data/umk/7427/toc_09-0041-01.pdf). Information on the Serbian education system was obtained from the official website of the Serbian Ministry of Education, Science and Technological Development (https://prosveta.gov.rs/).

Comparison of Türkiye and Finland in the Context of Quality Education

Goal 4, Quality Education, advocates an inclusive and equitable education process for all humanity. Another emphasis in this goal is lifelong education. Hunger, poverty, war and other unexpected and urgent crises, especially in developing countries, have undermined equality of opportunity in education. The decline in the number of children attending school, particularly in Africa, has reaffirmed the belief that achieving inclusive and quality education for all in United Nations member states is one of the most powerful and proven tools for sustainable development. Central to this goal is to ensure that all girls and boys complete free primary and secondary education by 2030. It also aims to ensure equal access to affordable vocational training, eliminate gender and wealth inequalities, and ensure access to quality higher education for all. The education systems of Canada, Russia, Finland and Serbia, which are among the leading countries in meeting these goals, and the Turkish education system were compared in order to reach recommendations that will further improve Turkish National Education with a sustainable development awareness. The similarities and differences in the education systems of the two countries are summarized in the tables below.

Table 5. *Comparison of the education systems of Türkiye and Finland*

	TÜRKİYE	FINLAND
FEATURES OF TEACHING PROGRAMS	-a monolingual country with a centralized education system -to be based on developments in science and technology -based on individual and community needs -producing knowledge -problem solving -critical thinking -gain values and skills -based on individual differences -based on metacognitive features -ensure meaningful and lasting learning	-education system linked to local government (***different)*** -based on equality of opportunity in education (***different)*** -ensuring the relationship between school and community (***different)*** school-specific teaching programs (***different)*** -based on individual differences ***(similar)*** -gain values and skills ***(similar)***

AIMS OF TEACHING PROGRAMS	-the right to education regardless of religion, language, race or ethnic origin -the right to lifelong general and vocational education and training -centralized curriculum ***Non-formal education*** -to provide literacy training -to raise individuals suitable for the age -to provide education on recognizing and protecting national culture	-the right to education without distinction of religion, language, race or ethnic origin ***(similar)*** -providing the right to lifelong general and vocational education and training, in particular for adults ***(similar)*** -equal opportunities in education ***(similar)*** -lifelong learning ***(similar)*** -accountability in education (***different)*** -to raise individuals with human values and ethical understanding (***different)***
THE PERSPECTIVE OF TEACHING PROGRAMS	-To raise individuals on the basis of values and competencies	-provide education for everyone, everywhere (***different)*** -raising individuals who are lifelong learners (***different)***
VALUES	-moral decision making -moral behavior	-preserving cultural values (***different)***
COMPETENCIES	-communication in the mother tongue -communication in a foreign language -core competencies in science/technology -digital competence -learning to learn -competencies related to citizenship -entrepreneurship -cultural awareness and expression	- learning to think and learn - cultural competence and interaction (***different)*** -observing the rights of self and others (***different)*** -building a sustainable future (***different)***
INDIVIDUAL DEVELOPMENT AND TEACHING PROGRAMS	-based on developmental stages -based on individual differences -based on lifelong learning	-based on the needs of schools (***different)*** create school-specific targets (***different)*** -achieving the main objectives of national education (***different)*** - based on developmental stages ***(similar)*** -based on individual differences ***(similar)***

One of the most fundamental features of national education in Türkiye and Finland is equal opportunity for all. In Finland, individual support is also provided to enable each student to achieve self-realization and reach their full potential. In both countries, there is teaching that is based on individual differences and provides value and skill development. The main difference between Türkiye and Finland is that in Türkiye there is a central curriculum prepared by the Ministry of National Education and the Board of Education, whereas in Finland schools are municipal institutions. In fact, the school management is directly appointed by the municipalities and the school's teaching staff is formed by the principal. This ensures a strong link between the school and the community. Each school in Finland has its own curriculum, management style and rules. Again, the achievement level of all schools in Finland is close to each other and therefore the quality of education is known to be high in every region of the country.

When the curricula of Türkiye and Finland are compared, the right to education without discrimination and equal opportunity in education draw attention. The emphasis on general and vocational education on the basis of lifelong learning is common. However, as a small difference, Finland also emphasizes lifelong learning on the basis of adult education. In the Finnish education system, it is considered important for students to have human values and ethical responsibility. In addition, students are expected to be individuals who can take responsibility for the welfare of society. Finland has also set a goal to create an accountable education system. To this end, all stakeholders are informed about the quality of the education system as a whole and are supported in the development of education policies.

When the two countries are compared in terms of the perspective of curricula, Turkish National Education aims to raise individuals on the basis of values and competencies, while Finnish National Education aims to provide education for everyone, everywhere. In Turkish National Education, values are included in the form of morality-based behavior and decision-making. In Finland, on the other hand, culture-based values are mentioned rather than morality. When a comparison is made in terms of competencies, it is seen that in Turkish National Education, there are competencies for communication, science and technology, citizenship and cultural differences. In Finland, on the other hand, learning to think and learn in order to ensure metacognition, respecting the rights of self and others, cultural competencies and intercultural interaction are mentioned. The existence of the Quality Education Goal is included in the competencies with the concept of building a sustainable future.

Finland has a school-based education system. The main purpose of the school is to ensure the personality development of the students, to support them in skill development, to provide them with the valid knowledge they will need in their professional life and to support their future education. Just like in Türkiye, schools in Finland do all this on the basis of developmental stages and individual differences.

Comparison of Türkiye and Canada in the Context of Quality Education

After Finland, another country compared to Türkiye is Canada. Information on these two countries is summarized in Table 6.

Table 6. *Comparison of the education systems of Türkiye and Canada*

	TÜRKİYE	CANADA
FEATURES OF TEACHING PROGRAMS	-a monolingual country with a centralized education system -to be based on developments in science and technology -based on the needs of the individual and society -producing knowledge -problem solving -critical thinking -gain values and skills -based on individual differences -based on metacognitive features -ensure meaningful and lasting learning	-a decentralized education system (***different)*** special state-specific curricula (***different)*** -based on developments in science and technology ***(similar)*** -generate knowledge ***(similar)*** -problem solving ***(similar)*** -critical thinking ***(similar)*** -gain skills ***(similar)***
AIMS OF TEACHING PROGRAMS	-the right to education regardless of religion, language, race or ethnic origin -the right to lifelong general and vocational education and training -centralized curriculum ***Non-formal education*** -to provide literacy training -to raise individuals suitable for the age -to provide education on recognizing and protecting national culture	-decentralized curriculum (***different)*** -offer the right to lifelong learning based on technology and science (***different)*** -developing critical skills through scientific and technological research (***different)*** -thinking about the bigger picture by making connections between science and technology and the changing world, including society, economy and environment (***different)***
COMPETENCIES	-communication in the mother tongue -communication in a foreign language -core competencies in science/technology -digital competence -learning to learn -competencies related to citizenship -entrepreneurship -cultural awareness and expression	-critical thinking and problem solving ***(similar)*** -innovation, creativity and entrepreneurship ***(similar)*** -self-directed learning ***(similar)*** -cooperation ***(similar)*** -communication ***(similar)*** -global citizenship and sustainability ***(similar)*** -digital literacy ***(similar)***
INDIVIDUAL DEVELOPMENT AND TEACHING PROGRAMS	-based on developmental stages -based on individual differences -based on lifelong learning	-based on problem solving (***different)*** -based on family, student, teacher and community needs (***different)*** -based on developmental stages -based on the collaboration of

	government, public resources and education partners (***different)***

The Canadian education system has no centralized ministry or department of education. According to the Canadian constitution, provincial governments are responsible for all levels of education. Therefore, it is different from the Turkish National Education System. In each province, the ministry of education has the authority to develop curricula and set the standard of assessment exams. Although there is no national ministry of education in Canada, there are departments in charge of determining and implementing the country's education policy. In Türkiye, there is a central curriculum prepared by the Ministry of National Education and the Board of Education.

When the two countries are compared in terms of the objectives of the curricula, it is seen that Canada has more science and technology based objectives. The concepts of non-formal education and lifelong learning, which are also emphasized in Turkish National Education, are addressed in terms of technology and science in Canada. While the Turkish Education System emphasizes equality in education, vocational education, literacy education, and raising individuals in accordance with the requirements of the age, Canada's aim is more specifically to raise individuals who think about the bigger picture by making connections between science and technology and the changing world, including society, economy and environment.

When the two countries are compared under the competencies heading, communication, science and technology, citizenship and cultural differences are mentioned in Turkish National Education. In Canada, on the other hand, higher order thinking skills, communication, individual learning and cooperation are mentioned. Sustainability is also included under this heading in Canada. Global citizenship and sustainability are other existing competencies. While in Türkiye there is a curriculum based on developmental stages, individual differences and lifelong learning, in Canada there is a curriculum based on solving daily life problems and developmental stages. Unlike in Türkiye, there is a program based on the needs of families, students, teachers and society. Again, the curricula are based on the cooperation of educational partners, government and public resources.

Comparison of Türkiye and Russia in the Context of Quality Education

The other two countries whose education systems were compared in this research are Türkiye and Russia. Information on these countries is given in the table below.

Table 7. *Comparison of the education systems of Türkiye and Russia*

	TÜRKİYE	RUSSIA
FEATURES OF TEACHING PROGRAMS	-a monolingual country with a centralized education system -to be based on developments in science and technology -based on the needs of the individual and society -producing knowledge -problem solving -critical thinking -gain values and skills -based on individual differences -based on metacognitive features -ensure meaningful and lasting learning	-an education system based on the Federal State Education Standard and the Estimated Core Curriculum for Basic General Education (***different)*** -(***different)*** curricula aimed at forming moral ideals -(***different)*** curricula aimed at building humanist ideals
AIMS OF TEACHING PROGRAMS	-the right to education regardless of religion, language, race or ethnic origin -the right to lifelong general and vocational education and training -centralized curriculum ***Non-formal education*** -to provide literacy training -to raise individuals suitable for the age -to provide education on recognizing and protecting national culture	-education on the basis of morality and ethics (***different)*** -education based on technology and science (***different)*** -awareness of the value of a safe way of life in the modern technological world (***different)*** -education based on environmental awareness (***different)*** -education based on tolerance (***different)*** -education based on the integration of arts and sciences (***different)***
THE PERSPECTIVE OF TEACHING PROGRAMS	-To raise individuals on the basis of values and competencies	- to raise individuals on the basis of values, competencies and levels of development ***(similar)***
VALUES	-moral decision making -moral behavior	In order to raise physiologically and psychologically Good Health and Well-being; (***different)*** -contributing to the happiness of the family -to help them gain an optimistic perspective on the world -maintaining a good mood -to create a healthy social environment to get away from the feeling of loneliness -encouraging them to pursue the

		arts so that they can become intellectuals -to create awareness that they are dependent on the environment and nature they live in -to create curiosity about scientific knowledge so that they can become knowledgeable -to gain responsibility for working to ensure well-being in his/her life
COMPETENCIES	-communication in the mother tongue -communication in a foreign language -core competencies in science/technology -digital competence -learning to learn -competencies related to citizenship -entrepreneurship -cultural awareness and expression	free and independent decision-making (***different)*** -making moral choices (***different)*** -expressing oneself and one's thoughts ***(similar)*** -caring for nature (***different)*** -communicate and interact effectively ***(similar)*** -explain the events around them scientifically (***different)***
INDIVIDUAL DEVELOPMENT AND TEACHING PROGRAMS	-based on developmental stages -based on individual differences -based on lifelong learning	-based on developmental stages ***(similar)***

The first striking difference between the education systems of Türkiye and Russia is the basic characteristic of the curriculum. In Türkiye, there is a central curriculum prepared by the Ministry of National Education and the Board of Education. In Russia, the existing curriculum is developed taking into account the requirements of the updated Federal State Educational Standard for Basic General Education and the Estimated Core Curriculum for Basic General Education. The program aims to form moral and humanistic ideals as a foundation. Comparing the objectives of the curricula, the Turkish National Education emphasizes equal right to education, lifelong learning, non-formal education, recognition and preservation of national culture, while in Russia the situation is different. The curriculum is based on morality and ethics, technology and science, environmental awareness, a safe way of life, and tolerance. The perspective of the curricula in both countries is similar. The emphasis on values, competencies and developmental level constitute the perspective of the curricula. Turkish National Education has a morality-based understanding of values. In Russia, on the other hand, values exist to create a healthy individual in every respect. For this, family happiness, having an optimistic outlook, building psychological resilience, being a social person, coping with feelings of loneliness, having intellectual knowledge, and taking responsibility for work are seen as necessities. Another value that gives an important clue in terms of Quality Education and sustainable development is the awareness of students that they are dependent on the nature they live in. The same emphasis is also seen in the competencies. Being attentive to nature and protecting the environment, having environmental knowledge is included as a competency. Other competencies emphasized in Russian National Education are making free and independent decisions, making moral choices, and effective communication. Turkish National Education lacks competencies in environmental knowledge and environmental awareness. In Türkiye, competencies related to communication, science and technology, citizenship, and cultural diversity are mentioned. Again, it seems important for both countries to create a curriculum based on individual differences, developmental stages and lifelong learning.

Comparison of Türkiye and Serbia in the Context of Quality Education

Another country compared with Turkish National Education is Serbia. Information on the two countries is summarized in Table 8.

Table 8. *Comparison of the education systems of Türkiye and Serbia*

	TÜRKİYE	SERBIA
FEATURES OF TEACHING PROGRAMS	-a monolingual country with a centralized education system -to be based on developments in science and technology -based on individual and community needs -producing knowledge -problem solving -critical thinking -gain values and skills -based on individual differences -based on metacognitive features -ensure meaningful and lasting learning	-centralized educational objectives under ministerial control (***different)*** -special teaching programs for schools (***different)*** -curricula based on inclusive education (***different)*** -gain values and skills ***(similar)*** -based on individual differences ***(similar)*** develop self-awareness (***different)*** -critical thinking ***(similar)*** -creative thinking ***(similar)*** - based on metacognitive features ***(similar)*** -ensure meaningful and lasting collaborative learning ***(similar)***
AIMS OF TEACHING PROGRAMS	-the right to education regardless of religion, language, race or ethnic origin -the right to lifelong general and vocational education and training -centralized curriculum ***Non-formal education*** -to provide literacy training -to raise individuals suitable for the age -to provide education on recognizing and protecting national culture	-providing equal right to education -providing interaction between family, society, economy, student (***different)*** -creating an education system that meets the needs of the society (***different)*** -inclusive education (***different)*** -decentralized curriculum (***different)*** ***Non-formal education*** -creating special education programs for adult education ***(similar)***

		-lifelong learning ***(similar)*** -offer vocational training -training to develop personal and national identity ***(similar)*** -provide education that supports full intellectual, emotional, social, moral and physical development according to developmental needs and interests (***differentiated)***
THE PERSPECTIVE OF TEACHING PROGRAMS	-To raise individuals on the basis of values and competencies	to raise individuals whose well-being is ensured and whose development is supported (***different)***
VALUES	-moral decision making -moral behavior	creating a safe non-violent environment (***different)*** -adopting a healthy lifestyle and becoming a physiologically and psychologically healthy individual (***different)*** -being aware of the importance of sustainable development, having awareness about the protection of nature, environment and environmental ethics (***different)*** -having a positive humanitarian attitude -have and respect children's rights, human rights, civil liberties and the ability to live in a democratically organized society (***different)*** -respect for racial, national, cultural, linguistic, religious, gender and age equality and equity, tolerance and diversity (***different)***
COMPETENCIES	-communication in the mother tongue -communication in a foreign language -core competencies in science/technology -digital competence -learning to learn -competencies related to citizenship -entrepreneurship	-effective communication ***(similar)*** -cultural awareness and expression ***(similar)*** -learning to learn ***(similar)*** -civic competencies ***(similar)*** -contemporary technological competencies ***(similar)***

	-cultural awareness and expression	
INDIVIDUAL DEVELOPMENT AND TEACHING PROGRAMS	-based on developmental stages -based on individual differences -based on lifelong learning	-based on developmental stages ***(similar)*** -based on individual differences ***(similar)*** -based on lifelong learning ***(similar)***

The first difference that draws attention when comparing the education systems of Türkiye and Serbia is the basic characteristic of the curriculum. In Türkiye, there is a central curriculum prepared by the Ministry of National Education and the Board of Education. In Serbia, on the other hand, there are basic educational objectives set by the Ministry of Education, Science and Technological Development. Within the framework of these objectives, each school has its own autonomous curriculum. In both Türkiye and Serbia, it is fundamental to provide equal right to education without any discrimination. The Serbian education system also has a clear emphasis on providing a quality, balanced, democratic, social and student-centered education that meets the needs of society. Both countries have curricula based on values and skills development. The Serbian education system also clearly emphasizes inclusive and individualized education.

A comparison of the objectives of the curricula reveals that both countries share the same right to education. Providing lifelong general and vocational education, planning activities on the basis of non-formal education, and training individuals for all the requirements of the age are other common points for both countries. It is clear that Turkish education aims to recognize and preserve national culture. Serbian education, on the other hand, emphasizes the development of national and personal identity. When Table 8 is analyzed, it is seen that there are features that distinguish Serbian education from Turkish education. This is seen as the aim to create an educational system that is oriented towards ensuring the interaction between family-community-economy-student and supporting full intellectual, emotional, social, moral and physical development according to developmental needs and interests. While Turkish education aims to raise individuals who have achieved values and competencies, in the other country the main goal is to raise individuals who have achieved prosperity.

In Turkish National Education, decision-making and behavior based on morality seem to be important. In Serbia, on the other hand, one of the main values is to raise individuals who are completely free from all forms of violence and who can create a safe environment. It is also important to raise individuals who have adopted a healthy lifestyle and are responsible for ensuring and protecting both their physical and psychological health. Another value that bears traces of the goal of Quality Education is to be aware of the importance of sustainable development, to protect nature and the environment, and to be conscious of environmental ethics. The value of living in a democratic society with awareness of all rights and freedoms and respect for diversity is also seen in this goal. It is clear that Serbia aims to raise individuals who are tolerant of all kinds of diversity, regardless of religion, language and race.

When the two countries are compared in terms of competencies, it is seen that there is no difference between them. Both countries mention competencies for communication, science and technology, citizenship and cultural diversity. Again, it seems important for both countries to create a curriculum based on individual differences, developmental stages and lifelong learning. Finally, for the goal of Quality Education, it is known that Serbia has launched a strategic action plan for all levels of education, implemented in 2021-2023, to improve all levels of education towards the relevant goals.

Conclusion

When the situation of Türkiye is analyzed in terms of the United Nations Global Sustainable Development Goals, it is an important result that Türkiye has not achieved the green code in any of the 17 goals. Türkiye continues to face significant challenges related to zero hunger, quality education, clean water and sanitation, sustainable cities and communities, and partnerships for the goals. At the same time, major challenges remain for Good Health and Well-being, gender equality, decent work and economic growth, industry, innovation and infrastructure, reducing inequality, climate action, life below water, life on land, peace, justice and strong institutions. It is said that Türkiye's failure to achieve the sustainable development goals may lead to a loss of balance in many environmental, economic and social issues (Demir and Atasoy, 2021). In addition, when all countries are analyzed in terms of the United Nations Sustainable Development Goals, it is seen that there is no country that has managed to achieve 17 goals simultaneously. Doğan and Yılmaz (2020) found that the D-8 countries are behind the goals and concluded that the wealth of the countries or the political leaders of the countries are not effective in achieving the goals.

In terms of the characteristics of the curricula of Türkiye and other countries, it is seen that the centralization feature of the Turkish curriculum is similar to that of Serbia, but differs from Finland, Canada and Russia. In three countries, decentralized education system is emphasized. At the same time, it is seen that these countries differ from Türkiye in terms of the unit preparing the curriculum. While the curriculum in Türkiye is prepared by the Ministry of National Education and the Board of Education, in Finland it is prepared by municipalities, in Canada by special units, and in Serbia by the Ministry of Education, Science and Technological Development. Er and Atıcı (2015) reported that curricula in Finland are determined locally and that parents, students, teachers and support staff play a role in the curriculum process. The flexible nature of the programs enables solutions to be produced with urgent intervention during any disruption (Demirkan, 2018).

When the objectives of Türkiye's and other countries' curricula are examined, it is seen that emphasis is placed on the objectives of equality in education, lifelong learning, raising individuals in accordance with the requirements of the age, and protecting national culture. It was determined that similar objectives were set with Serbia. In Finland, adult education, developing individuals who can take responsibility for ensuring the welfare of society, and accountability in education are emphasized. Demirkan (2018) in his study comparing the education systems of Finland and Türkiye, it is seen that, unlike Türkiye, in Finland, special team studies are carried out in the preparation of lifelong education programs for individuals and draw attention to lifelong learning where adults can receive education according to their different competencies and needs. It can be said that lifelong activities should be developed and increased in Türkiye. In Canada, the emphasis on science and technology in the curriculum objectives is particularly noteworthy. When İnce and Yıldırım evaluated the 5th grade science curriculum in the context of Canada and Türkiye, they found that it supports the Canadian science and technology findings. Due to the rapid advancement of technology and the increase in digitalization, emphasizing technology in curriculum objectives can provide the opportunity to raise more people in accordance with the needs of the age (Gök & Sayıcı, 2022). In Russia, awareness of the value of a safe way of life on the basis of morality and ethics, education on the basis of environmental awareness, education on the basis of tolerance, education on the basis of integration of art and science are different. The inclusion of environmental education may lead to an increase in the rate of raising environmentally conscious individuals (Erten, Köseoğlu, & Gök, 2022). In terms of our country, the fact that environmental education is not specified in the objectives of the curriculum may have a negative impact on our access to quality education.

When the perspective of the curricula of Türkiye and other countries is examined, it is seen that raising individuals on the basis of values and competencies is at the center in Türkiye. In terms of curriculum perspective, Türkiye is similar to Russia and differs from other countries in a few points. In Finland, the perspective of curricula is to provide education for everyone everywhere and to raise individuals who are lifelong learners. The fact that the state provides education services for individuals at all age levels and eliminates discrimination between individuals can be said to be on the way to creating a knowledge society (Genç, 2022). In Serbia, it is seen that raising individuals whose welfare is ensured and whose development is supported is at the center. In this respect, it can be said that Serbia attaches importance to social development and supports individual development in parallel with Türkiye.

When Türkiye and other countries are examined in terms of the values in the curriculum, it is seen that moral decision-making and moral behavior are the values aimed in Türkiye, while in Finland these values are to protect cultural values. In Russia, it is aimed to raise individuals who are healthy in every sense, who are happy in their families, who have a positive view of the world, who have a healthy social environment to get away from the feeling of loneliness, who are encouraged to be intellectual, who are encouraged to art branches to encourage them to be intellectual, who have gained responsibility for work, and who have curious values towards scientific knowledge. It can be said that Russia attaches importance to developing students as a whole and integrating them into society. In Serbia, it is seen that the values to be acquired are providing safe environments free from violence, creating Good Health and Well-being in every sense, having the importance of sustainable development, being individuals with positive attitudes, respecting children's rights, human rights, civil liberties and the ability to live in a democratically organized society, respecting racial, national, cultural, cultural, linguistic, religious, gender and age equality and equality, tolerance and diversity. In Serbia and Russia, unlike in Türkiye, there are statements that environmental protection and sustainable development are important and targeted. The formation of values related to environmental protection requires individuals to be interested in the environment. In this way, individuals can develop awareness towards protecting the environment (Erten, 2015). At the same time, students can gain environmental awareness through targeted environmental education (Erten, Köseoğlu, & Gök, 2022). It can be said that awareness of sustainable development goals, which our country lacks in this respect, should be increased and emphasized in the goals.

When the competencies in the curricula of Türkiye and other countries are examined, it can be said that there are some differences between Türkiye and other countries in terms of communication in mother tongue, communication in a foreign language, science and technology competencies, digital competencies, learning to learn, competencies related to citizenship, entrepreneurship, cultural awareness and expression. The values targeted in Finland are individuals' learning to think and learn, cultural competence and interaction, respecting the rights of self and others, and building a sustainable future. Based on our research findings, it can be said that both countries want to provide scientific process skills. Scientific thinking skills are the thinking skills we use in defining the problem and evaluating the results (Can Aran & Derman, 2020). In Canada, the desired competencies are critical thinking and problem solving, innovation, creativity and entrepreneurship, self-directed learning, collaboration, communication, global citizenship and sustainability, and digital literacy. It can be said that the concept of digital literacy attracted particular attention in Canada. Considering that digital literacy provides technological environments that facilitate the learning process and that these environments include skills such as problem solving and critical thinking, its importance should not be ignored (Şarlakkaya & Sülün, 2022). In Russia, it is seen that the targeted competencies are making free and independent decisions, making moral choices, expressing oneself and one's thoughts, being attentive to nature, communicating and interacting effectively, and explaining the events around them scientifically. In Russia, it is seen that the most prominent concept is individuals' caring attitude towards nature. This is possible with individuals with positive environmental attitudes (Erten, Köseoğlu, & Gök, 2022). It can be said that all these steps can contribute to the realization of quality education on behalf of the country. In Serbia, effective communication, cultural awareness and expression can be listed as learning to learn, competencies related to citizenship, and technological competencies for the age. In general, considering that 21st century skills consist of learning and innovation skills, life and career skills, information media and technology skills, it is seen that the programs of the countries cover these skill competencies (Şan & İlhan, 2022).

When individual development and curricula of Türkiye and other countries are compared, it is seen that Türkiye is based on developmental stages, individual differences and lifelong learning. While Türkiye has similarities with Russia and Serbia in terms of individual development, there are some differences with other countries. In Finland, it is seen that schools are based on the needs of schools, creating school-specific goals, reaching the basic goals of national education, taking developmental periods as the basis and individual differences as the center. It can be said that Finland takes regional needs into consideration, especially by targeting education according to schools (Er & Atıcı, 2016). Meeting the needs according to the region can enable the country to realize its sustainable development goals by providing regional development. Canada, on the other hand, draws attention to problem solving, family, student, teacher and community needs, and developmental periods. In Canada, it can be said that the welfare of the society is especially important.

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About The Authors

Sinan ERTEN, PhD, is Professor of Faculty of Education Department of Mathematics and Science Education at Hacettepe University in Ankara, Turkey. He holds a PhD in Didaktik Der Biyologie from Justus-Liebig Universitaet Giessen of Germany. His main area of interest is the study of environmental education, teacher education and sexual health education.

E-mail: serten@hacettepe.edu.tr , **ORCID:** 0000-0001-9546-2387

Pelin KOSEOGLU, is Research Assistant of Science Teaching at Süleyman Demirel University in Isparta, Turkey. She holds a master degree in Science Education from Ege University of Turkey. She is still continuing her doctoral education at Hacettepe University. Her main area of interest are science teaching, teacher training, environmental education and informal science education.

E-mail: pelinkoseoglu@sdu.edu.tr , **ORCID:** 0000-0002-5559-9052

Zubeyde GUNES, was born in the city of Kilis in 1996. She completed her primary and secondary education in the same city. She continued her education at Kilis 7 Aralik University for her undergraduate education in 2014 and her master's degree in 2018. STEM in science education in graduate education. She has conducted a study titled "Comparative Analysis of Applications with a Multiple Holistic Approach." Currently, she continues her education as a doctoral student in the field of science education at Hacettepe University, department of mathematics and science education.

E-mail: zubeydegnss@gmail.com , **ORCID:** 0000-0002-2003-9637

Muge OZKANBAS, was born in Adana in 1991 and completed her primary, secondary and high school education in Adana and her university education was at Çukurova University in science teaching and classroom teaching. She completed her master's degree at Çukurova University. Her master's thesis topic was on POGIL in science education and the application of POGIL in secondary school students. She is also working on misconceptions of pre-service science teachers on gases, secondary school students' views on science curriculum, burnout levels of science teachers. She is currently continuing her doctoral education at Hacettepe University. At the same time, she has been working as a science teacher in the Ministry of National Education since 2013.

E-mail: mgeozk3@gmail.com , **ORCID:** 0000-0002-9932-6662

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of paper titled "**Türkiye's position in the global sustainable development goals: A comparison on quality education**" belongs to the authors.

SECTION 2

SCIENCE EDUCATION

Misconceptions and Science Education

Ayse Ceren ATMACA-AKSOY
Necmettin Erbakan University

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Introduction

Concept

Individuals face many different events in their daily lives. Some of these events may involve different challenges or problems. Individuals need various information to solve these problems. This knowledge consists of concepts. Concepts serve as the basic structure for knowledge. Individuals will make sense of this information correctly if they structure the concepts appropriately. Scientific knowledge is knowledge produced from relationships among concepts. In this context, if a general definition is made, concepts can be expressed as the qualities of categories for definitions that reflect the relationship of individuals with the universe. Based on this definition, it would be reasonable to say that concepts are necessary to understand and comprehend the functioning of the universe (Riche, 2000). Concepts are structures that do not exist in concrete reality. They are the models of a phenomenon, thought or object in our minds. In this context, in the concrete world, we encounter not concepts but examples or representations of these concepts. In this case, in order to learn concepts, these representations and models should be well known. As mentioned before, acquiring knowledge is possible by learning concepts. Concepts are structures that organize mental processes in the learning process. The structuring of knowledge in the minds of individuals takes place in this process (Maclellan, 2005).

Although concepts have certain characteristics, these characteristics may change over time in order to adapt to the requirements of the current era. In this context, concepts can be redefined. These characteristics are;

- Concepts have a starting point, the original. These starting points are the first form of the relevant concept in the mind of the individual. Concepts have an origin in the minds of individuals.
- Concepts are classified in terms of their properties.
- The structures we call concepts are formed by direct or indirect observation of the properties of events, phenomena or objects. With direct observations, concrete features of concepts are formed. Indirect observations form the intangible properties of concepts.
- In some cases, certain features may be attributed to more than one concept.
- It is in close relationship with language. The structures we call concepts are expressed with words and vocabulary. In this context, concepts are also in close relationship with cultures. Concepts are affected by all elements affecting culture and gain meaning.

- Concepts are affected by social and individual differences. Changes in individuals' lives and the society they live in are reflected in the way they understand phenomena. Therefore, concepts may differ (Glock, 2010; Ozmen, 2017).

Concepts are structures that are made sense of and shaped in the minds of individuals. Some procedures are used in the process of making sense of and shaping concepts in the minds of individuals. Generalization is one of them. The process of generalization can be expressed as the process of classifying related objects, phenomena, thoughts or behaviors based on similar characteristics and naming these classes. There are many factors affecting this process. Improper realization of the generalization process causes the related concept not to be understood correctly. In this case, the concept is learned incorrectly. The fact that there are few observations and experiences in the generalization process is one of the factors that increase the likelihood of incorrect generalization. More or less generalization than necessary may cause complexity and uncertainty about the meaning of the concept and its relationship with other concepts. Another process used in the formation of concepts is the discrimination process. In this process, individuals base the concepts they are interested in on the different properties of phenomena or objects, that is, their dissimilar properties. The discrimination process is very important for the emergence of clarity between concepts (Wathall, 2016).

Individuals begin to observe the world and their environment from the moment they are born. As a result of these observations, they develop a perspective on events and phenomena and form their thoughts and ideas. The knowledge and ideas that individuals acquire through their own experiences, experiences and experiences may not have the same meaning as scientifically accepted concepts. The wrong meanings attributed to concepts in these contradictions appear as misconceptions. In its most basic definition, misconceptions are the interpretation of concepts in the minds of individuals in a way that is far from scientific and contradicts scientific acceptances (Baxter, 1985; Sewell, 2002).

Misconceptions

Learning is not only a process that takes place in educational institutions. Individuals acquire various knowledge by observing their environment and the world from the moment they are born. When they come to educational institutions, they come with a certain amount of prior learning and prior knowledge. This prior knowledge that individuals acquire as a result of their experiences plays an important role in the processes of making sense of new concepts and structuring scientific knowledge. The learning process is realized by restructuring prior knowledge in the mind with new concepts. In this context, an incorrect interpretation of the concepts in the old and prior knowledge will also affect the person's subsequent learning (Piaget, 1985). Learning is a lifelong process starting from the birth of an individual. The individual who learns throughout his/her life may occasionally learn incompatible with scientific facts under the influence of past experiences, prior knowledge or many environmental factors (Leonard at al., 2014). These learnings by individuals that contradict scientific facts have been named in different ways by different researchers over time. Some of these are;

- Pre-concepts (Ausubel at al., 1968; Clement, 1993)
- Alternative Frameworks (Driver & Easley, 1978),

- Conceptual Frameworks (Driver & Erickson, 1983),
- Children's Science (Gilbert at al., 1982),
- Prejudices (Osborne & Freyberg, 1985),
- Misconceptions (Clement at al., 1989; Novak, 1988),
- Intuitive Concepts (Bar, 1989),
- Misunderstandings (Helm, 1980; Spada, 1994),
- Students' Definitions (Nakhleh, 1992),
- Conceptual Difficulties (McDermott, 1993),
- Phenomenological Principles (DiSessa, 1993),
- Children's ideas (Osborne at al., 1993),
- First Concepts (Chi at al., 1994),
- Naive Beliefs (Caramazza at al., 1980),
- Ideas (Kuiper, 1994),
- General Sensory Concepts (Halloun & Hestenes, 1985; Spada, 1994),
- Faithless Beliefs (Hills, 1989),
- Alternative Concepts (Atwood & Atwood, 1996; Klammer, 1998),
- Wrong Conception (DiSessa & Sherin, 1998),
- Mental Models (Greca & Moreira, 2001; Vosniadou, 1994),
- Common Sense Concepts (Chi, 2005),
- İmmature Thoughts (Nehm & Ha, 2011)

Misconceptions are the structures formed as a result of individuals' unscientific interpretation of their environment, which they discover with their own experiences and experiences starting from an early age. The concepts obtained as a result of the individual's interpretation of the world with a non-scientific thought system also emerge as concepts that contradict scientific facts. Concepts that are made sense of in individuals' mental processes with reasoning systems that are far from scientific facts cause misconceptions (Gooding, & Metz, 2011). There are many individual factors that cause misconceptions. Individuals' past experiences, experiences and experiences, values and ethical judgments, norms and beliefs are some of them. Some learning under the influence of these factors may cause misconceptions because it is far from scientific (Griffiths & Grant, 1985).

Misconceptions are not the wrong answers that individuals give randomly in the face of an event or a question. The reason for misconceptions is not the lack of knowledge present in the individual. Misconceptions are a situation that arises as a result of incorrect or incomplete structuring of the concept in the mental processes of the individual. Individuals use their own unique thought systems in defining and making sense of their environment, which causes each individual to show differences in expressing their environment. If there are faulty or missing areas and gaps in this thought system, individuals tend to misinterpret concepts. This situation forms the basis of misconceptions. If individuals in the learning process understand a concept differently from its scientifically accepted meaning and learning is realized, this will affect their current and future learning and cause misconceptions (Mishra, 2020).

Misconceptions and errors are often confused. Misconceptions and errors are not the same content. All misconceptions are errors, but not all errors are misconceptions. Misconceptions are one of the reasons why errors occur. Misconceptions are constructs that cause erroneous scientific knowledge as a result of misunderstanding and structuring of the concept (Holmes at al., 2013). Individuals are not aware that their misconceptions are unscientific and inaccurate knowledge that contradicts scientific facts. From the viewpoint of individuals, that information is scientific, correct information. As a result of this situation, as long as misconceptions are not identified and corrected, they will cause the individual to perform wrong learning throughout his/her life. There are certain characteristics of these structures that are far from scientific and contradictory in the minds of individuals (Ibrahim & Sunanto, 2022).

These features have been addressed by various researchers at different times with different contents. In his study, Nachtigall (1990) listed the characteristics of misconceptions as individual-specific, sufficient in explaining limited events, inconsistent among themselves and with scientific knowledge, incoherent, resistant, and arising from individual, environmental and technological factors. The researcher added that these constructs can emerge in different ways in the same subject. Wessel (1998) emphasized in his study that misconceptions are structures that are formed as a result of individual experiences and can be seen in every individual without discrimination. Güneş (2005) emphasized in his study that misconceptions are resistant structures and are difficult to correct with traditional methods. The researcher stated that these structures cannot be detected with classical questions asked to individuals and that these structures have individual differences because they develop through the experiences of the individual.

Causes of Misconceptions

Taylor & Kowalski (2004) defined misconceptions as unscientific constructs that are contrary to scientifically accepted facts obtained through personal practice and experience. The acceptance of these structures as correct knowledge by individuals causes these structures to be resistant to change. Misconceptions, which are accepted as a scientific fact by the individual and take place in his/her mind, may cause the new information to be learned to be ignored or distorted. This situation may cause the misconception to continue or strengthen its existence in the mind of the individual. In this context, it is very important to understand the nature and sources of misconceptions in order to identify and correct these misconceptions (Menz et al., 2021).

Committee on Undergraduate Science Education (1997) listed the sources and causes of misconceptions as; information obtained by individuals from non-scientific sources, perspectives that contradict scientific facts, individuals trying to find solutions to the contradictions occurring in their mental processes with wrong or weak models, and the difference between daily and academic language. Önen (2005) listed the reasons for misconceptions in his study;

- Prejudices and unscientific pre-knowledge present in the individual,
- The relationships among concepts are not well structured in the learner's mind,
- The instructor uses unscientific and outdated teaching methods,
- The individual is not included in the learning environment, the individual experiences a passive teaching process,
- Failure to concretize intangible concepts

- Student misinterpretation of the differences between daily language and academic language,
- Non-scientific knowledge acquired as a result of daily experiences,
- Misinterpretation of erroneous information resulting from the misunderstanding of concepts,
- Teaching in classroom environments that are not suitable for teaching,
- Inappropriate readiness of the learner, teacher and course material,
- Not associating the acquired knowledge with daily life, not establishing a connection with daily life.

In another study on this subject, Costu at al. (2007) stated the reasons for the occurrence of misconceptions in six items in general. These are; incorrect completion or interpretation of missing information in the learner's mind, experiments conducted for concretization, methods used in the presentation of course content, prior knowledge and experiences of the individual, textbooks used, failure to establish relationships between words and terms. The researchers emphasized that incompatibility, inaccuracy or deficiency in these six factors would cause misconceptions in the learner.

The reasons for the formation of misconceptions are that the teaching does not reach maturity in the learner's mind, new learning is carried out without determining the status of the individual's prior learning, incompatible, different expressions and visuals are used for a concept, the material used is not suitable for the nature and characteristics of the concept, generalizations made more or less than necessary, memorized information, teaching too many concepts at the same time, insufficiency of prior knowledge, inability to establish a relationship between new and old concepts. Incomplete or incorrect information in teaching materials such as textbooks and posters used as resources in lessons, content and visuals that cause misinterpretation, and incorrect information obtained from non-academic pages or sites on the internet are among the elements of today's technological age that cause misconceptions. In addition, the instructor's presentation of his/her own interpretations and explanations to the learner as scientific knowledge, the use of foreign terms with unknown meanings, incomplete, inaccurate, incompatible or outdated materials are among the factors that cause misconceptions (Taylor & Kowalski, 2014).

Methods Used in Determining and Eliminating Misconceptions

Misconceptions are resistant structures that are closed to change. In this context, they are permanent. Misconceptions are very difficult to detect, eliminate and correct. However, it is imperative to correct these misconceptions in order to realize learning in a correct and scientific way. The first step to be taken to correct misconceptions is to identify these misconceptions clearly and accurately. Many different methods have been used to identify misconceptions. Since some of these methods have more disadvantages than others, their use is not recommended today. Examples of methods used to identify misconceptions include interviews, multiple-choice tests, POE (predict-observe-explain) method and progressive diagnostic tests (Maharani at al., 2019; Maskill & Cachapuz, 1989; Liew & Treagust, 1994; Putri at al., 2021).

Interview

The interview method is an effective method used to determine an individual's structures such as feelings, thoughts, attitudes and beliefs. This method is a process carried out by two individuals expressing themselves verbally. In this process, communication is usually established with the question and answer technique. Although it is an effective and common method in determining misconceptions, the analysis and data collection process takes a considerable amount of time (Chen et al, 2009).

Multiple Choice Tests

Multiple-choice tests are one of the methods used to identify misconceptions. These tests have the advantages of collecting and analyzing a large number of data in a short time. However, the use of these tests to determine misconceptions is not preferred today due to the fact that these tests cannot determine the reason for giving the answer and the questions are closed-ended, that is, they force the student to choose one of the available options. Since the reason for the student's answer cannot be determined in multiple-choice tests, it does not provide information about the cause of the misconception. In this case, it is not clear whether the error is a misconception or a lack of knowledge (Cakır & Aldemir, 2011).

Predict-Observe-Explain Method

The POE method is one of the methods used to identify misconceptions. The first step of this strategy is the guess phase. At this stage, the learner is presented with a situation and asked to make a prediction. The second stage is the observation stage. At this stage, learners make observations through experiments and applications. They obtain information. The last stage is the explanation stage. At this stage, learners compare their predictions in the first stage with the results in the observation stage. If there is a discrepancy between predictions and observations, they try to explain the reasons for this discrepancy (Kibirige at al., 2014). In this context, misconceptions in learners can be identified with this method. With the comments and explanations they will make during the explanation phase, information about the causes of these misconceptions will also be revealed (Chen at al., 2018).

Progressive Diagnostic Tests

Progressive diagnostic tests are also one of the widely used methods to identify misconceptions. Although progressive diagnostic tests appear in the literature as two-, three- or four-tier tests, four-tier diagnostic tests are more in demand nowadays. Two-tier diagnostic tests have all the advantages of multiple-choice tests and also provide the reason for the student's answer. The first stage in these tests is a classic multiple-choice question. The second stage asks for the reason for the answer given in the first stage. The second stage can be multiple-choice or open-ended, sometimes both. The disadvantage of these tests is that they do not question whether the student is sure of his/her answer. This causes these tests to be unable to distinguish between lack of knowledge and misconceptions. Two-tier tests were updated and three-tier tests were created. The difference of the three-tier tests from the two-tier tests is the addition of a confidence step as the last step. However, the

fact that this confidence step is single does not provide clarity about whether the individual is sure of his/her answer to which step. This is a disadvantage of three-tier tests. Finally, in order to overcome the disadvantages of three-tier tests, four-tier tests were created with the addition of the second confidence step. In the four-tier tests, the confidence steps added after the content and reasoning steps provide clear information about which of the answers the individual is sure of or not. With the four-tier diagnostic tests developed, 12 types of lack of knowledge, false positives, false negatives, scientific knowledge and misconceptions can be identified. The disadvantages of four-stage tests are that they take a long time to administer and analyze, and the possibility of the answers of first and third stages affecting each other (Caleon & Subramaniam, 2010a; Caleon & Subramaniam, 2010b; Sreenivasulu & Subramaniam,2013; Taslıdere,2016; Treagust & Duit, 2008).
What needs to be done after determining misconceptions is to eliminate these misconceptions. Unless the misconceptions are eliminated, they will pose a risk for the future learning of the individual and will cause mislearning. In this context, the elimination of misconceptions is very important for the continuation of education and training activities in accordance with their purpose. Many different methods are used to eliminate misconceptions. Concept maps, conceptual change texts, concept cartoons are examples of methods commonly used to eliminate misconceptions.

Concept Maps

Concept maps are one of the methods used to ensure meaningful learning (Martin et al., 2000). Concept maps provide learners with the opportunity to associate new concepts with existing concepts while acquiring new concepts, and in this context, to realize meaningful and deep learning. It presents the relationships between concepts with a holistic approach. In addition, as a visual material, it enables the concept or information to take place concretely in the mind (Liu at al., 2009; Tekkaya, 2003).

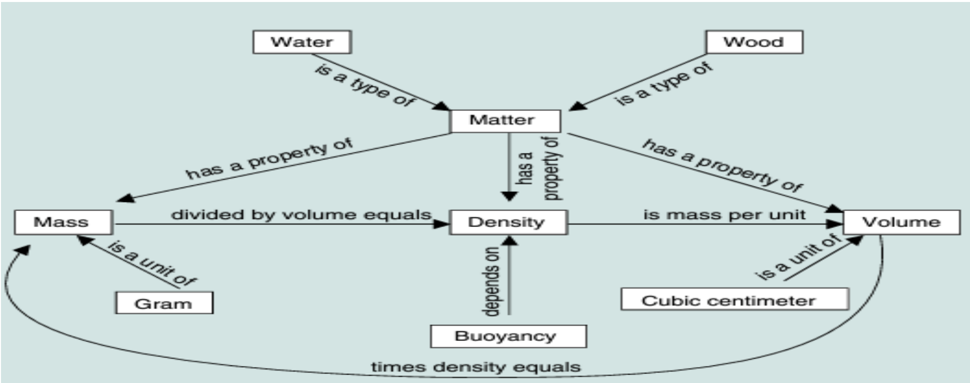

Figure 1. *Concept Map on Density and Buoyancy (Vanides at al., 2005)*

Conceptual Change Texts

The aim of conceptual change texts is to change the wrong information available in the learners with correct information. Conceptual change texts are texts that clearly reveal the incompatibilities and contradictions between scientifically validated knowledge and misconceptions. In conceptual change texts, the misconception existing in the learner is included in the text. The difference between misconceptions about the related concept and scientific knowledge is emphasized. Thus, the learner realizes his/her misconception and this misconception is eliminated with scientific knowledge (Beerenwinkel at al., 2011; Hynd, 2001).

Concept Cartoons

Concept cartoons are drawings prepared with the aim of arousing curiosity in the learner, creating a discussion environment and distinguishing between correct scientific knowledge and misconceptions (Long & Marson, 2003). There are several characters in concept cartoons. The dialogues between these characters emphasize the differences between correct and incorrect information. While one of the characters in the cartoon defends the scientifically valid idea, the others defend ideas that are not scientifically valid and contain misconceptions. In this context, learners can clearly see the difference between scientific and non-scientific ideas and eliminate their existing misconceptions (Morris at al., 2007).

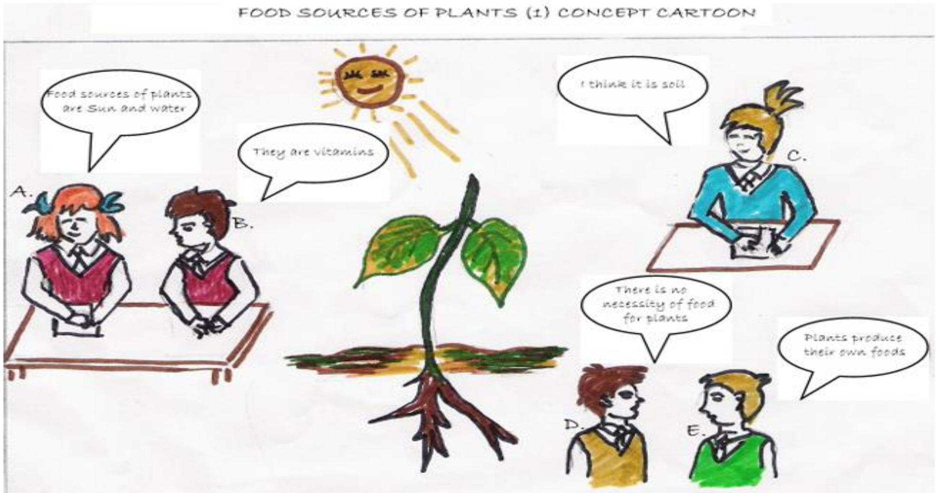

Figure 2. *Concept Cartoon on Nutrient Sources of Plants* (Ekici at al., 2007)

The Importance of Misconceptions in Science Education and Examples

All efforts to understand one's environment, the structure and functioning of the world in which one lives are defined as science. Individuals have to understand the order that exists in their environment and the functioning of this order in order to continue their lives. Existing knowledge can be made sense of by understanding this order. In this context, new scientific knowledge is produced. Science is a branch of science that includes many sub-disciplines. Interdisciplinary relations are very important for science. Science is life itself (Fuller, 2004).

This is the age of knowledge and technology. Therefore, it is the age of science. New information is produced every day and new inventions and discoveries are made. It is one of the duties and responsibilities of the science discipline that individuals and societies can follow and keep up with the developments and changes in science and technology, in short, to have the literacy skills of these fields. In this context, the realization of science education in accordance with its purpose, correct and complete is very important in terms of social as well as individual (Emrahoğlu & Ozturk, 2010). The sole purpose of science education is not only to transfer sub-disciplinary and interdisciplinary knowledge to individuals. Science is a living discipline. In this context, it is one of the aims of science to provide individuals with skills and behaviors appropriate to the requirements of the age in which they live. Individuals who have received a well-equipped science education continue their lives as individuals who are open to change and development that may occur in their environment, are productive, and have 21st century skills. In this context, they can use all the knowledge, skills, attitudes and behaviors they have gained in a beneficial way for their nation and the whole world (Afandi at al., 2018; Yıldız & Zengin, 2021). The importance of science education has been recognized by all societies. In this context, various methods and strategies have been developed over time to provide effective and efficient science education. When we look at today's education system, it is seen that concept-oriented teaching and education has gained importance. This situation necessitates the correct and complete teaching of key concepts in science (Wright & Perna, 1992).

Science contains a large number of intangible concepts due to its disciplines and nature. One of the main reasons why science is known as a difficult science is these intangible concepts. When learners do not make sense of intangible concepts in their minds adequately and correctly, they may create incomplete learning or misconceptions. This situation leads to failure (Soecharto at al., 2019). There are many examples of misconceptions in science disciplines. As mentioned before, science is a complex science involving interdisciplinary relationships. In this context, it contains many intangible concepts. Misconceptions that arise as a result of structuring and interpreting these concepts away from scientific understanding are very common in science education. As in all educational sciences, the biggest obstacle to the effective and efficient realization of science education is the misconceptions existing in individuals (Günbatar & Sarı, 2005). Some examples of misconceptions identified by various studies and researchers in science disciplines are presented below. Three examples were selected for each sub-discipline.
Examples of misconceptions in Physical Science;

- Force is directly proportional to speed, not acceleration (Eryılmaz & Tatlı, 2000).
- Energy cannot be stored (Solomon, 1985).
- If an object is moving, there are forces acting on this object in the direction of its motion (Kolçak at al., 2014).

Examples of misconceptions in Chemistry Science;

- Electrons have a positive charge (Özmen, 2004).
- The shells in which electrons are embedded are called atomic orbitals (Park & Light, 2009).
- When gases are produced from the combustion reaction of a liquid and a solid, the total mass decreases even if the system is closed (Chang at al., 2010).

Examples of misconceptions in Biological Science;

- Rain falls when clouds evaporate (Cardak, 2009).
- While all animal cells are independent of each other, plant cells are connected to each other by cell walls (Dikmenli & Cardak, 2004).
- Fermentation is respiration without oxygen (Sadava at al., 2014).

Examples of misconceptions about Astronomy Science;

- The biggest star is the Pole Star.
- All stars are white in color.
- All objects that can be seen in space are planets (cited in Keles & Babaoğlu, 2022).

Examples of misconceptions in Environmental Science;

- The greenhouse effect is a completely artificial phenomenon (Atmaca Aksoy, 2022).
- The main reason for the increase in skin cancer cases is global warming (McCuin at al., 2014).
- The greenhouse effect is a purely anthropogenic phenomenon (Fajarini at al., 2018).

Examples of misconceptions about Earth Science;

- There are no volcanoes in regions with cold climates (Dove, 1998).
- Summer is warmer than winter because the earth is closer to the sun in summer (Schoon, 1992).
- Earthquakes occur in regions with hot climates (Mark, 2013).

When the literature is examined, it is seen that many researchers have carried out studies to identify and eliminate misconceptions in terms of science disciplines. Misconceptions are the most serious obstacle to science education. The fact that these structures are resistant and permanent structures creates a risk for the current and future learning of the individual and ensures that education and training is not realized in an effective and efficient manner in accordance with its purpose. In this context, individuals who have learned incorrectly will use this unscientific knowledge in their daily lives as long as they live and even transfer it to other people. This situation reveals the importance of identifying and eliminating misconceptions (Yagbasan & Gulcicek, 2003).

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About the Author

Ayse Ceren ATMACA-AKSOY, PhD**,** is a research assistant at Necmettin Erbakan University, Ahmet Kelesoğlu Faculty of Education, Department of Science Education. She completed her doctoral education at Hacettepe University, Department of Science Education in 2022. Her research interests are sustainable development, environmental education and misconceptions.

E-mail: acatmaca@erbakan.edu.tr, **ORCID:** 0000-0002-4908-7157

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of paper titled "**Misconceptions and science education"** belongs to the author

Place-based SSI Instruction: Current Status and Prospects

Umran Betul Cebesoy
Usak University

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Introduction

Socioscientific issues (SSI) have been prevalent over two decades in science education. While these issues have a significant role in the advancement of scientific literacy (Zeidler et al., 2019), they also develop moral reasoning, ethical consideration, and social and character development of individuals (Zeidler & Lewis, 2003; Zeidler & Keefer, 2003; Zeidler et al., 2005). A wide range of issues including genetic engineering, cloning, renewable energy, genetically modified foods, and climate change could be labeled as SSI since they are complex and ill-structured issues that do not have clear-cut solutions (Herman et al., 2020; Sadler, 2004a; Sadler & Zeidler, 2004). Among them, some are closely related to the environment. Individuals need to make informed decisions while considering varying viewpoints, environmental considerations, and nature itself (Herman, 2018; Herman et al., 2020). However, to develop informed decision-making skills of individuals, appropriate contexts where they could develop these skills in addition to developing affective and cognitive skills need to be provided (Herman, 2020; Sadler, 2004b). This is possible with deliberately and intentionally designed SSI-based instruction. Place-based SSI instruction has been lately used for this purpose in science education research (e.g., Herman, 2018; Herman et al., 2019, 2020). This chapter first explored the meaning of place-based education and the characteristics of place-based instruction. Then, place-based science education research and how it can be adapted to SSI-based instruction are presented.

Place-based Education

Place-based education (PBE) can be described as the process of teaching ideas in different disciplines such as language, arts, mathematics, social studies, science, and other subjects across the curriculum by using the local community and environment as an integrating framework for learning on all levels (Powers, 2004; Sobel, 2004). The power of PBE lies in leveraging a sense of place. PBE uses the sense of place to connect students to local communities and the wider world (Teton Science Schools, 2019; Woodhouse & Knapp, 2000). The term "sense of place" can be described as a collection of personal or collective meanings and attachments to specific locations (Semken, 2005).

This educational strategy emphasizes hands-on, real-world learning experiences (Knapp, 2005; Sobel, 2004). PBE is not a new development, and it backs to an early experiment in connecting student interests to contextual learning in the neighborhood (Smith, 2002). In this sense, PBE is closely related to outdoor education. It typically incorporates traditional outdoor education methodologies as promoted by John Dewey (Woodhouse & Knapp, 2000). Like outdoor education, PBE also has similar characteristics to environmental education (EE) such as being interdisciplinary and learner-centered as well as requiring informed decision-making. In addition, both help students to develop and comprehend their "sense of place" by considering it not only from an ecological but also from an economic and cultural standpoint. The difference between the two lies in the scope and priority. While PBE offers a much wider scope, EE concentrates specifically on issues about the environment and sustainability and typically takes place in informal learning environments like camps, nature centers, and outdoor education institutes. PBE can be implemented anytime and anywhere, including formal learning environments like K–12 schools, colleges, and universities (Teton Science Schools, 2019).

Sense of place is an important attribution of PBE (Semken, 2005). Sense of place includes three important aspects that also need to be addressed during PBE:
(a) cognitive domain (knowledge as place meaning),
(b) affective domain (place attachment; attitudes and preferences as place meanings)
(c) psychomotor domain (kinesthetic abilities acquired or used in particular physical locations) (Semken & Freeman, 2008).

The main benefit of PBE is that it helps students feel more a part of their communities and the areas they live in (Smith, 2002). In this sense, students' sense of place is enriched through PBE (Semken, 2005). In addition to creating stronger ties between the community and learners, it increases students' appreciation for the natural world and fosters a stronger commitment to serving as active, contributing citizens (Sobel, 2004). PBE also raises student achievement while also enhancing a community's social and economic vitality (Powers, 2004; Sobel, 2004). Similar benefits are also endorsed for teachers: It enriches teachers' sense of place, enables them to access a wide range of perspectives, and resources, and fosters their confidence (Powers, 2004; Semken et al., 2017; Semken, 2005).

Characteristics of PBE

PBE has some basic characteristics: (a) the curriculum is based on surrounding phenomena; (b) the curriculum integrates self, others, and place by considering economic, multigenerational, ecological, and multicultural dimensions; (c) it focuses on learner experiences which make learners 'knowledge creators'; (d) students' questions and concerns play a central role in determining the context that is studied; (e) it frequently crosses the boundaries between the school and community; (f) student work is evaluated based on its contributions to sustainability and well-being of the community, and (g) it is interdisciplinary by nature (Smith, 2002; p. 593; Woodhouse & Knapp, 2002, p. 2).

Place-based Science Education Research

According to Sobel's (2004) definition of PBE, it could be used to teach ideas in different disciplines by using the local community and environment. PBE has long been used in science education research (Buxton, 2010; Lim & Calabrese Barton, 2006, Semken, 2005; Semken & Freeman, 2008; Semken et al., 2017; van Eijck & Roth, 2007a, 2007b, 2009). Semken et al. (2017) argue that indigenous (e.g., Native Americans, Native Alaskans), rural, and underrepresented groups (e.g., African Americans and other ethnicities) are forced to relocate from the places that are most meaningful to them. Consequently, Semken (Semken, 2005; Semken & Freeman, 2008) developed place-based geoscience programs for culturally diverse groups (e.g., native Americans). In such a study, Semken (2005) created an Indigenous Physical Geology course, utilizing the geology, physiography, and hydrology of the Colorado Plateau which is based on the Colorado Plateau and Navajo culture. The semester-long course consisted of 12 modules covering various and significant facets of Plateau geology, climate, and environmental quality. He observed significant gains in students' place attachment and increased understanding of place.

In another study, Buxton (2010) developed a place-based project (The Social Problem Solving through Science) for disadvantaged middle school students about local environmental challenges with implications for human health and well-being. The results revealed that the students enhanced their science content knowledge and developed their sense of place as members of society.

Lim and Calabrese Barton (2006) explored how low-income urban middle school students' sense of place was leveraged and scientific ways of thinking enhanced during an environmental class that included field trips to school neighborhoods and playgrounds. The results revealed that students' scientific ways of thinking were enhanced. In addition, the sense of place approach provided learning opportunities for connected science. The authors addressed the importance of aligning science learning with the students' sense of place. If aligned carefully and science learning is contextualized in the students' sense of place, learning may become interesting, inspiring, and significant for the learners.

In another study, van Eijck and Roth (2007a) provided assistance to middle school teachers in the area to develop a curriculum that centers on the watershed of a single community in western Canada. The curriculum allowed students to study the main creek that drains the watershed and learn about biology, chemistry, physics, and environmental science. The curriculum was developed iteratively and involved scientists, environmentalists, water technicians, farmers, elders from the Aboriginal community, local politicians, and parents. The results were promising: The curriculum developed succeeded in increasing the scientific literacy of students. Student learning exceeded what they would have learned in a typical science class. In addition, they guided their neighborhood toward a sustainable future. These students took part in changing their community rather than just memorizing words for an exam or copying notes that would be forgotten after the unit.

Exploring narratives of scientists and aboriginal people's explanation of a local issue about the salmon run, van Eijck and Roth (2007b) concluded that traditional ecological knowledge and scientific knowledge are simultaneously available but also are incommensurable and irreducible to each other. The authors pointed out that even though the nature of scientific knowledge implies local heterogeneity, dynamics, and plurality, it is vice versa in local contexts.

The literature summarized above points out the importance of place-based science education for different groups (indigenous, rural, underrepresented, and economically disadvantaged groups). While it could be used in rural and local settings (van Eijck & Roth, 2007a; Semken, 2005), it could also be adapted to urban settings as in Lim and Calabrese Barton's (2006) study. The physical locations could be recreational (playground leisure: Lim & Calabrese Barton, 2006) or occupational (field trips: Lim & Calabrese Barton, 2006; Semken, 2005; van Eijck & Roth, 2007a). Nevertheless, the studies reported important gains for students: increased science content knowledge and scientific understanding (Buxton, 2010; van Eijck & Roth, 2007a), enhanced scientific ways of thinking (Lim & Calabrese Barton, 2006), being active members of their community (van Eijck & Roth, 2007a), leveraged sense of place and place attachment (Lim & Calabrese Barton, 2006; Semken, 2005; van Eijck & Roth, 2007a). At the same time, Lim and Calabrese Barton (2006) pointed out the careful alignment and contextualization of science in students' sense of place. Specific features of place-based science education were addressed: For instance, Semken (2005, p.153) identified five essential characteristics of place-based geoscience education that also can be applied to place-based science education:

1. Its content needs to specifically focus on a location's geology and other natural features.
2. It incorporates—or at least, recognizes—the various meanings that place has for the community, the students, and the teacher.
3. It offers knowledge through firsthand encounters in that place or in a setting that vividly suggests that location.
4. It encourages and supports residing in a place by sustainably considering environmental and cultural aspects.
5. It enhances the instructor's and students' sense of place.

Place-based SSI Instruction and its Premises

PBE has been used more and more to promote SSI engagement (Herman et al., 2013). By combining PBE with SSI, students have firsthand interactions with individuals and the environment that are affected by environmental SSI (Herman et al., 2020). Place-based SSI instruction aims to strengthen students' sense of place and attachment to real "others" (people and the environment) that are impacted by SSI to promote ecological and cultural sustainability (Herman et al., 2018).

The studies using place-based SSI instruction demonstrated promising evidence. In one of the earlier studies, Herman et al. (2013) investigated undergraduate biology majors' attitudes toward waterways and content knowledge after participating in a local waterway cleanup project. The participants showed significantly higher pro-environmental attitudes and content knowledge about waterways over time than their peers who did not participate in the program.

Another study by Herman et al. (2018) explored how students' affective responses to nature and those affected by environmental issues were affected by place-based SSI instruction. This time the authentic setting was Yellowstone wolf reintroduction. The results revealed that the students' levels of compassion and care for people and the environment affected by environmental issues significantly increased. By using the same authentic context, Herman et al. (2019) explored how secondary students' trophic cascade explanations changed after participating in place-based SSI instruction. The results showed that students' trophic cascade explanations became significantly more accurate and complex implying a more nuanced nature of science (NOS) view.

Herman et al. (2020) explored how undergraduate emotive reasoning developed after participating in a local place-based SSI instruction held in the Greater Yellowstone Area. The researchers revealed that more students showed moderated concern (higher sense of emotive reasoning) and deep compassion for nature and people who experience difficulties stemming from environmental SSI after participating in place-based SSI instruction.

A more recent study by Herman et al. (2023) explored how fourth-grade students' NOS views developed after participating in the Missouri River Socioscientific Issues Program. The program included after-school classroom and field trip instruction that was centered on the local Missouri River ecosystem, endangered species, and human use issues, as well as how scientists investigate these issues. When compared to the control group who did not participate in the Program, the participating students articulated much more nuanced, non-stereotypical opinions about how scientists investigate and comprehend Missouri River SSI and what role science plays in finding solutions to those problems.

As seen Herman and his colleagues (Herman et al., 2018; 2019; 2020; 2023) extensively used local authentic cases for place-based SSI instruction. Different contexts were used for place-based SSI instruction as well. In such a study, Powell (2021) used the hydraulic fracking issue as a local issue for place-based SSI instruction to develop middle school students' evidence-based reasoning and critical thinking dispositions. Powell (2021) reported that students receiving place-based SSI instruction could engage in evidence-based reasoning about the advantages and disadvantages of hydraulic fracturing for the environment, the economy, and public health by using the data they had gathered from their investigation. Moreover, the students were able to create persuasive arguments for and against authorizing hydraulic fracturing in their states by applying their scientific and engineering knowledge.

In the Korean context, Kim et al. (2020) developed a place-based SSI instruction by using fine dust, abandoned pets, and recycling issues and explored how the instruction affected middle school students' sense of place and character development. The statistical analysis revealed that both scores gathered in sense of place and character development improved after participating in the place-based SSI instruction.

Haze pollution, a local environmental problem in the northern region of Thailand, was used as a local authentic context by Ladachart et al. (2020). They interviewed 17 students (grades 7–12) by using an open-ended questionnaire on haze pollution about the causes, processes, effects, and solutions. They indicated that as haze pollution is a local SSI, it could be used as a context for place-based learning progression to develop a more sophisticated and consistent understanding of the causes, consequences, and solutions of haze pollution.

Place-based SSI instruction was used in different studies in Turkey as well. In such a study, Capkinoglu et al. (2020) used three different modalities (implementing outdoor field trips, reading newspapers about SSI, and visual and verbal presentations about SSI) by using five local SSI to investigate the quality of argumentation by middle school students. They concluded that the newspaper group performed better when compared to other groups (field trip and presentation groups) while the field trip group had the lowest overall quality of argumentation out of all three groups even though this group interacted with different stakeholders at the site. Capkioglu et al. (2020) interpreted this interesting finding that firsthand experiences with SSI in real-world settings might be insufficient to produce compelling arguments unless the instruction about rational analysis of the situations, outcomes, and individuals affected by those SSI were included.

Lastly, Avsar Erumit et al. (2023) developed role-play activities that were integrated into place-based SSI instruction about climate issues. They examined the development of preservice teachers' understanding of the NOS views and their values as global citizens after participating in the place-based intervention. The results revealed that the place-based SSI intervention improved participants' perspectives on NOS and fostered their values as global citizens.

The literature reviewed here attests to the global significance of place-based SSI instruction. Different studies in different countries adopted place-based SSI instruction by using various local issues. The results pointed out important outcomes for the participants such as much more nuanced NOS views (Avsar Erumit et al., 2023; Herman et al., 2019; 2023), increased content knowledge (Herman et al. 2018), more sophisticated and consistent understanding of local SSI (Ladachart et al. 2020), a higher sense of emotive reasoning and deep compassion for nature and people who experience difficulties stemming from environmental SSI (Herman et al., 2020), engagement in evidence-based reasoning about the advantages and disadvantages of local SSI (Powell, 2021) and character development as global citizens (Avsar Erumit et al., 2023; Kim et al. 2020).

Prospects on place-based SSI instruction

Capkinoglu et al.'s (2020) findings showed the importance of careful scaffolding in place-based SSI instruction. Unless this kind of support, firsthand experiences with SSI in real-world settings might be insufficient to produce compelling arguments. Supporting this conclusion, Lim and Calabrese Barton (2006) pointed out the careful alignment and contextualization of science in students' sense of place. Thus, effective place-based SSI instruction needs to contain some aspects which are summarized in Figure 1.

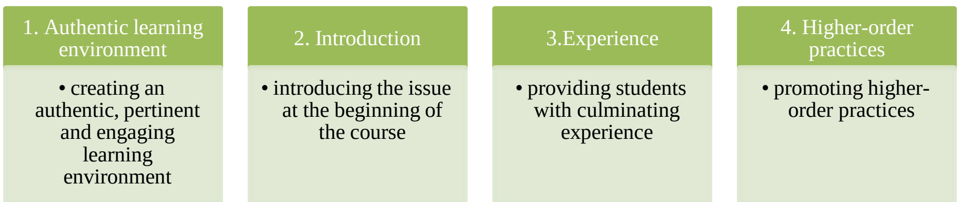

Figure 1. *Essential aspects of place-based SSI instruction*

1. **Creating a compelling issue:** The first step is creating an engaging, pertinent, and authentic learning environment for learners.
2. **Introduction of the issue at the beginning of the course:** The issue should be presented at the very beginning of the course.
3. **Providing experience:** A culminating experience should be incorporated into the design of the course so that students can apply the higher-order practices included in the learning experiences, integrate their own commitments, compare perspectives, and synthesize ideas.
4. **Higher-order practices:** The instruction should promote higher-order practices (e.g., scientific argumentation, reasoning, critical thinking, and

decision-making) through scaffolding experiences and encouraging students to engage with the topic by considering multiple perspectives (Herman et al., 2018, 2020).

Herman et al. (2018, 2020) developed a six-week place-based SSI instruction by considering the above-mentioned points. The course was split into three sections: (1) pre-departure instruction, (2) field experience, and (3) post-field experience coursework. Each section is summarized below:

Pre-departure Instruction

This phase is an important step in place-based SSI instruction. This phase corresponds to the second point that was addressed by Herman et al. (2018, 2020). This step includes many scaffolded opportunities for students to engage in emotive reasoning and perspective-taking before field experience. First, the researchers formally taught perspective-taking and the emotional nature of controversial topics. Then, a familiar issue (corresponding to the first step above) was presented: the continual expansion of their home university into the community. The students engaged with a range of members of the local community who had an interest in the university's expansion during this experience. The students interviewed locals about the university’s expansion and how they felt about it. Group discussions on different perspectives and biases were held.

Field Experience

During the field experience, the students interacted with a wide range of stakeholders (e.g., ranchers, members of the Native American Community, hunters, and wildlife biologists) who are impacted by the environmental SSI. Interacting with different stakeholders and group discussions with members of these groups was fruitful in helping students consider the intrinsic value of nature as an entity. Moreover, they had a chance to evaluate different stakeholders' and nature's points of view on environmental SSI resolution. In the end, the students used their experiences to consider different perspectives to resolve the Yellowstone environmental SSI of wolf reintroduction and hunting.

Post-field Instruction

The final three weeks were devoted to post-filed instruction. Through this period, students applied the knowledge they gained during field experience about wolf management issues. The students wrote a letter of inquiry to the faculty, outlining the topic they wanted to write about and providing justifications. When the faculty approved the query, each student produced public documents (such as flyers, bumper stickers, and newsletters) and an executive dossier outlining various points of view on the matter (Herman et al., 2020).

As seen Herman et al.’s (2020) design of place-based SS instruction (pre-departure, field trip, and post-field instruction) can be considered a good and detailed instruction model for place-based SSI instruction. Their design consisted of four elements (creating a compelling issue, introducing the issue at the beginning, providing experience, and promoting higher-order practices) of SSI-based instruction proposed by Herman et al. (2018). Their design is also compatible with

Semken's (2005) five essential characteristics (focusing on a location's geology and other natural characteristics, incorporating various meanings of place for the community, the students, and the teacher, offering first-hand experience, residing in a place by sustainably considering environmental and cultural aspects, and finally enriching the sense of place for both teacher and students).

Place-based SSI instruction and Science Teacher Education Programs

Herman et al. (2018, 2020) created a six-week place-based SSI instruction for undergraduate students offered at a small university in Virginia. This instruction model can be adapted to teacher education programs in Türkiye. For this purpose, an elective course named 'Science and Technology Related Problems' offered in the 7th semester of science teacher education programs can be used. The researcher herself developed a six-week place-based SSI instruction focusing on a local issue about gold mining. Following Herman et al.'s (2020) sections (pre-departure, field trip, and post-instruction), the researcher created her course. The events in each section are presented below:

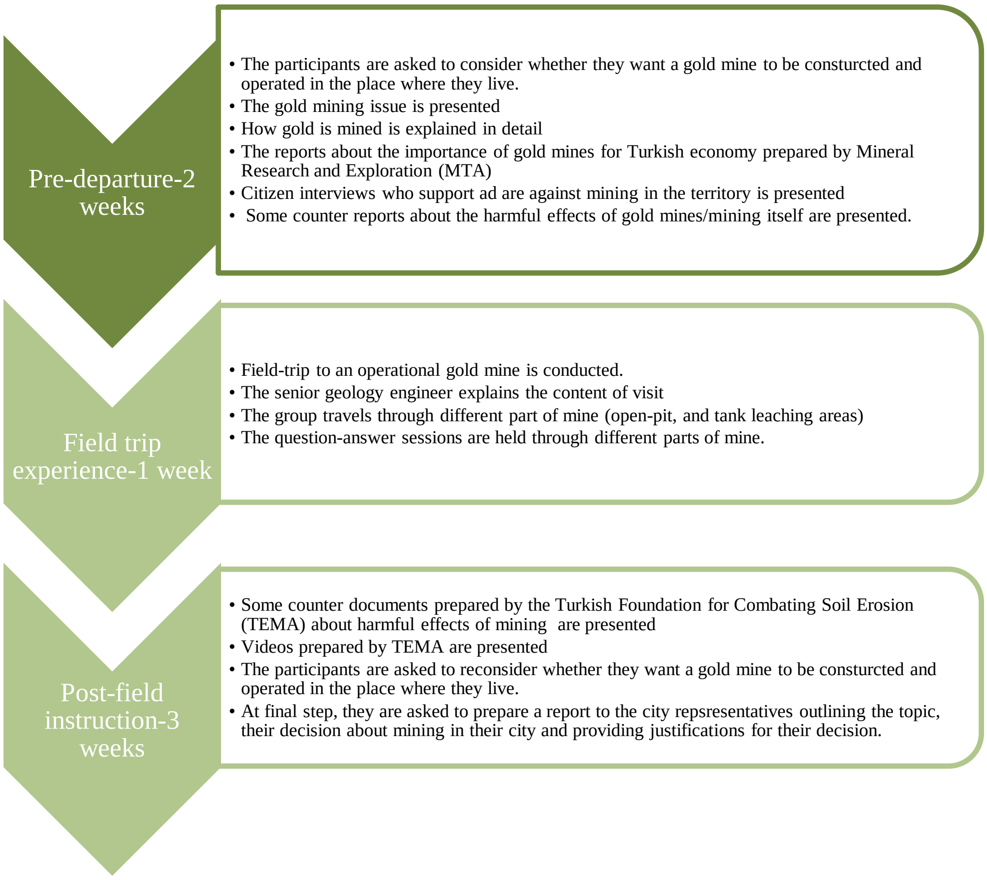

Figure 2. *The events held in SSI-based instruction*

This six-week instruction can be helpful for enhancing pre-service teachers' sense of place and place attachment. Moreover, they consider different stakeholders' views (locals who are against and support mining in the territory, MTA reports on how gold mining is beneficial for the Turkish economy, and TEMA reports about how mining is destructive for the soil, water, and humans). They interact with the locals and the senior geology engineer who directs the visit during the field trip to the mine. These interactions help pre-service teachers to reconsider the issue after the field trip.

Planning and implementing a place-based SSI instruction in a formal course can be difficult as it requires planning, and obtaining required permissions from the university, and the mine itself. Moreover, transportation to gold mines requires attention as operated gold mines are usually located in the outer parts of cities. In addition, due to security reasons, only authorized entry is allowed, and the official paperwork needs to be completed beforehand.

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About The Author

Umran Betul CEBESOY is working as Assoc. Prof. in the Department of Mathematics and Science Education of Usak University. She was a visiting scholar at the department of Teacher Education at Stockholm University in 2019 and conducted a series of research about pre-service science teachers' decision-making skills in genetics-related SSI and the development of science teachers' pedagogical content knowledge in SSI-based instruction. She completed her Ph.D. at the Middle East Technical University in 2014. She investigated the genetics literacy levels of science teachers and their decision-making skills in genetics-related SSI.

E-mail: ubetulcebesoy@gmail.com, **ORCID ID:** 0000-0001-7753-1203

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of paper titled "**Place-based SSI instruction: Current status and prospects**" belongs to the author.

SECTION 3

MATHEMATICS EDUCATION

Realistic Mathematics Education

Alper Mustafa INCI
Ministry of National Education

Bilge PEKER
Necmettin Erbakan University

Naci KUCUKGENCAY
Necmettin Erbakan University

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Introduction

Mathematics serves as a significant tool enabling us to delve into the depths of knowledge and understanding as a universal language. Mathematics is a discipline that is not exclusive only to scientists; it is a field that individuals consistently require in their daily lives. However, for many individuals, mathematics can be perceived as a world filled with abstract concepts and complex formulas. Realistic Mathematics Education aims to connect mathematical concepts to real-life contexts for students and to make sense of this discipline through concrete experiences. This book chapter aims to provide a detailed overview of the Realistic Mathematics Education (RME) teaching theory.

In the process of developing mathematical thinking, the connections students establish with the world they live in can transform knowledge into a tool that is usable throughout their lives rather than just a learned concept. While the ability to perform rapid calculations and apply mathematical formulas and rules quickly may not be as crucial as before, individuals are now expected to effectively solve problems, engage in logical reasoning, and adapt to new situations (Birgin and Tutak, 2006). Furthermore, mathematics education has various benefits such as enhancing creative thinking, reasoning skills, and the ability to appreciate aesthetics in an individual (Gür, 2006). Freudenthal (2012) expressed the connection between mathematics and real life as "mathematics is life itself, arising from real-life problems".

From the past to the present, many theories have been developed in the field of mathematics education. Realistic Mathematics Education (RME) is a relatively recent teaching theory that began to take root in the 20th century. Various definitions exist regarding this approach.

According to Van den Heuvel-Panhuizen (2000), within the framework of the Realistic Mathematics Education (RME) theory, students generate meaningful learning in their minds by establishing a bridge between informal and formal knowledge through addressing real-life problems. The informal knowledge is gradually transformed into formal knowledge in the student's cognitive processes.

Mathematics should include real-life experiences and all imaginative constructs that an individual can visualize in their mind. The word "realistic", which forms the name of the RME approach, covers not only real life but also everything real and imaginary. Freudenthal (1968), on the other hand, defined this approach as an in-depth exploratory process involving recognizing a problem situation, solving the problem, generating a subject, reshaping that subject, and making it meaningful by concretizing it. Freudenthal argued against the traditional method in mathematics education, considering it anti-didactic to present formal knowledge created by rules first and then engage in application. Instead, he asserted that real life is no different from mathematics and that formal knowledge can be reached by starting from real-life problems.

History of Realistic Mathematics Education

After the establishment of the foundations of Realistic Mathematics Education (RME), this innovative movement triggered a significant transformation in mathematics education in the Netherlands. Developed in the mid-20th century under the leadership of Hans Freudenthal, this teaching theory is based on the intuitionist philosophy of mathematics and was shaped under the influence of Jan Brouwer, who was Freudenthal's student (Iemhoff, 2014). The theoretical foundations of RME gained a formal structure with the "Wiskobas Project" initiated by Wijdeveld and Goffree in 1968, and was supported by the institute called "The Instituut Ontwikkeling Wiskundeonderwijs" (IOWO) in 1971 under the leadership of Hans Freudenthal. The initiation of the Wiskobas Project and the establishment of IOWO aimed to launch a national mathematics education reform with innovations in mathematics teacher training (Van den Heuvel-Panhuizen and Drijvers, 2020). The Wiskobas Project aimed not only to reform mathematics education in the Netherlands but also to bring about innovations in international mathematics education (Cansız, 2016).

The RME approach, proposed by Hans Freudenthal in the 1970s as a reaction to the traditional approach, has been shaped around Freudenthal's views on mathematics education. For Freudenthal, mathematics is a human activity and cannot be abstracted from real life (Zulkardi, 2000). One of Freudenthal's approaches to creating the RME theory is the idea that people will use mathematics to solve everyday problems in the future (Gravemeijer and Terwel, 2000). This educational approach, which emerged in response to the existing understanding of mathematics education, has been accepted in various countries such as the United States, Japan, the United Kingdom, Germany, Malaysia, Denmark and incorporated into the process (Çetin, 2018). As an alternative to this, 'New Math', that is, the structuralist approach, was being discussed instead of the traditional understanding. Dutch educator and mathematician Hans Freudenthal advocated for the modernization of education and moved beyond the structuralist approach, establishing the unique principles for realistic mathematics education. The foundations of realistic mathematics education were laid by the Wiskobas Project, with the involvement of Adri Treffers (Van den Heuvel-Panhuizen, 2014).

RME is a teaching method specific to the field (mathematics education) (Treffers, 1987; Gravemeijer, 1994; Van den Heuvel-Panhuizen, 1998). The significance of RME is the considerable inclusion of a variety of "realistic" situations in the learning process. The mentioned realistic situations serve as a source to initiate the development of mathematical concepts and tools, providing a structure for students to apply their mathematical knowledge in later stages. This structure gradually becomes more formal and general over time. According to Gravemeijer (1999), in RME, the term "realistic" is crucial when used in the sense of "real-world" situations, yet in this context, the concept of "realistic" has a broader connotation. In RME, the concept of “realistic” means presenting students with problem situations they can imagine. The Dutch equivalent of the English word "realistic" in RME is "zich realiseren", that is, to imagine, to comprehend (Alacacı, 2016; Topbaş Tat, 2020). Therefore, the problems presented in RME can come from the real world, but they can also originate from the fantasy world of fairy tales or the formal world of mathematics as long as they are experientially real in the student's mind.

Mathematization

One of the fundamental concepts of RME is Freudenthal's (2012) idea of mathematics as a human activity. For Freudenthal, mathematics was not the body of mathematical knowledge, but the activity of solving problems and looking for problems, and, more generally, the activity of organizing a subject from reality or mathematical subject which he called ‘mathematization’ (Heuvel-Panhuizen, 2003). Freudenthal (2012) explained very clearly what mathematics is about with the following statements: “There is no mathematics without mathematizing”. This activity-based interpretation of mathematics has had significant implications for how mathematics education is conceptualized.
Here, it is to reveal and enrich mathematical knowledge through a gradual process of mathematization (Alacacı, 2016; Topbaş Tat, 2020). Treffers (1987) expressed the way of mathematization in two ways: these are horizontal and vertical mathematization. This statement brought about a change in what is known about mathematization. Freudenthal (1991) examined horizontal mathematization as transitioning from real life to the world of symbols, while he expressed vertical mathematization as movements in the world of symbols. During this process, students became aware of solution methods, while simultaneously exploring relationships between concepts, and could make practical applications (Van den Heuvel-Panhuizen, 2003). However, in RME, horizontal and vertical mathematization should complement each other. Because, for mathematization to occur, first horizontal and then vertical mathematization are targeted.

Horizontal and Vertical Mathematization

Horizontal mathematization is defined as the process of mentally visualizing a given real-life problem, formalizing it, and transferring real-life problems to mathematical problems (Van den Heuvel-Panhuizen, 2000). Horizontal mathematization is not limited to a specific process or stage in teaching; what matters here is that the selected real-life problems are applicable (Atasoy, 2017).

During the process of horizontal mathematization, students are expected to:

- Use mathematical tools in solving or organizing problems related to real-life situations
- Express and define mathematics within a context
- Visualize and formalize the problem in different ways
- Explore and express relationships within real-life problems and transform the problem into a mathematical one (Üzel, 2007).

Vertical mathematization, on the other hand, is the process of relating and organizing within the mathematical system using the findings or models that students have discovered at the end of the horizontal mathematization process (Van den Heuvel-Panhuizen, 2003). Being able to prove, making adjustments to models to make them suitable for the situation, and generalizing them are the most evident characteristics of vertical mathematization (Zulkardi, 1999). Vertical mathematization leads to a structuring within the mathematical system, and students review the situation with their own activities and interpretations (İnce, 2019). Here, while the individual activities of students are important, individuals achieve a higher level of mathematical understanding at the end of the vertical mathematization process.

During the vertical mathematization process, mathematical systems are reevaluated within their own framework. In this process, students are expected to:

- Express a relationship in a formula,
- Internalize and adapt example situations and provide different examples,
- Combine examples and generalize them by formalizing (Üzel, 2007).

Horizontal and vertical mathematization is given in Figure 1.

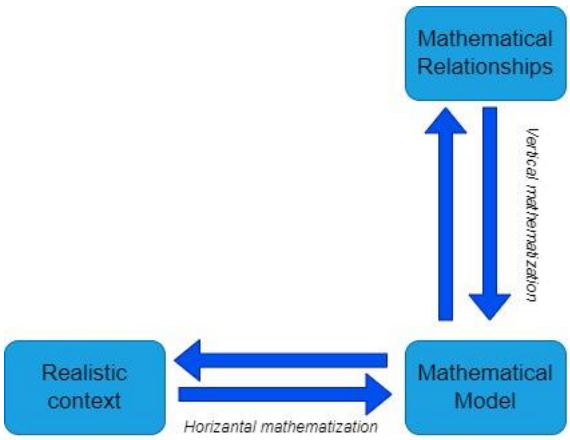

Figure 1. *Horizontal and Vertical Mathematization (Özdemir and Üzel, 2013)*

When Figure 1 is examined, the process of mathematization begins with the creation of a real context experimentally, and it continues with the creation of a mathematical model, which is termed as horizontal mathematization. A framework for mathematical relationships is established through mathematical models, which is termed as vertical mathematization. Similarly, starting from the framework of mathematical relationships, the same process can be experienced. The process of mathematization progresses gradually, and the first stage is completed with horizontal mathematization. The second stage continues with vertical mathematization and concludes. In other words, the necessary and sufficient condition for being able to perform vertical mathematization is the completion of horizontal mathematization (Freudenthal, 1983). According to De Lange (1987), on the other hand, performing horizontal mathematization is not a prerequisite for vertical mathematization; the mathematization process can take different paths.

Basic Principles for the Design Process of Realistic Mathematics Education

Gravemeijer (1994, 1999) defines three fundamental intuitive principles for the RME teaching design process as follows:

- Guided Reinvention
- Didactical Phenomenology
- Self Developed or Emergent Models (Barnes, 2004).

The detailed headings related to these principles are presented below.

Guided Reinvention

The basis of this principle is the process of reaching formal knowledge with the student's own mental power, based on real-life experiences. According to Freudenthal (2012), guided reinvention is the process in which individuals create unique solution paths and discover formal mathematical knowledge for themselves when confronted with real-life situations. It is not possible for the student to reach all formal knowledge through their own mental power alone (Freudenthal, 1991). Here, the main purpose of the guided reinvention principle is not just to make the concept discovered but to use the discovery as a tool to bridge informal knowledge with formal knowledge (Graveimeijer and Doorman, 1999).

Students should be guided in the process of reaching formal knowledge, and realistic problem situations involving activities and materials should be provided to help them bridge informal knowledge with formal knowledge (Kwon, 2002). In the process of reaching formal knowledge, the guide should be instructive in the use of logical solutions and steering away from incorrect methods (Drijvers, 2003). Thus, the reinvention process that occurs with a guide is defined as guided reinvention (Freudenthal, 1991).

Gravemeijer (1994) has modeled the stages of guided reinvention, and this model is presented in Figure 2.

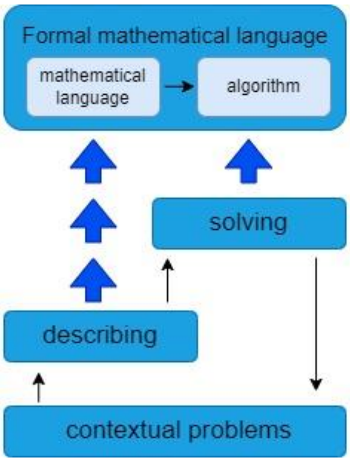

Figure 2. *Guided Reinvention Model (Gravemeijer, 1994)*

It is to search for or provide contexts that are experimentally real for students and can be used as starting points for gradual mathematization. In the early stages of RME, the principle of reinvention inspired from references to the history of mathematics. Later, this has evolved into accepting students' informal solution methods as a source of inspiration. Streefland (1991) explained this situation as sometimes the informal ways students follow while solving applied problems can anticipate the more formal mathematics targeted by the teacher. For example, while solving problems like dividing three pizzas among four children, students might be observed to reach more mathematically grounded solution methods, such as adding and subtracting with fractions with unequal denominators (Gravemeijer, 1994).

Didactical Phenomenology

Didactic phenomenology aims to explain the process of how concepts form by analyzing it (Kwon, 2002). Stimulating sources that enable the rediscovery of concepts are environmental problems. In other words, the primary source that causes the formation of mathematical concepts is real-life situations, as it was in history. For the beginning of the rediscovery of concepts, it is important to present individuals with problem situations that they can eventually generalize (Gravemeijer, Heuvel, and Streefland, 1990). According to Treffers and Goffree (1985), this principle should fulfil four functions:

- Concept Formation: It should enable students to access mathematics in a natural and motivating way.
- Model Formation: It should provide a solid foundation for thinking and learning formal operations, procedures, and rules alongside other models.
- Applicability: It should use reality as a source and field of application.
- Application: It should make use of students' specific skills in applied areas (Barnes, 2004).

Didactic phenomenology describes how mathematical knowledge should be formed in the student. Gravemeijer (1994) states that the aim of didactic phenomenology principle is to find real-life situations that can serve as a source for the generalization of concepts, contributing to the vertical mathematization process. The term "real" here may not necessarily refer to commonly encountered situations but rather to events that individuals can construct in their own minds (Nelissen, 1999). This process is expressed in the student through the term "gradual mathematization," consisting of horizontal and then vertical components (Alacacı, 2016).

For instance, to construct length as a mathematical object, students should be exposed to situations that require organizing facts based on length (Gravemeijer, 1994). In the framework of didactic phenomenology, situations applying a specific mathematical topic should be investigated to assess their suitability as impact points for the advanced process of mathematization. Considering the historical evolution of mathematics from practical problem-solving, it would make sense to seek problems in contemporary applications that lead to this process. Later, it can be said that formal mathematics emerged through the generalization and transformation of problem-solving methods and concepts developed specifically for these identified situations into formalized mathematics (Gravemeijer and Tervel, 2000). According to the didactic phenomenology principle, there are two different phenomenological situations for a mathematical concept. These are mathematical phenomenology and real-life phenomenology. In mathematical phenomenology, the goal is to explain the mathematical structure of a concept to the individual and to explain the problems that may arise in the process of concept formation. In the real-life phenomenology, the aim is to explain the mathematical structures within a real-life situation and investigate whether it enhances or hinders an individual's conceptual understanding (Oldham et al., 1999).

Self Developed or Emergent Models

This principle targets models that students develop on their own. In the rediscovery of concepts, individuals reach a formal understanding through modeling real-life situations and using these models (Gravemeijer, 1999). In other words, the models developed by the individual serve as a bridge between informal knowledge and formal knowledge.

During the mathematization process, students are presented with real-life situations, and the student, without being exposed to external influences, comprehends and models this situation. Later, this model is generalized to extend beyond just that particular problem and becomes applicable to similar situations (Treffers, 1991).

When planning teaching, educators should choose problem situations that allow students to comprehend and model effectively. Thus, the student, by starting from situations they can model, completes their own process of learning mathematics. For example, in elementary school mathematics textbooks, the teaching of the number line is directly introduced by drawing the shape, sometimes referencing models such as a garden fence. According to Freudenthal, the founder of RME, all mathematical concepts emerge through individuals mathematizing their real-life experiences (Gravemeijer, 1990). Therefore, the teaching of the number line can also occur through mathematizing a real situation. Without doing so, teaching should not be approached with an attitude like "this is called a number line" (Altun, 2006).

Key Principles of Realistic Mathematics Education

Treffers (1991) summarized the fundamental principles of the RME approach under five headings. These principles are listed below.

- Creation and concretization
- Levels and models
- In-depth thinking and special assignments
- Social context and interaction
- Structuring and collaborative processing

These principles are explained in detail in this section.

***Creation and Concretization*:** According to this principle, instruction should begin by addressing a concrete concept. The knowledge should be taught through a constructivist approach rather than being directly transmitted in the learning process. Exactly, the individual should undergo the process of learning mathematics by starting from concrete concepts instead of receiving ready-made knowledge. The fundamental element necessary for initiating the student's learning process is real problems encountered, and through these problems, the student is motivated to find themselves within the process of learning mathematics (Gravemeijer, 1994; Barnes, 2004).

According to Freudenthal (1999), real-life situations are not just tools that conclude the learning process but rather sources that start and maintain the process. These real-life situations should be selected logically and in accordance with the mathematical structure for students to be able to visualize them in their minds and reveal their prior knowledge (Van den Heuvel-Panhuizen and Wijers, 2005). As a concrete tool, real-life situations hold a significant place in the RME approach.

Because the student observes aspects of their own life in solving real-life problems, they use it as a motivational tool (Gravemeijer and Doorman, 1999).

Levels and Models: Modeling informal knowledge in the mathematization process makes it easier to access formal knowledge. Continuing through the process by creating a model allows the individual to make a comprehensible formalization (Treffers, 1991).

Gravemeijer (1994) has illustrated the process of creating a model in four levels: situational level, reference level, general level, and formal level.

1. Situational Level: At this level, individuals use their informal knowledge and strategies that are relevant to the given problem situation.
2. Reference Level: Individuals at this level create a model by referencing the presented problem situation.
3. General Level: At this stage, individuals generalize the created model. They develop the model to use it in different situations.
4. Formal Level: At this level, individuals engage with traditional rules. It represents the formal level of mathematics.

Swetz and Hartler (1991) have articulated the modeling process in four stages. These stages are outlined below and schematized in Figure 3.

1. Observation and perception of the problem situation.

2. Identifying factors affecting the problem and determining the relationship between factors.

3. Transferring the conducted analyses into a model.

4. Testing the suitability of the obtained result for the problem and reinterpreting it.

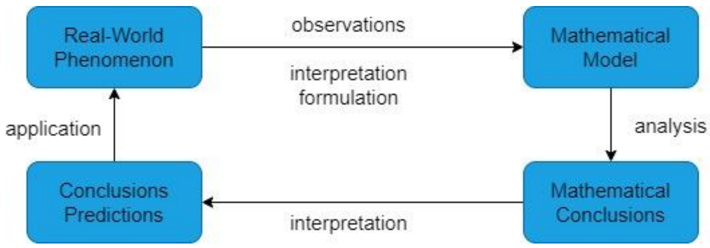

Figure 3. *Modeling Process (Swetz and Hartler, 1991)*

In-Depth Thinking and Special Assignments: In-depth thinking can be defined as an idea put forward by reflecting on one's own thoughts or the thoughts of others (Memnun, 2011). This principle emphasizes the importance of the production carried out by the individual. Therefore, De Lange (1995) argued that individuals should be given assignments such as conducting experiments, writing articles, and making inferences from experiments in order to enhance their productivity.

According to the RME approach, students should be motivated to develop strategies on their own and produce a product, and opportunities should be provided for this (Widjaja and Heck, 2003). With these opportunities provided, it becomes easier for students to construct knowledge.

Social Context and Interaction: This principle constitutes a significant portion of the RME approach in terms of student-teacher and student-student interaction.

Because the RME approach describes learning mathematics as a social activity. Just like in the traditional approach, not only student-teacher interaction but also student-student interaction is crucial for this approach (Treffers, 1991).

The RME approach recognizes that all students can't learn at the same pace simultaneously. Therefore, it organizes learning by grouping individuals who are learning simultaneously into interactive groups. Thus, during the learning process, they build a sense of self-confidence as they realize their own learning through interaction with each other (Van den Heuvel-Panhuizen and Wijers, 2005; Nelissen and Tomic, 1993).

Structuring and Collaborative Processing: According to the RME approach, providing information ready-made to students is an unacceptable concept. According to RME, the student structures knowledge in their mind based on real situations (Treffers, 1991).

Mathematics is a whole, and treating topics separately means ignoring the relationship between them. Therefore, the integrity of the topics is used in solving real-life problems. The topics should be taught in an integrated manner, emphasizing their interconnectedness, rather than addressing them separately. In this way, students structure the connection between mathematical concepts by processing topics together in their minds (Zulkardi, 1999).

Teaching and Learning Principles of Realistic Mathematics Education

As mentioned in the previous section, Treffers considered the RME approach as five principles, and Van den Heuvel-Panhuiezen (2000), who has contributed to numerous studies in mathematics education, has developed these principles. Van den Heuvel–Panhuizen and Wijers (2005) explained these principles under six headings in their study.

Principle of Activity

Based on Freudenthal's statement *"Mathematization is a learning activity."*, the student is at the very center of the learning process and realizes their own learning. Students are confronted with real-life problems, they develop strategies to solve the problem and thereby access the knowledge.

In this principle, the individual does not take what is ready; instead, they actively engage in the process to produce an outcome. Taking this principle into account, during the teaching process, the student should be active within the lesson and not left in a passive state. Otherwise, the ready-made information that the student passively receives loses its instructive quality (Freudenthal, 1968; 2012).

Principle of Reality

The aim of mathematics education is to comprehend mathematical concepts and the systematics of mathematics, to reflect them in real life, and to acquire fundamental mathematical skills for education and advancement in a specific field (MONE, 2018). The RME approach also serves this purpose by using reality as a source. The important thing here is to present real situations that the student can make sense of and to enable him to access the information himself.

The RME approach suggests that solving a problem situation does not begin by using ready-made and abstract mathematical knowledge (Wubbels et al., 1997). In RME, there is a process of starting from the real and reaching the abstract. In this context, real can refer to either a real-life situation or a fiction.

Principle of Level

The process of mathematization involves progressing through specific levels, from understanding and modeling problem situations to interpreting models and reaching formal mathematical knowledge. Without completing the first level, it is not possible to transfer what is done at the first level to the second level.

Models have an important place in this process. After transforming the problem situation into informal knowledge, models serve as a bridge until formal knowledge is reached. A specific model created for a situation should be generalized to be applicable to all similar situations (Van den Panhuizen-Heuvel and Wijer, 2005).

This principle is important for establishing a mathematical perspective and ensuring consistency in the development of the mathematics program (Memnun, 2011).

Principle of Interrelationship

Since mathematics has an integrated structure, each mathematical topic cannot create a meaningful community on its own. The RME approach also advocates teaching mathematics as a whole without breaking it down into parts. It is important for the student to have knowledge about multiple subjects while solving a problem for developing a better strategy for the problem. In other words, in the process of mathematization, the student needs to have knowledge about interconnected subjects to comprehend the information.

Freudenthal (2012) expressed that presenting mathematical topics independently would result in the student's inability to establish connections between the pieces of information and a faster tendency to forget. When preparing the mathematics curriculum, this principle of the RME should be considered, and mathematical topics should be organized in a spiral structure.

Principle of Interaction

Van den Heuvel-Panhuizen and Drijvers (2014) defined the process of learning mathematics as a social activity. According to this definition, in the process of learning mathematics, students should be in a social environment, where they can share their thoughts, strategies, and solutions with each other. This way, students, by seeing different thoughts and strategies from their own, realize that there is not only one way to solve a problem situation. They can develop their own strategies by making comments on different strategies.

In an environment where the whole class shares with each other without any level distinction, everyone feels productive, and all individuals become motivated in the learning process. Different understanding levels should be addressed in the same environment without internal grouping, and problem situations that appeal to different levels of understanding should be presented for the realization of the teaching process as a whole (Van den Heuvel-Panhuizen, 2000).

Classroom environments should be created in the learning process where all individuals can interact with each other, based on this principle of the RME.

Principle of Guidance

Freudenthal (1991) said that the individual should be guided in the process of rediscovering mathematics. In the process of guiding the individual, situations that will leave them passive should be avoided. Because Freudenthal described the mathematization process as a situation in which the individual is active. Rather than telling the individual what information to acquire, the teacher should guide them on how to access the information.

The teacher should create a suitable environment for the student in the process of learning mathematics, and carefully identify the source that initiates the mathematization process. An inadequately identified source may cease to be guiding in initiating the process.

Lesson Design Suitable for Realistic Mathematics Education

Streefland (1991) stated that the design of lessons appropriate for RME should take place in three stages. These three stages are the classroom level, the lesson level, and the theoretical level. These stages are examined under the headings below.

Classroom Level

This level aims to carry out the horizontal mathematization process, which is one of the mathematization processes. Therefore, in the first stage of this level, a realistic life situation is presented to the student, where they can comprehend and reach a product. Then, this realistic situation is related . In this way, students are provided with the opportunity to create symbols, graphs, or models for the problem situation. In this process, an interactive classroom environment is provided where students can actively participate, express their thoughts, and be open to different perspectives. As a result of their interactions, tasks are assigned to students to ensure the continuity of the process and to enable them to present their own products (Zulkardi, 1999). Below, the classroom level modeling process is provided in Figure 5.

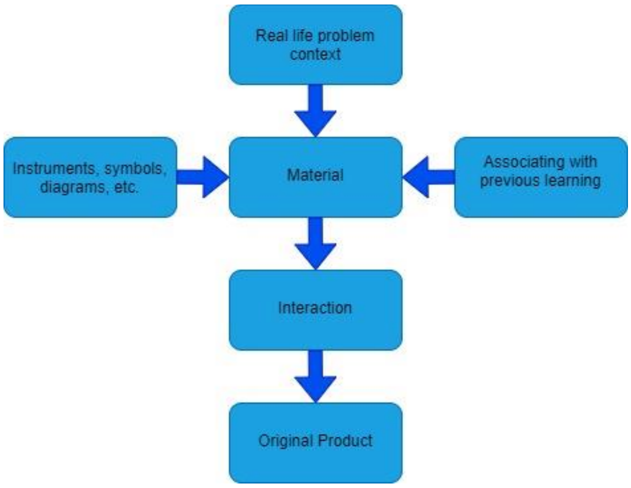

Figure 5. *Classroom Level Lesson Modeling Process (Özdemir, 2020)*

Lesson Level

This level is a preparatory stage for transitioning to the theoretical level. The materials presented at the classroom level are used in the teaching process according to the instructional purpose of the lesson. After these materials are tested at the classroom level, it is expected that they will be further developed and used at the general level (Zulkardi, 1999).

Theoretical Level

The theoretical level, unlike the classroom level, aims for vertical mathematization. The materials presented in the previous two levels and instructional products serve as resources for this level. By using the materials and products generated in the previous two levels, a general theory is developed. This theory is then tested and developed on different concrete models.

In the Realistic Mathematics Education approach, the following four components are considered to create a lesson plan.

1. Goals

In mathematics education, according to the three target levels identified by De Lange (1995), the goals of traditional mathematics teaching are considered as lower-level, while the goals set by the RME approach are described as middle and upper-level goals. The reason traditional mathematics teaching goals are considered lower-level is that they consist of theoretical knowledge and definitions. In the RME approach, skills such as establishing relationships between concepts are considered middle-level goals, while goals like reasoning, strategy development, model creation, and producing a product are classified as upper-level (Zainurie, 2007). Realistic mathematics teaching suggests that lesson design should consist of middle and upper-level goals.

2. Materials

The mathematics teaching program should be designed in a way that allows students to discover for themselves, represent information with concrete models, and learn by doing and experiencing (Bulut, 2004). Materials have an important place in this process. Concrete materials enable students to think and provide them with the confidence to solve problems (Brecht, 2000). De Lange (1996) proposed the idea that materials should be related to real life for students to comprehend. These materials should be associated with real-life problems that serve as a source for the mathematization process.

3. Activities

In the RME approach, the teacher has a major role in the classroom. This role is shaped not as a transmitter of information, but as a deliverer of information. In all stages of the mathematization process, the teacher guides the student through the following steps.

- It provides students with real-life situations to serve as the source for the mathematization process,
- Enables students to establish relationships between concepts by providing hints for making sense of the situation,
- Creates an environment for students to interact with each other, share their thoughts,
- Provides opportunities for students to apply their solutions,
- Offers different contextual problems to students to generalize their problem-solving approaches.

In this stage, guidance actively plays a role in the process as a motivational tool for the student.

4. Evaluation

According to the Realistic Mathematics Education approach, evaluation should be made throughout the process, not just at the end. The teacher may ask students to write compositions, practice, and conduct experiments for observation throughout the process to assess their progress. The tasks performed by the students assist the teacher in planning for the next lesson and designing the lesson. At the same time, the assessment conducted during the teaching process encourages idea and strategy sharing among students, allowing them to develop their own strategies. In other words, evaluation during the teaching process is also instructive.

De Lange (1995) mentioned five basic features for evaluation. These features are given below.

- Evaluation aims to improve learning and teaching. In other words, evaluation should be actively conducted throughout the learning process to measure students' progress.
- Evaluation stages should allow for understanding what the student knows or doesn't know about a concept.
- Evaluation should actively engage all levels of mathematical goals (lower, middle, upper).
- Evaluation should include objective tests and problems that can measure whether the student has truly learned.
- Evaluation tools should be easily accessible and compatible with the structure and culture of the teaching environment.

In this case, the development of evaluation tools must be important. The stages of developing evaluation tools are given below.

- Contexts appropriate to the real situation are selected, starting from a source that students can make sense of.
- Relationships are established between previously learned concepts and those currently being learned.
- Following the activity principle, students interact to create thoughts based on each other's ideas and develop new models and materials.
- Opportunities are provided for students to mathematize based on the models they develop through interaction with each other.
- Evaluation materials should consist of open-ended questions that can lead students to original products (Zulkardi, 1999).

The Relation of Realistic Mathematics Teaching to Other Learning Approaches

Realistic Mathematics Teaching and Constructivism

Constructivist learning, which focuses on how knowledge is acquired, is distinct from teaching theories. In contrast, the RME is a teaching theory. Realistic Mathematics Education is compatible with constructivism, but it differs in the way knowledge is structured. While Realistic Mathematics Education rejects the separation of theoretical knowledge from application, constructivism does not reject this (Panhuizen 2001). In constructivism, the acquisition of knowledge is based on concrete materials and informal knowledge in accordance with the constructivist theory. The main distinction between Realistic Mathematics Teaching and constructivism lies in how the teaching begins. Realistic Mathematics Education always begins with contextual problems, while in the constructivist approach, the situation is not always the same. For teachers and experts to effectively implement Realistic Mathematics Education, they need to have a good understanding of contextual problems and be able to distinguish them from other types of problems.

Realistic Mathematics Education and Learning Through Discovery

Demirel (2005) defined learning through discovery as the process of exploring the learning material by using existing knowledge without presenting the learning material in its final form. Jacobsen lists the steps of learning through discovery as follows:
1) Teacher presenting examples,
2) Students explaining the examples,
3) Teacher providing additional examples, ... etc. (Senemoğlu, 1997).
As can be seen, in discovery teaching, the subject is tried to be discovered through the examples given by the teacher. However, in RME, the learning process is realised as a problem-solving process. According to Realistic Mathematics Teaching, the teacher does not constantly give examples to students. On the contrary, students are expected to find suitable examples for the given situation.

Conclusion

On the foundation of RME, various sources of data such as cultural and social life, the physical environment, history, geography, and folk literature are used to create a meaningful context for learning (Altun, 2006, p. 235). In the teaching process in this approach, Lange (1996), William (1997), and Majewska (2019) aim to establish connections with daily life activities and use materials related to the teaching process. The cultural richness of nations provides opportunities to create learning environments that encourage students to acquire and rediscover formal mathematical concepts. Research has shown that RME has positive effects on both students and teachers, including increased interest and appreciation for mathematics, improved mathematical proficiency, enhanced problem-solving skills, and increased student motivation (İnci, 2023). Increasing the number of studies and directing teachers and education professionals towards RME is believed not only to enhance mathematical achievement but also to positively influence attitudes towards mathematics (Bintaş et al., 2003; Çilingir, 2015; Gravemeijer, 2020). This approach aims to guide students in viewing mathematics as a tool for out-of-school activities and to help them construct mathematical meanings based on concrete experiences and intuitions (Göğün, 2009).

Due to the abstract nature of mathematics, the mathematics curriculum focuses on conceptual and procedural knowledge, encouraging abstract thinking rather than concrete real-life models. Learning mathematics involves more than acquiring basic skills; it includes thinking critically, understanding problem-solving strategies, developing a positive attitude, and realizing the significance of mathematics as an essential tool in real life (Göğün, 2009, p. 11). Current curricula emphasize that mathematics is learnable for everyone and aim to cultivate individuals with high-level thinking skills. The problem-based learning approach encourages students to be more active participants in solving mathematical problems. RME is a model that gives students the opportunity to apply mathematical concepts in daily life. Therefore, teachers should be provided with support to enhance their professional development in RME strategies. Preparing RME-appropriate problems and investigating whether these problems are compatible with existing evaluation types is also important. The studies show that RME gives positive results when used as a long-term approach. Therefore, it is recommended to prepare more RME-appropriate lesson plans and extend the duration of these lessons.

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About the Authors

Alper Mustafa INCI: He was born in Konya in 1997. After completing her undergraduate education at Konya Necmettin Erbakan University in 2019, he completed her master's degree at Necmettin Erbakan University, Department of Mathematics Education in 2023. He has studies on realistic mathematics education, mathematical concepts, and mathematical language. He has been working as a mathematics teacher in Karaman since 2020.

E-mail: alpermustafainci@gmail.com, **ORCID ID:** 0000-0002-5270-2966

Bilge PEKER: She received her PhD degree in Mathematics from Selcuk University. Currently, she is working as an Associate Professor of Mathematics in the department of mathematics and science education at Necmettin Erbakan University where she is conducting research activities not only in the areas of algebra and number theory, especially Diophantine equations, Pell equations, Diophantine m-tuples but also in areas of mathematics education.

E-mail: bpeker@erbakan.edu.tr, **ORCID ID:** 0000-0002-0787-4996

Naci KUCUKGENCAY: He works as a mathematics teacher at Cumra Science and Art Center under the Ministry of National Education, and is a PhD candidate in the department of mathematics education at Necmettin Erbakan University. He has conducted studies on affective characteristics of mathematics, popularization of mathematics, technology integration to mathematics education, teacher education, STEAM, and history of mathematics.

E-mail: kucukgencaynaci@gmail.com, **ORCID ID:** 0000-0003-4956-781X

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of paper titled "**Realistic mathematics education** " belongs to the authors.

Mathematical Literacy: Connecting the Real World and Mathematics

Nailul Himmi
Universitas Riau Kepulauan

Sadidah Hasanah
Sekolah Globe National Plus 2 Batam

Mangaratua Simanjorang
Universitas Negeri Medan

Syawal Gultom
Universitas Negeri Medan

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Introduction

The society today needs not only those who can understand science but also those who are beyond it. As we know with the evolution of the viewpoint that mathematics is not only the ability to calculate but also the capacity to associate applied mathematics with the real world. It's so necessary to solve a very complex problem. One that supports that ability is education.

Through education one can enhance and develop the creative, flexible, problem-solving, collaborative, and innovative thinking skills needed to lead life. Education is expected to equip a person to apply knowledge to everyday life. These abilities should be fostered in education through the subjects that are taught in classrooms. These expectations are reflected in the core competencies of the Curriculum Contents Standard 2013 (Permendikbud No 68 Tahun 2013, 2013).

The core competence (KI) of the cognitive domain for each subject is to equip the student with factual, conceptual, and procedural knowledge based on the student's curiosity about science, technology, cultural arts related to phenomena and apparent events. The core competence domain of the skills for each subject is to process, present, and plunge into concrete fields (using, deforming, scaling, modifying, and making) and abstract fields(writing, reading, counting, drawing, and writing), according to what is learned in school and other similar sources in the perspective/theory.

Based on the Content Standard, mathematics as one of the compulsory subjects is expected not only to equip students with the ability to use calculations or formulas in the work on the test, but also to involve their skillful and analytical skills in solving everyday problems. This is in line with the National Council of Teaching Mathematics (NCTM) view that makes problem solving, reasoning, and proof, communication and representation, the standard processes in mathematical learning (NCTM, 2000).

Mathematics requires students not only to have the ability to calculate, but also to have a logical and critical ability to solve problems. Problem solving is not just a routine problem but more to the problems faced on a daily basis. Such a mathematical ability is known as mathematics literacy.

According to a survey conducted by the Programme for International Student Assessment (PISA), the mathematical literacy from students in Indonesia is still low (OECD, 2014). Indonesia is below the international average (Kementerian Pendidikan dan Kebudayaan, 2023). Not only that, the majority of students can solve problems only below level 2. Given the facts mentioned, the mathematical literacy of students in Indonesia still needs to be improved. How examples of issues and some efforts in improving mathematical literacy are expressed in this article.

Literature studies are research activities that gather data from libraries, read and record and manage the literature obtained. As for the focus of the question to be discussed in this article is

1. What is mathematical literacy?
2. How is the process of mathematization understood by PISA?
3. What are competences required to undertake the Process of Mathematical Literacy?
4. How is mathematical literacy urgent in life?
5. How does the process analyze the ability to literate mathematically?

In this study, data collection is carried out by gathering shared sources, whether journals, books, or supporting reports to answer the proposed problem. Journals are obtained from various articles from journals that are indexed from sinta 1 to sinta 6. Books / reports from google schoolar. The keywords for the journals and books collected are mathematical literacy, PISA and mathematics literacy in life. Procedures for writing articles of this literary study are: (a) searching for various literature, (b) choosing relevant literature with abstract reading, (c) writing important things to find the concepts studied, (d) conceptualization, (e) data analysis in the form of analysis of the content of the journal, (f) results and discussion (g) conclusions.

Mathematical Literacy

Mathematical literacy is popularized by the OECD/PISA.

> “Mathematical literacy is an individual’s capacity to formulate, employ, and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena. It assists individuals to recognizes the role that mathematics plays in the world and to make the well-founded judgments and decisions needed by constructive, engaged and reflective citizens”.

The definition by PISA shows that mathematical literacy relates to the use of reasoning, concepts, facts, and mathematic tools in finding solutions to solving everyday problems so that it is not just the ability to master mathematics itself.

The phrase "mathematical literacy" was first established by (NCTM, 2000) as part of the goal of mathematics education to become a mathematician, before it was introduced through PISA. According to this definition, mathematical literacy is "the capacity of an individual to investigate, to hypothesize, and to reason logically as well as to effectively use a variety of mathematical methods to solve problems." Their capacity for mathematics should increase as they become literate. The four primary components of mathematical literacy in problem solving-exploring, linking, and logically solving—as well as the use of various mathematical techniques, are covered in this comprehension. This key element helps him solve problems on a daily basis while also advancing his mathematics skills.

Said another way, (Ojose, 2011) contends that mathematical literacy is the ability to understand and apply the principles of mathematics in daily situations. In this way, someone with strong mathematical literacy is sensitive to the mathematical principles that apply to the issue or situation they are dealing with. Following this sensitivity, problem solving using mathematical ideas was carried out.

According to this perspective, literacy in the context of mathematics was defined by (NCTM, 2020)as the ability to apply mathematical reasoning to solve difficulties in daily life in order to better prepare oneself for life's challenges. The goal of mathematical thinking is to be able to reason logically, solve problems, communicate, and explain (OECD, 2014). This way of thinking is established using methods, ideas, and quantitative information pertinent to the issue at hand.

(Ojose, 2011)added the word "effective" in the sense of mathematical literacy to support the earlier opinion. The capacity to apply mathematical knowledge and comprehension to successfully navigate the difficulties of daily life is known as mathematical literacy (Kirsner et al., 1993). A mathematically literate person must be able to apply their knowledge and comprehension efficiently in addition to being able to use it.

Five aforementioned viewpoints all highlight the same idea, which is how to apply mathematical knowledge to solve problems in daily life more successfully. A mathematically literate person will identify or comprehend which mathematical concepts are pertinent to the problem they are tackling as they work through this challenge. The ability to articulate the issue into its mathematical form so that it can subsequently be solved developed from this consciousness. Investigating, linking, formulating, defining, developing, and other mathematical thinking processes are all part of this process. The three primary stages of this thought process are formulating, using, and interpreting. Therefore, the ability to formulate, use, and interpret mathematics in a variety of contexts to solve problems in daily life can be characterized as mathematical literacy. Which can be represented as follows (OECD, 2013) :

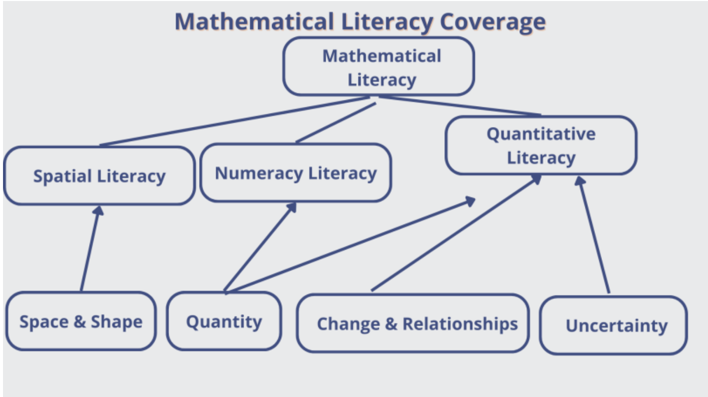


Figure 1. *Mathematical Literacy Coverage*

Mathematical literacy encompasses spatial literacy, numeracy and quantitative. Spatial literacy refers to our awareness of space. This ability requires an understanding of the nature of objects, relative positions and other things associated with the reservoir.

Additionally, Traffer's defines numeracy as the capacity to handle data and numbers as well as assess claims based on circumstances and facts requiring estimates and mental processes in practical settings. This skill involves the recognition, comprehension, and application of numerical statements in a range of real-world situations. The capacity to answer practical problems with numbers is known as numeracy. Quantitative literacy, which is broader than numeracy, is the capacity to recognize, comprehend, and apply quantity statements in everyday situations. This ability's primary component is the capacity to modify quantitative claims in situations that are known or unknown.

Mathematics as the Key to Literacy

Mathematical literacy is about dealing with 'real' problems (real world problem). Which means that the problem that exists is not pure mathematics, but is placed in some sort of 'situation'. In short, students must 'solve' real-world problems that require the skills and competences students acquire through school and life experience. The process of solving such problems by PISA is called the process of 'matematisation'.

Mathematization can simply be described as the process of triggering a phenomenon. Mathematizing itself is the process of modeling a phenomenon mathematically. The process of mathematization understood by PISA is not merely the creation of a mathematical model or representation of an issue, but a process involving the translation of a real problem into mathematics until the process of solving the problem. The stages of the mathematical process according to PISA are as follows:

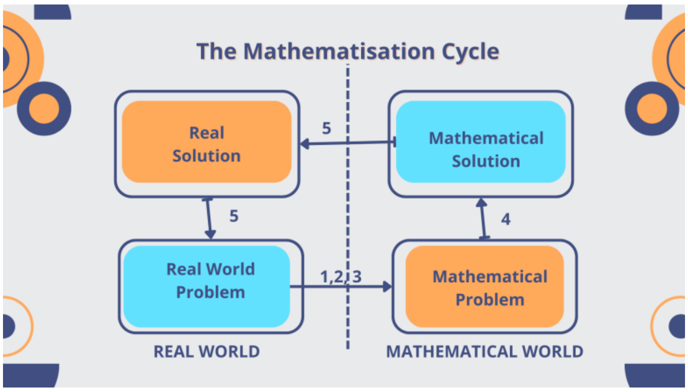


Figure 2. *The Mathematisation Cycle*

1. The process of mathematization begins with a problem that exists in the real world. This process of formulation includes the process of constructing, simplifying, and compiling a mathematical model of a given problem. This stage requires the ability to understand information and mathematical concepts that are relevant to the problem.
2. Then the problem solver tries to identify a mathematical step or form that is relevant and suitable for the situation and rearrange the problem according to the mathematics concept identified.
3. Then followed by a gradual cutting-down of things from reality or sorting out what is needed to solve existing problems. These three steps lead us from real-world problems to mathematical problems.
4. The fourth step is to solve the mathematical problem identified in three previous steps.
5. In this fifth step, questions will arise. What does that mathematical solution mean in the real world? So this is the process of interpreting answers into language in the real world.

To understand this cycle better by giving examples. The following items have been tested in the field for PISA but were rejected due to high difficulty levels. The item was previously released by the OECD. To make the mathematical process clear we have changed the question:

HEARTBEAT

For health reason people should limit their efforts, for instance during sports, in order not to exceed a certain heartbeat frequency.

For years the relationship between a person's recaommended maximum heart rate and the person's age was describe by the following formula:

Recommended maximum heart rate $= 220 - age$

Recent research showed that this formula should be modified slightly. The new formula is as follows:

Recommended maximum heart rate $= 208 - (0.7 \times age)$

QUESTION 1. HEARTBEAT

What is the main difference between the two formulas and how do they affect the maximum allowable heart rate?

Figure 3. *The example question for PISA*

1. The process of mathematization begins with a problem that exists in the real world. Clearly from this item, the realty in this case is physical fitness. An important rule when doing exercise is that one should not force oneself to

exercise in order to be fit, as this may cause health problems. We can jump to this conclusion because of the maximum heart rate text.

2. Then the problem solver tries to identify mathematically relevant, and rearrange the problem according to the mathematical concept identified. It seems clear that we have two words formulas that need to be understood, and indeed so asked to compare these two formulas, and what the real meaning of the formula gives the relationship between the recommended maximum heart rate and a person's age.
3. Next we gradually sort from reality to what to use. There are various interpretations of mathematical difficulties that can be made. One way is to change the formula into formal mathematics to:
$$y = 220 - x$$
$$y = 208 - 0.7x$$
Of course we have learned that y expresses maximum heart rate in b/m and x age in years. Another way to define a problem into mathematics is to draw a graph from a given formula. The three steps above take us from real-world problems to mathematical problems.
4. The fourth step is to solve the mathematical problem that exists The mathematics problem that is faced is to compare two formulas or graphs, and to see the differences from people of a particular age. A good way to start is to find out where both formulas give the same result or where both graphs cut. So we can solve this by solving the equation:
$$220 - x = 208 - 0.7x$$
From these equations we get $x = 40$ and $y = 180$ So two charts cut at points $(40, 180)$. And the first equation gradient is -1, and the second $-0{,}7$ so, we know that the second chart is 'less sharp' than the first. Or the $y = 220 - x$ chart lies 'on top' of the $y = 208 - 0.7x$ chart for x values smaller than 40, and below for x value greater than S.
5. What this mathematical solution actually means in the real world is the question that now arises. In other words, if we understand that x is a person's age and maximal heart rate, it shouldn't be too difficult. The two algorithms get the same conclusion when a person is 40 years old: a maximum heart rate of 180. In extreme terms, if the age is zero, the maximum heart rate attained using the previous method was 220, however under the new formula it is only 208. This indicates that the old formula permits a higher heart rate for younger people. But modern insights allow for larger maximal heart rates for the older ones, in this case for individuals over 40. For example, and once again extreme: for the age of 100 years we see that the old formula gives us a maximum of 120 and the new 138.

Competence Required for Mathematical Literacy

Some competences are required to undertake the process of mathematical literacy.

1. Mathematical thingkig and reasoning. Ask questions that match the mathematical characteristics, know what kinds of answers are obtained using mathematics, differentiate the questions given, and know the limits of the concepts used.
2. Mathematical argumentation. Knowing how to prove something, knowing other proofs using mathematical reasoning, having a desire to look further into a proof, and being able to create and express arguments mathematically.

3. Mathematical communication is the ability to express answers in a variety of ways, whether orally, in writing, or in other visual forms, and to understand the answers of others.
4. Modelling. Able to organize plans in the press looking for answers, translate reality into mathematical forms, both context and the real world, do several ways to solve a problem, analyze the steps taken, can give credentials or find solutions to a modeling process.
5. Problem posing and solving. Can define and solve problems in a variety of ways.
6. Representaion. Able to represent mathematical objects in various forms.
7. Symbols. Using symbols both formally and technically in the use of language and also in mathematical operations.
8. Tools and technology. Using a tool or technology that feels appropriate to what is needed.

To be mathematically "mathematically literate" one has to master the above competence to find variable answers. Besides, one also needs confidence in their own ability to use mathematics and comfort in using ideas quantitatively. Appreciation of mathematics from a philosophical and social historical point of view is also needed. So from that one can conclude that a mathematician is also an expert in literature. But today's school curricula rarely emphasize insight and still not many actively support learning that emphasizes litation. It is unfortunate that the development of insights in mathematics is better supported even from the pre-school level. Many countries have begun to respond seriously to students' mathematical literacy. For example, Singapore, which has grown rapidly for PISA scores, could be proof that there is still a lot to be improved in the availability of increased mathematical literacy.

The Competencies Cluster

When doing real mathematics, then requires simultaneously in the use of many skills. To operate this mathematical competence, it would be very helpful if the skills were divided into three groups (Rosa & Orey, 2023). The Competence Cluster according to PISA is:

Cluster 1. Reproduction
These clusters are closely related to definition and computation, knowledge of facts, representation, recognition of equivalents, remembering mathematical objects and properties, performing routine procedures, applying standard algorithms, and developing technical skills. Handles and operates with statements and expressions containing symbols and formulas in the'standard' forms associated with this level. Items in cluster 1 are often in double selection, empty content, match, or (limited) open question format.

Cluster 2. Connections
In this cluster, we start to draw links between many mathematical domains and strands, as well as integrate data to answer basic issues where students have choices about how to approach problems and how to apply mathematical tools. They still need to use mathematics to solve the problem, even though it shouldn't be one of those repetitive ones. According to the circumstance and goal, students at this level are also asked to handle a variety of representational formats. Students must be able

to differentiate between and connect various assertions, including definitions, claims, examples, conditioned statements, and supporting data, in order to complete the connection component.

From the point of view of mathematical languages, another aspect of this cluster is the definition and interpretation of symbolic and formal languages as well as the understanding of languages and their relationship with real-world languages. Items in these clusters are often placed in context and involve students in mathematical decision-making.

Cluster 3. Reflection
Related to mathematical tinging, generalization, and insight. In cluster 3, students are asked to mathematize situations (recognize and filter the mathematics that exist on the subject and use the math to solve problems). They have to analyze, interpret, develop their own models and strategies, and make mathematical arguments including evidence and generalizations. This competence includes critical components and model analysis and reflection on processes. Students should not only be capable of solving problems but also be able to make questions that match the material they master.

This competence works well only if the student can communicate properly in a variety of ways (misalnya, secara lisan, dalam bentuk tertulis, menggunakan visualisasi). Communication is meant to make a two-way process that the student must also be able to understand communication with mathematical components by others. Competence on cluster 3 quite often combines skills and competences usually associated with the other two groups.

Cluster 3, which goes into the heart of mathematics and mathematical literacy, is difficult to test. Double selection is clearly not the format of the choice in cluster 3. Contextual questions with several answers (with or without increased levels of complexity) are more likely to be promising formats. However, both the design and evaluation of students' answers are very difficult to make. It can be said that we can describe eight competencies that match the three on the competence cluster. The actual PISA framework does this in detail (meaning eight competencies when they play in the reproductive cluster, in the conjunctival cluster in the reflexive cluster.

The Urgency of Mathematical Literacy in Life

Based on the understanding described above, mathematical literacy is the ability of a person to formulate, use and interpret mathematics in various contexts of solving problems in everyday life effectively. It will encourage one to perceive and understand the use of math in daily life. Sensitivity to the usefulness of mathematic will help one to think numerically and spatially in order to interpret and analyze critically everyday situations with greater confidence. In politics, for example, a society with good mathematical literacy can turn statistical data into quantitative facts and effective information to choose legislative candidates more wisely. Thus, it is expected to create a critical and democratic society (De Lange, 2016).

In the world of work, for example, methematic literacy also has a vital housing role. Although at present our performance has been greatly assisted by computers, we need to have mathematical literacy skills. The current job demands are no longer on how to use mathematical calculations but more on how we understand a system and how to develop it. This ability is essential for level officers to prevent upwards. By understanding the system, they can develop the system dynamically as needed (OECD, 2014).

Other examples, when shopping, we are often faced with a selection of goods. Some of them may get discounts or bonuses in the form of vouchers or something. With mathematical literacy, we can determine the goods to be chosen by considering the more economical price. In addition to mentioned examples, there are many problems of everyday life that require literacy skills. From simple things to more complex things. From defining effective routes to policymaking in the business world, both require literacy.

Mathematical Literacy Analysis

For a deeper look at how the differences and variations in mathematical abilities are, the author gives two details about mathematics literacy taken from the PISA issue and then friends from Grade A Mathematics Education in 2019 to answer the question .

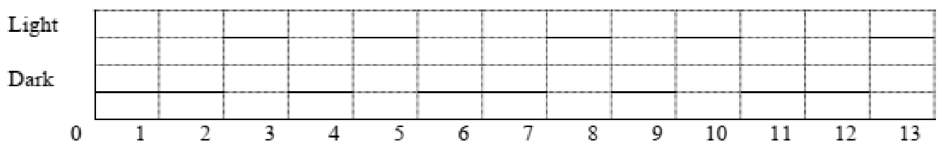
In the hope of an understanding of the mathematical ability to solve the problem. But this is definitely just an illustration because the mathematical literacy of graduate students must be different from that of high school and senior high school students. The question given is as follows:

TASK 1. LIGHTHOUSE

Lighthouse are towers with a light beacon on top. Lighthouses assist sea ships in finding their way at night when they are sailing close to the shore.

A lighthouse beacon sends out light flashes with a regular fixed pattern. Every lighthouse has its own pattern.

In the diagram below you see the pattern of certain lighthouse. The light flashes alternate with dark periods.



It is a regular pattern. After some time the pattern repeats itself. The same taken by one complete cycle of a pattern, before it starts to repeat. Is called the period. When you find the period of a pattern. It is wasy to extend the diagram for the next second or menutes or even hours.

Item type: Multiple-choice
Competency Cluster: Connections
Overarching idea: Change and relationships
Situation: Public
TASK 1. LIGHTHOUSE
Which of the following could be the period of the pattern of this lighthouse?

a. 2 seconds b. 3 seconds c. 5 seconds d. 12 seconds

For how many seconds does the lighthouse send out light flashes in 1 minute?

a. 4 b. 12 c. 20 d. 24

Figure 4. *The example question for PISA*

Here's the answers and the mathematical steps.

Table 1. *Scoring Mathematics Steps*

No	Mathematic steps	Discussions	Score
1	Starts with a problem situated in reality	On the question of known patterns on the flashlight, "dark-light", asked how many seconds the pattern was formed on a flashlight.	3
2	Identify the relevant mathematics, and reorganizes the problem according to the mathematical concepts identified	There's a pattern that we can understand. There is a relationship between light and time. We can turn that pattern into a mathematical formula.	5
3	Followed by gradually trimming away the reality. These three steps take us from real world problems to mathematical problems	Make a pattern on the outer light 1-2 dark 2-3 bright 3-4 dark 4-5 bright 5-7 dark 7-8 bright 8-9 dark 9-10 bright	5
4	Solving the mathematical problem	From patterns we've created we know that the pattern of the mercury changes every 5 seconds which means that in one period there are 4 light changes that are dark-light-dark.	5
5	Describe what is the meaning of this strictly mathematical solution in terms of the real world	Which means every 5 seconds the spark will return to the same pattern.	3

No	Mathematic steps	Discussions	Score
1	Starts with a problem situated in reality	The problem is how many times space craft emits rays in 1minutes	3
2	Identify the relevant mathematics, and reorganizes the problem according to the mathematical concepts identified	The length of time affects how many times the lightning flashes. These relationships can be attributed to comparison formulas	5
3	Followed by gradually trimming away the reality. These three steps take us from real world problems to mathematical problems	There are several strategies that can be used as follows. 1. When each period is 5 seconds, there will be 12 periods per minute. 2. 2. Or we can use the 5 times per 10 seconds multiple approach, then in one minute we will multiply by 6.	5
4	Solving the mathematical problem	1. 5 seconds = 1 period 1 period = 2 patterns of light So, in 1 minute = $12 \times 2 = 24$	5

		2. 2. 10 seconds = 2 periods 2 periods = 4 pattern of light Then, in one minute = 6 × 4 = 24	
5	Describe what is the meaning of this strictly mathematical solution in terms of the real world	In 1 minute the spacecraft willemits 24 rays	3

Item type: open constructed-response
Competency Cluster: Connections
Overarching idea: Quantity
Situation: Public
TASK 2.
There are three apartments in the buildings. The largest, apartment 1, has atotal area $95m^2$. Apartements 2 and 3 have areas of $85m^2$ and $70m^2$ respectively. The selling price for the building is 300.000zeds. how much should the owner of apartment 2 pay? Show your work

Figure 5. *The example question for PISA*

Table 2. *Scoring Mathematics Steps*

No	Mathematics steps	Discussions	Score
1	Starts with a problem situated in reality	The problem is that the price of apartments is different.	3
2	Identify the relevant mathematics, and reorganizes the problem according to the mathematical concepts identified	The total price of the apartment is known, we are asked to find out the price of a second apartment. To find the price of the second apartment can by making the equation.	5
3	Followed by gradually trimming away the reality. These three steps take us from real world problems to mathematical problems	Making the form of the equation as follows: $95x + 85x + 70x = 30000\ zeds$ With x is the price of the square permetter of the apartment from the Equation we can obtain the entire area of apartment $95m^2 + 85m^2 + 70m^2 = 250m^2$	5
4	Solving the mathematical problem	So the price of the second apartment is $\frac{85}{250} \times 300000\ zeds = 102000\ zeds$ Which means $\frac{85}{250} = 1200\ zeds$ for each m^2, so the price for apartment 2	5

		is 102000 *Zeds*	
5	Describe what is the meaning of this strictly mathematical solution in terms of the real world	Means the price for the 2nd apartment is 102000 *zeds*	3

Here are some of the answers from the two tasks.

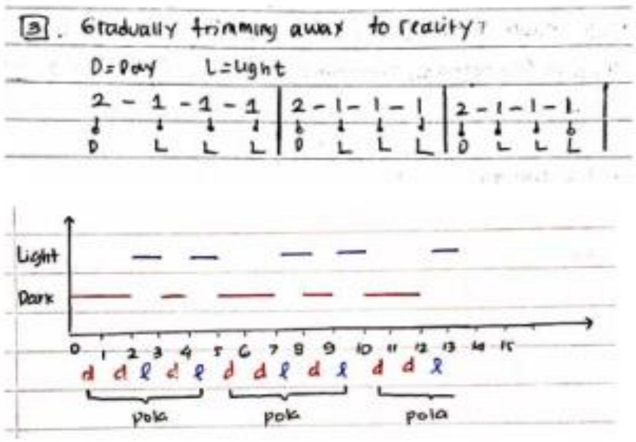


Figure 6. *The example question for PISA*

Above is an example of a third mathematical process where the process is to bring real-world questions into mathematics. From the two answers above we can get that to the same answer each individual is able to give different interpretations. So we can conclude that the process of mathematics can depend on how the experience and ability of a person understand their mathematical material.

Development of Mathematical Literacy

The process of mathematization is a crucial component of mathematical literacy, as has already been discussed. The process involves creating, applying, analyzing, and assessing mathematical concepts in a variety of settings. In actuality, the scenario or context of the problem that needs to be solved plays a major role in the method or representation that is used. It requires the skill of the student to apply his knowledge in a variety of contexts.

In fact, there are still a lot of students who have trouble doing it. Students who have been able to apply their knowledge to a problem do not necessarily apply it to different problems. Students need to experience problem-solving processes in different situations and contexts in order to be able to use their skills effectively. This experience can be facilitated through learning methods that give students the experience.

This can be facilitated by a variety of learning strategies or approaches. Several of them include problem-based learning, problem solving, contextual teaching and learning, and realistic approaches to mathematics. At this point, students will transform real-world issues into mathematical problems using their literary skills, answer them, and then interpret the results in authentic settings. They utilise and develop their mathematical literacy in this way.

Learning challenges are more than just problems. Four requirements should be met by the problem to be used: it must be real, complex, compelling, and powerful (OECD, 2022). The problem actually describes the actual problem as well as the broader context, which is the real point. Additionally, the challenge is meant to be so difficult that pupils must figure out the correct questions. Furthermore, the topics raised shouldn't be limited to commonplace narratives. The issues raised may be overly familiar or unfamiliar. And next need an Interventions aimed at enhancing academic numeracy will be more successful if they address language development in addition to mathematical competency (Prince & Frith, 2020) and than the pursuit of social justice and peace, think about decentralizing global mathematical knowledge and placing local mathematical practice, or margin, at the center of the mathematics education process (Rosa & Orey, 2023).

Conclusion

The capacity to effectively formulate, apply, and comprehend mathematics in a range of situations including difficulties from daily life is known as mathematical literacy. From the perspective of computations, numbers, and spaces, mathematics includes all ideas, methods, facts, and mathematical instruments. Process-wise, this skill encompasses not just computation but also thinking, communicating, and other mathematical thought processes. Mathematical processes provide a summary of these procedures.

To put it simply, mathematics is the process of translating and resolving real-world issues. All mathematical objects are involved in this process of issue solution. After a solution is found, it is applied to a real-world scenario or environment. A procedure like this will make someone more aware of how mathematics is used to solve difficulties in daily life. His sensitivity will enable him to tackle the issue quickly and successfully. This is applicable to everyday issues as well as complicated work-related issues.

Given the importance of mathematical literacy, efforts are needed to develop such skills. Education in this respect mathematical education has an important role to play in realizing it. As described earlier, learning mathematics should provide an opportunity or experience for students to solve problems in various situations. Through this way students will activate their literacy skills while developing them.

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Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of paper titled "**Mathematical literacy: Connecting the real world and mathematics"** belongs to the authors.

About The Authors

Nailul Himmi

Universitas Riau Kepulauan & Universitas Negeri Medan

Jl. Pahlawan no 99 Batam, Kepulauan Riau, Indonesia

E-mail: *nailulhimmi@fkip.unrika.ac.id*, **ORCID ID:** 0000-0003-0411-8594

Sadida Hasanah

Sekolah Globe National Plus 2 Batam

Komp. Batu Aji Center Park Blok G, Batam, Kepulauan Riau, Indonesia

ORCID ID: 0000-0002-3990-4504

Mangaratua Simanjorang

Universitas Negeri Medan

Jl. Williem Iskandar, Medan, North Sumatera

ORCID ID: 0000-0002-1238-3550

Syawal Gultom

Universitas Negeri Medan

Jl. Williem Iskandar, Medan, North Sumatera

ORCID ID: 0000-0001-9766-2438

SECTION 4

STEM EDUCATION

Web Based Instruction and A Sample Portal Design That Can Be Used in Web Based Instruction

Oguz CETIN
Niğde Ömer Halisdemir University

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Introduction

Today's rapid economic, social, scientific and technological developments have significantly changed our way of life. In particular, the impact of scientific and technological developments on our lives today is perhaps more evident than ever before. Although there is not yet a complete consensus on the level of knowledge reached by contemporary civilisation, considering the information explosion brought about by developments in science and technology and the possibilities offered by information technologies to social and economic development, it seems appropriate to call the stage described by Toffler as the "third wave" as the "information age" and the society envisaged by this period as the "information society". The ways of accessing information in the information society envisaged by the information age are differentiating, and this differentiation leads to the emergence of contemporary educational needs. Especially the rapid developments in technology drag all societies towards an information-centred life and as a natural consequence of this, education programmes are organised in this direction. Since investments in education are increasing, education policies are reshaped with this perspective. In this context, most of the developed and developing countries have been realising many innovations in recent years in order to improve their education systems. In particular, the natural cyclical relationship between science and technology - the fact that scientific research develops new technologies, while new technologies enable scientific research to be carried out under more favourable conditions - reveals the necessity of educating individuals who think scientifically and are technologically literate.

Undoubtedly, in the 21st century, which we call the information age, the fact that multimedia (hypermedia) tools, especially computers and the Internet, are used in many areas of life and have even entered into homes makes it necessary to change learning environments in raising technology literate individuals. In terms of the realisation of meaningful learning, the results that the development and use of multimedia-supported teaching activities that can stimulate students' visual and intellectual structures increase students' achievement are included in many research findings in the literature. At this point, the use of multimedia tools in educational environments has rapidly become widespread because it helps active learning, interaction and self-learning, which are mentioned in both the learning cycle approach, the four-stage model 4E, 5E and 7E models, which are different application forms of constructivist learning theory, and other learning theories. Especially the developments in computer and Internet technologies have dramatically increased the methods used in the teaching-learning process and educators have developed new teaching-learning models using multimedia tools. Depending on the developments in information technologies and especially the inclusion of the Internet in education, several new models such as Distance Education (DE), then computer assisted education, then Web Based Instruction (WBI), E-learning, Internet Supported Education, Internet Based Distance Education (IBDE) have emerged. WBI, which is a sub-type of DE and realised by using Internet technologies, has an important place in education. It is seen as a development that will affect the classical understanding of education and training and change the quality of the education process. Web pages are developed for education in the Internet environment and these pages are enriched with text, graphics, sound and animations and made interactive. Students can follow academic publications from digital libraries, send e-mails to their advisors to discuss their projects and enrol in Web-based courses from their homes. At this point, it would be appropriate to give information about WBI, which is a sub-type of DE.

Web Based Instruction (WBI)

When the literature on WBI is analysed, it is seen that there are studies that have the same aim but have emerged under different titles. These differences are not an indication of an intellectual difference, but only of the fact that the subject is new and therefore common accepted standards have not yet been reached. Especially what is intended to be expressed with the concepts of IBDE, WBI and E-learning are basically very similar ideas. "The use of all kinds of Internet facilities for the purpose of distance education" is referred to as IBDE, and this type of learning is called WBI or E-learning.

Although there is no consensus on the definition of the concepts, IBDE is a general approach that covers all educational models using the Internet infrastructure. Models such as E-learning, Internet Based Asynchronous Education, Web Based Corporate Training, Web Based Distance Education, Web Based Virtual Classroom, WBI are models that are generally considered within the scope of IBDE.

Definition and Meaning of Web Based Instruction

Teleconference calls using the Internet network, electronic mail replacing traditional mail, electronic books and periodicals providing an alternative to printed resources are tools that have been used as part of IBDE. Almost all of the different tools used under the name of IBDE are utilised in WBI. Web page structures are organised to access the content, e-mail lists are used to ensure and maintain healthy communication, discussion lists and chat programmes are used to increase interaction.

At this point, WBI can be defined as a learning-teaching model that can be easily accessible, can support flexible storage and display options, can provide an easy, very powerful publishing format and can include multimedia elements. According to another definition, WBI is "the realisation of the education of individuals by using Web technologies in the organisation of pre-planned teaching-learning activities for any purpose".

With WBI, audio, video, image, graphic, written text, animation and the like can be used together to explain a subject. This not only enables students to learn information through auditory and visual means, but also enables them to actively access information and learn through trial and error and error correction. Simulations of natural applications of complex concepts are presented to the students and they are enabled to learn with their own abilities and knowledge.
WBI is an effective way of supporting the learning environment and with this feature, it seems to be able to respond to the needs provided that the necessary dialogue is provided by involving computer and communication technologies. The basic elements of the Internet are information, transfer and production of information. The Internet contributes to the education system as it provides access to more information at greater speeds. Due to the use of the Internet with WBI, it has become possible for anyone to access the information they want from anywhere, regardless of where the information is located.

WBI via the Internet offers many additional benefits to educators. Firstly, and perhaps most importantly, WBI systems are less device dependent. Secondly, information and resources can be easily accessed by anyone at any time and place (provided they have a computer with an Internet connection). Thirdly, it is easier to update and manage the materials and information available on the site server.
The time spent in the current education and training process is very long, often there is not enough teaching staff and the inability to provide classrooms, laboratories and educational materials causes disruption of the education and training process. Since WBI provides the requirements of producing information, storing, sharing and accessing it easily, its use in business life and daily life has become increasingly widespread. Internet and Web are the most valid ways of accessing information easily, cheaply, quickly and safely and exchanging ideas on numerous subjects.
Different methods can be used in WBI, including Asynchronous (e-mail, discussion lists, discussion forums) and synchronous (chat-chat channels, real-time audio/visual conferences, applications, etc.).

In terms of understanding and practice, WBI shows a change from objectivist approaches to constructivist approaches. In particular, the fact that network-based learning environments allow access to various communication channels such as student-content, student-student, student-teacher, student-other multimedia resources and student-other teaching staff leads to the emergence of learning as a product of interaction in virtual classrooms. WBI aims to realise the individual's own learning by using the features of the Internet such as time and space independence depending on the constructivist learning approach.

By using constructivist learning approach with WBI, students can produce their own graphics, Web pages or any project related to the subject; they can be directed to team work; they can discuss the subjects in e-mail, forum or chat pages; they can learn in a realistic environment by developing problem solving skills with activities such as audio, video, interactive activities, simulated experiments in virtual environment, animations etc.

The fulfilment of the above-mentioned functions that should be present in WBI and the integration of the constructivist approach into WBI can only be realised through an appropriate instructional design.

According to the researches in the literature, the number of indexed Web pages exceeded 11.5 billion in mid-2005 and new Web pages are created at the rate of 8 per cent of the existing Web pages on a weekly basis. At this point, content for WBI should be developed more by educators.

Based on the information given above, in the next section, a sample WBI portal designed according to McManus' (1996) Hypermedia Design Model, which contains the elements that should be present in WBI and is based on the constructivist approach, is introduced.

A Sample Web Based Instruction Portal Designed for Science Education

It is important that the content of WBI is up-to-date, adequate, related to other informatics software, appropriate to grammar rules and includes multimedia applications. In addition, in the selection and preparation of materials, target audience characteristics, learning styles should be determined correctly, appropriate media tools should be selected, and attention should be paid to present materials that will meet the needs. In curriculum design, attention should be paid to the organisation of the content, the topics to be covered, the media tools to be used, the teaching strategies to be determined, the system to be used to evaluate the success of the course, the feedback methods to be determined and the methods to be used in the production of tools and materials.

When designing WBI content, all the variables of instruction need to be considered. It is quite easy to simply put information together and put it on the Web, but this is a very small part of designing instruction. In the organisation of all variables, instructional design theories should be used. At this point, in the sample content presented, the descriptive approach was used in the design dimension and the steps of the Hypermedia Design Model were taken into consideration. The sample WBI portal was designed for Science Curriculum outcomes at all grade levels in secondary school.

In the dimension of defining the learning domain, document analysis method was performed before the design was realised. Since document analysis involves the analysis of written materials containing information about the phenomenon or phenomena targeted to be investigated, the applications in the literature and textbooks were examined within the framework of the acquisitions in the secondary school Science Curriculum.

In addition, studies on misconceptions in the literature were analysed and activities were planned to prevent possible misconceptions.

While designing, the following points were taken into consideration in line with the expert guidance;

- Before writing the information on the subject, the concepts that should be taught depending on the objectives and achievements of the course determined by the Ministry of National Education were determined.
- It was determined how and with which definition the determined concepts would be taught.
- After the definition of the concept was determined, activities such as concept maps, experiments, etc. were designed to teach this concept more effectively.

- The order in which the concepts would be taught was determined.
- The materials needed to ensure the transition between concepts and the connection between concepts have been developed.

To prevent the students from getting bored, the lectures were kept as short as possible and elements such as animations, activities, experiments and games were used to make the students more active.

It is aimed to have the following qualities in the prepared portal;
- To create a teaching plan suitable for each student,
- Creating a platform suitable for the structure of Science Lesson (Spiralling),
- Analysing students' learning styles,
- To provide students with quality attention strategies,
- Analysing students' learning strategies,
- Analysing students' self-regulation skills,
- To determine the scientific process skills of students.

Therefore, it is desired that the portal to be prepared should be designed as a special platform suitable for each student structure and that students should progress at their own pace according to their readiness levels. In the preparation of the portal, the UNESCO Standards determined for the distance education process were taken as a basis. These standards require the distance education system to have the following features;
- Security (Encryption-Authentication)
- Access Individual/Group Access Password
- Course Design, Development Integration
- Personalisation
- Course Supervision
- Practice and Evaluation
- Student Profile Management
- Online Communication and Group Work
- Productivity Tools
- Technical Competence

In the digital portal prepared on this basis, the preliminary determination of student achievements, the creation of the Step Lock System that supports spiral learning, and in this way, by determining the student's preliminary readiness, it is ensured that he/she can follow the course only in accordance with his/her own competence as simple, intermediate and advanced level. The portal was designed according to the "Hypermedia Design Model" developed by McManus and based on constructivist thinking. In this framework, a portal has been prepared for each student with a user-membership system where he/she can make his/her own navigation and arrangements, follow the content he/she wants within the same step (subject level) and complete the content appropriate to his/her level. In addition, the parent and school information system was also included in the portal.

It has been agreed that the platform will include the following elements;
- Rich subject content
- Topic summary

- Applications that appeal to more than one sense organ (audio narration, video, animation, simulation, educational game, concept map, experiment, puzzle, etc.)
- Forum pages where students can communicate with each other and their teachers
- Download links where information about science can be downloaded
- Short messaging module
- Links to puzzles, drama, video, picture, experiment, activity, lecture, presentation, project etc. related to science (as archive)
- File sharing module (allows students to share files with each other)
- Online lectures
- Online test solutions
- Online homework assignment system
- Notebook
- Search engine
- Calendar
- Links to useful sites

The prepared portal is expected to provide contribution and diversity to scientific studies in secondary school science education, to bring results and suggestions that will be useful in the studies to be carried out on the development of the secondary school science curriculum, to provide new options to the methods, techniques and activities used in science teaching, to create new thoughts, discussions and research topics for science education practices, It is desired that the Internet, especially distance education, will generalise to other fields of education by developing creativity for other fields, increase the learning skills of students and thus reduce the workload of teachers, enable students to realise their own learning strategy profiles and gain study skills in this direction, develop self-learning skills, and contribute to raising a successful new generation in the numerical fields and science that our country aims for.

Technical Infrastructure Used in the Portal

- For software consistency, Codeigniter version 3.1.13 framework was preferred instead of spaghetti code (https://www.codeigniter.com/).
- The portal is written in PHP 7.2 version.
- MySQL 8.0.34 was used as the database.
- The server has been selected to be hosted within Turkey in accordance with KVKK.
- The server is built with Linux operating system.
- Apache 2.4.57 is used.
- Server management is provided by Cpanel 110.0. (build 5) version.
- CronJob definitions have been made for automated processes.
- Cloudflare system is used as a proxy server (https://www.cloudflare.com/).
- Agile software principles were adopted during the creation of the portal. Scrum methodology was used. Sprint meetings were arranged with 3-day intervals, software developer, project manager and test user communication and feedbacks were always prioritised and modular development was focused.
- During the creation of the software, clean code methods were preferred and SOLID software principles were adopted as a guide.

- Jetbrains product PHPStorm tool was used as IDE.
- Trello was used for Task Board for task management (https://trello.com/).
- Bootstrap 4 is used in the design with flexible (responsive) feature.
- Meister Task (https://www.meistertask.com) programme was used for task-work monitoring.
- PhpStorm IDE produced by Jetbrain company was used for software production.
- During the production process of the software, the GitHub system, which uses the GitHub infrastructure, was used by constantly considering the versioning logic, and the developed software was stored and versioned in the private repository.

The portal is currently hosted on a server purchased with project resources and can be accessed from https://obecaportal.net/. The server on which the portal is hosted is capable of handling heavy traffic and providing high performance.

Portal Corporate Page

The website, which shows the institutional face of the system, hosts the introduction and user login and registration processes, has been completed. On this homepage, which emphasises the convenience, measurability, accessibility, quality content and the step-lock feature that forms the backbone of the portal, the features and objectives of the portal have been tried to be explained to users and interested parties with understandable and simple content. When users search the address https://obecaportal.net/ in their Web browsers, they first encounter this home page. The homepage contains informative links about the portal, videos, sliders and content introducing the portal, student statistics, social media links, contact information, About Us, Contact Us, User Registration and Log In menus for registered users.

Figure 1. *Web Based Instruction Portal Home Page*

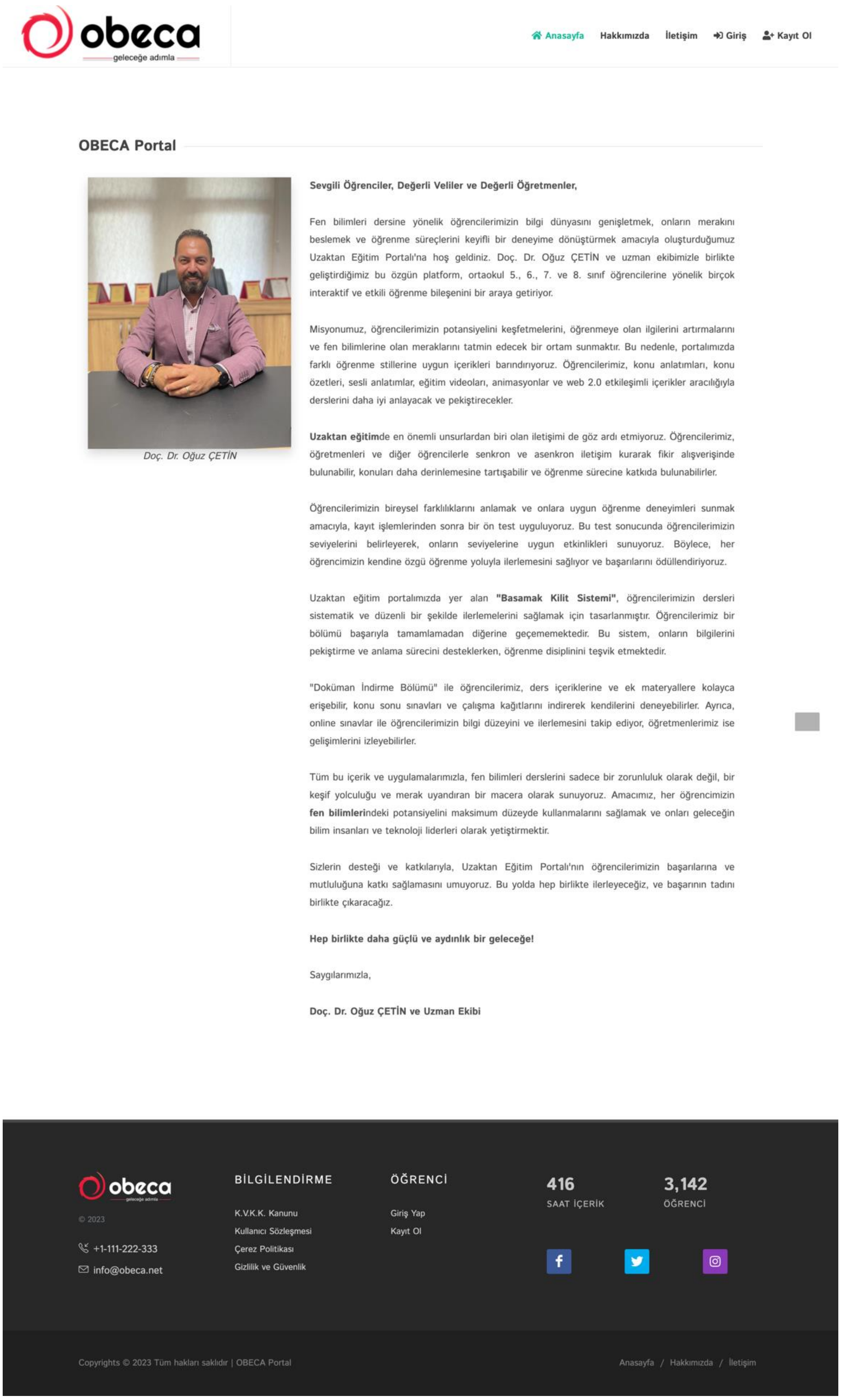
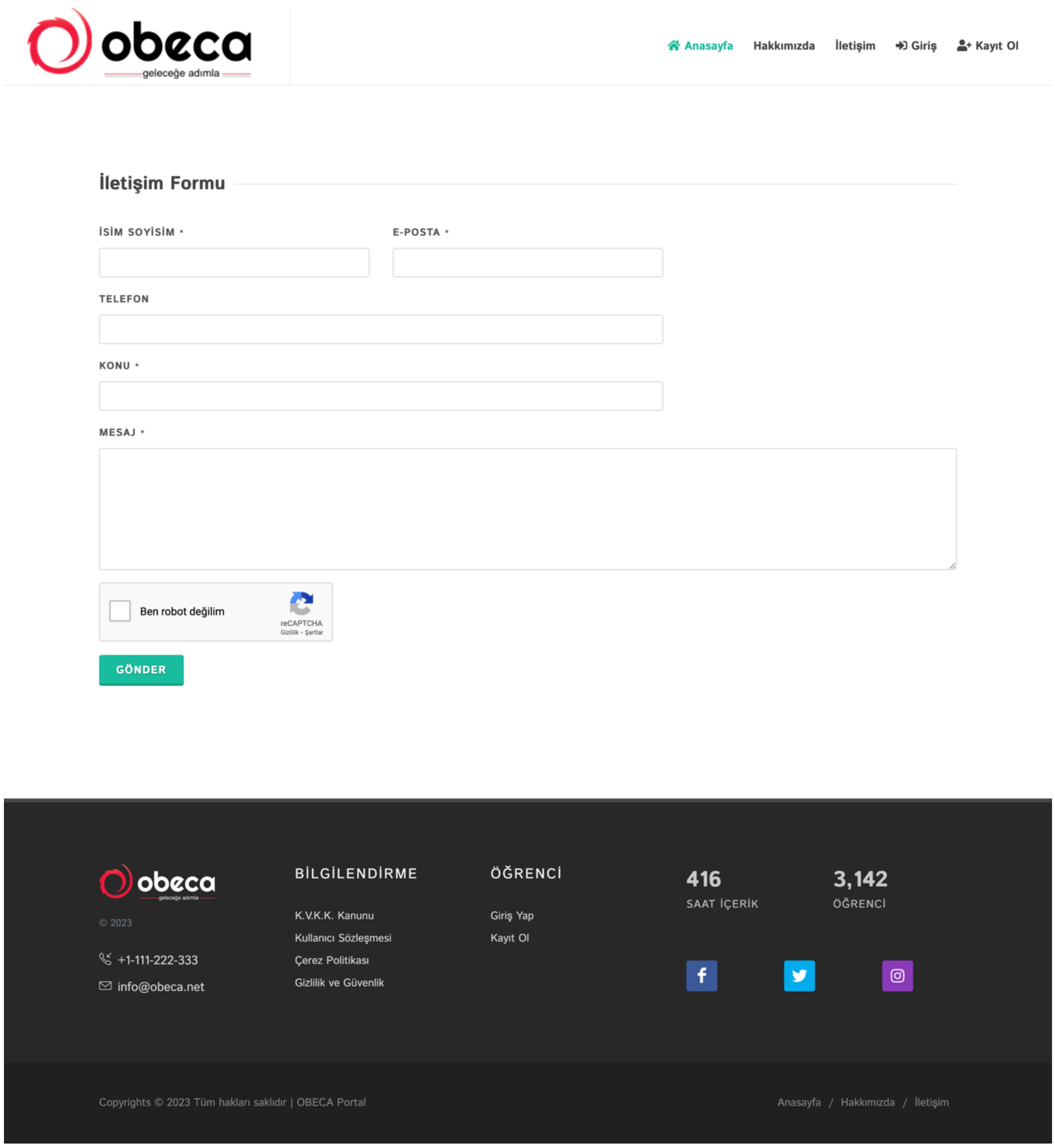


Figure 2. *Menus on the Home Page*



All messages sent via the contact form are sent to info@obecaportal.net.

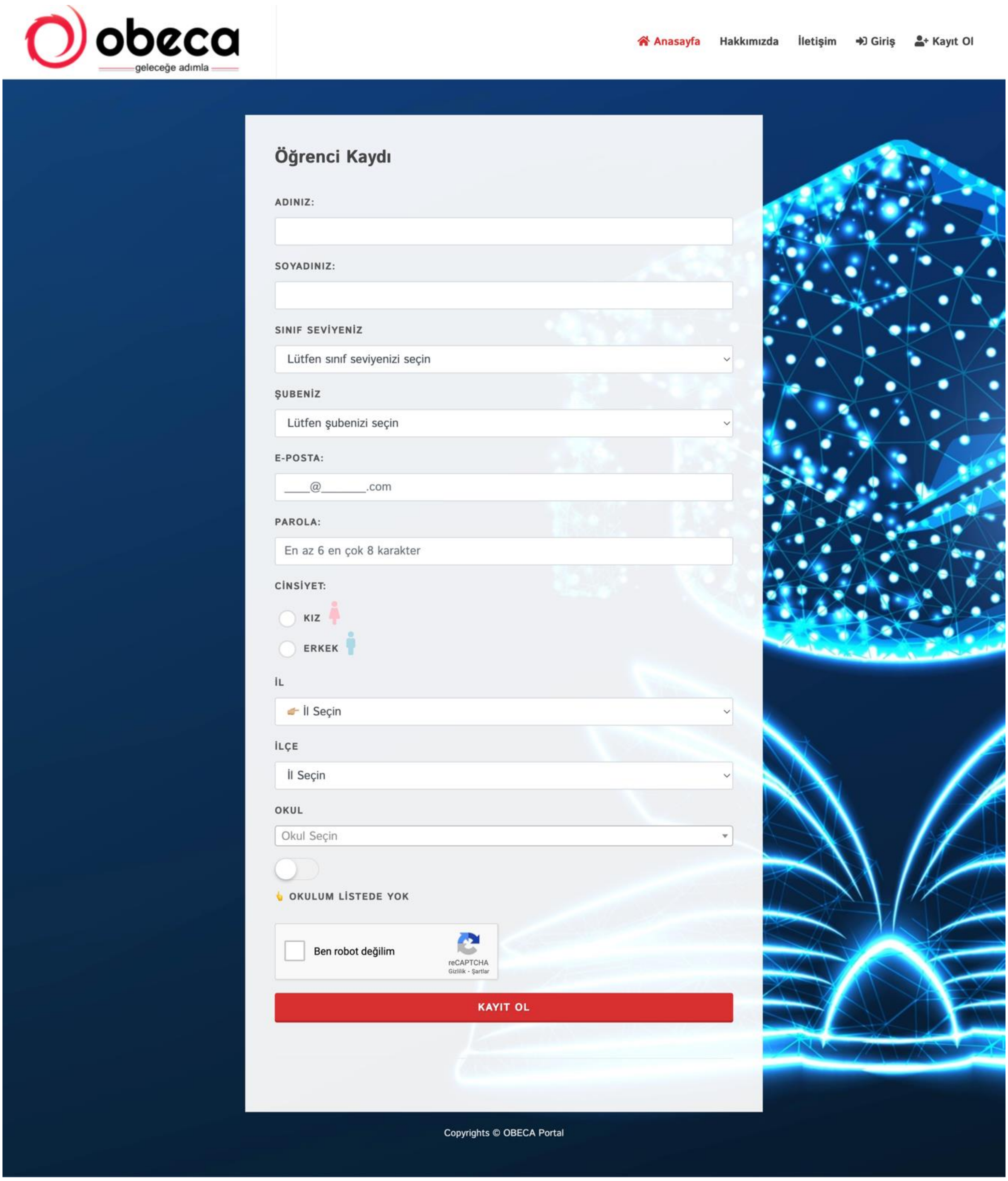


Figure 3. *Student Registration Section*

Student registration section is encrypted with high security. All educational institutions in Turkey are registered in the system. After the student performs the membership process, he/she is seen as a passive member in the management panel, and if he/she makes the payment using the payment information sent by the system to the e-mail address he/she wrote during membership, he/she switches from passive membership to active membership.

Portal's Student Panel

Students registered to the portal system must first take a pre-assessment exam in the system in order to view the educational content suitable for their readiness and knowledge levels within the step-lock system. The most unique and R&D feature of the portal, which makes it different from other Web-based education portals, is that each student operates the education process with content appropriate to his/her level after a pre-assessment. Students are classified in three different levels as "Beginner", "Intermediate" and "Advanced". At the same time, all units in the portal are designed according to the step-lock system. The reason for this is that in order to learn a subject in science course, it is a prerequisite that another subject should be learnt beforehand (spiralling).

In the portal, when the student logs into the system with the Login window, he/she first encounters the First Exam module. In other words, after the first login, the student takes a 20-question readiness exam (pre-test) that examines the science acquisitions of the previous academic year. According to the results of this exam, the level of the student is determined. In order to ensure this, a question pool system was created in the management panel during the preparation phase of the portal, which allows the entry of beginner, intermediate and upper level questions, and also allows the students to determine how many questions will be shown at which level and to randomly draw questions from the prepared question bank. There are 462 questions and answers in this first exam system.

At the same time, the question pool system also includes an evaluation and grading feature within the algorithm that evaluates the performance of the students in the first exam according to the previously determined success ranges that can be changed from the admin panel and associates the student with the educational content according to his/her level. In this way, it is ensured that the student starts his/her studies with the educational content suitable for his/her level according to the result obtained after the first exam.

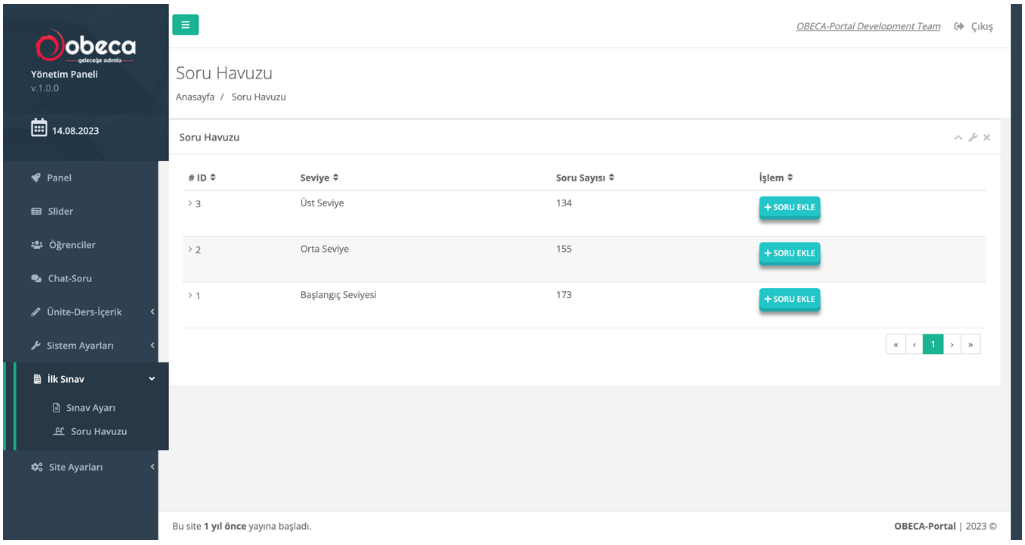
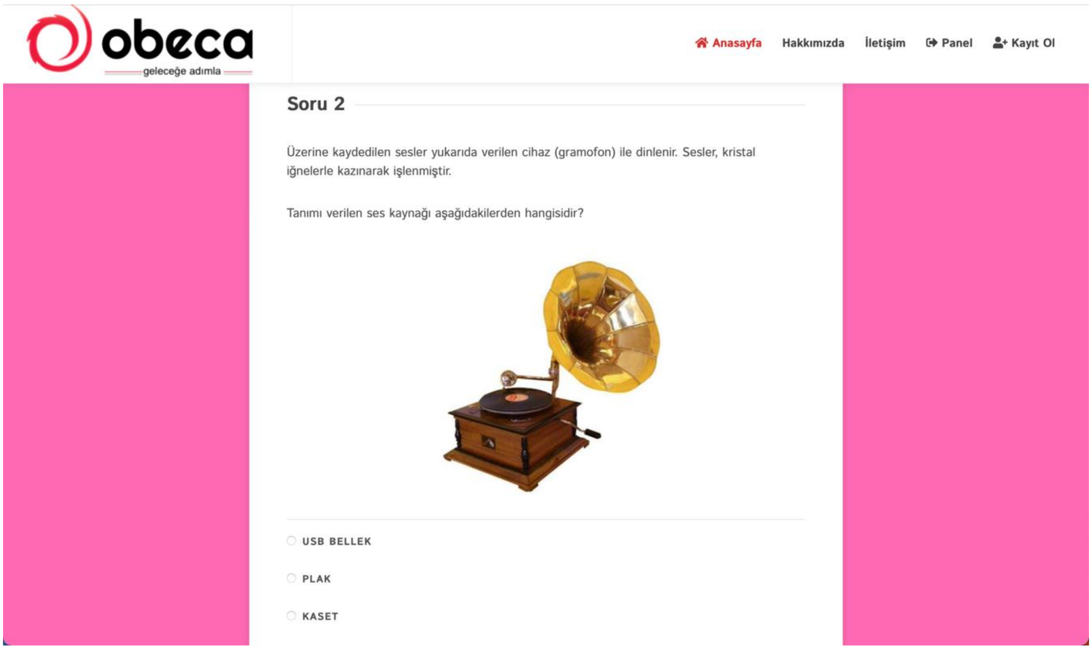
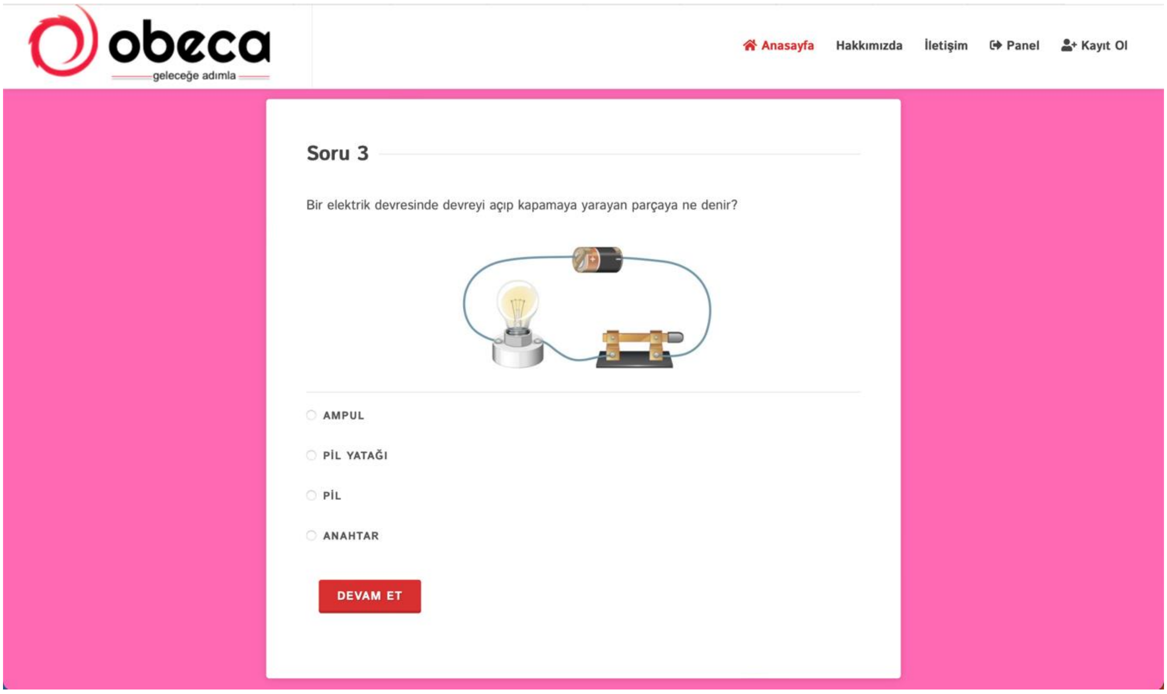


Figure 4. *Question Pool Entry Screen*

The top image shows the first exam question pool login screen. In the lower images, there are images from the first exam screen that the newly enrolled student will encounter. The page theme changes according to the gender of the student. The exam process is monitored in case of internet or power outage, or if the student leaves the exam unfinished for any reason, and the exam continues from where it left off when the student next visits the portal. No student who completes the exam and does not reach the result screen has no chance to access the student panel and therefore the learning content.





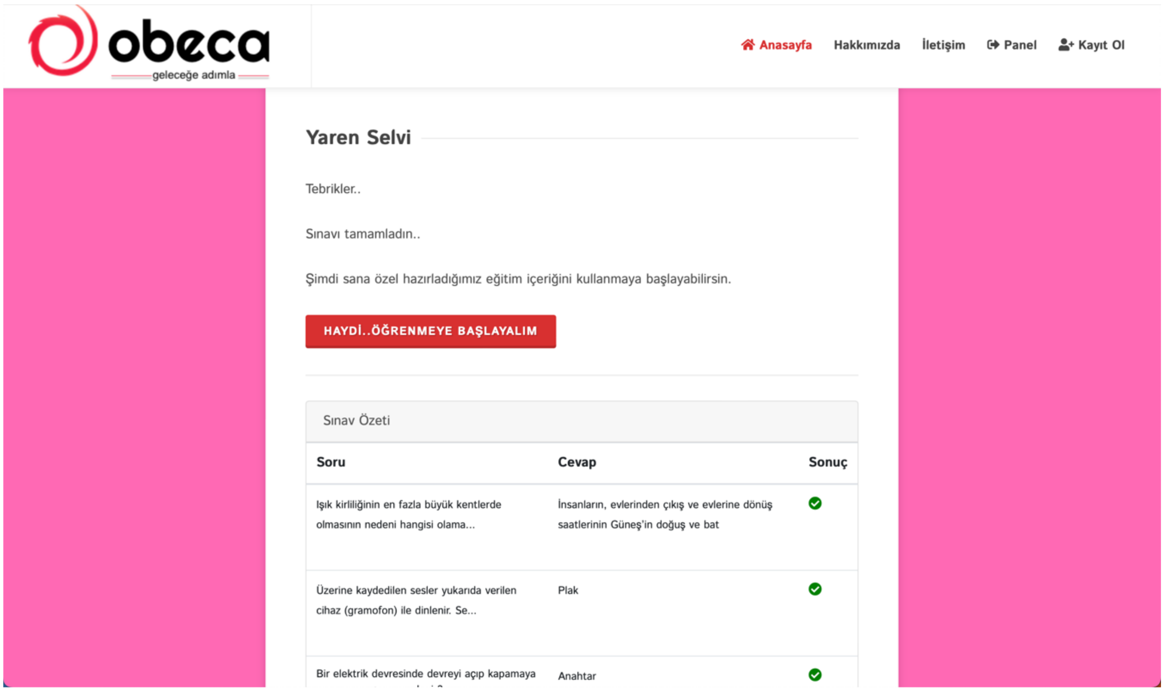


Figure 5. *First Exam Screen*

After completing the first exam action mentioned above, the student can see the answers he/she has given in the exam and from here, he/she can see the page we call the student panel, which contains the educational content and the student's success statistics.

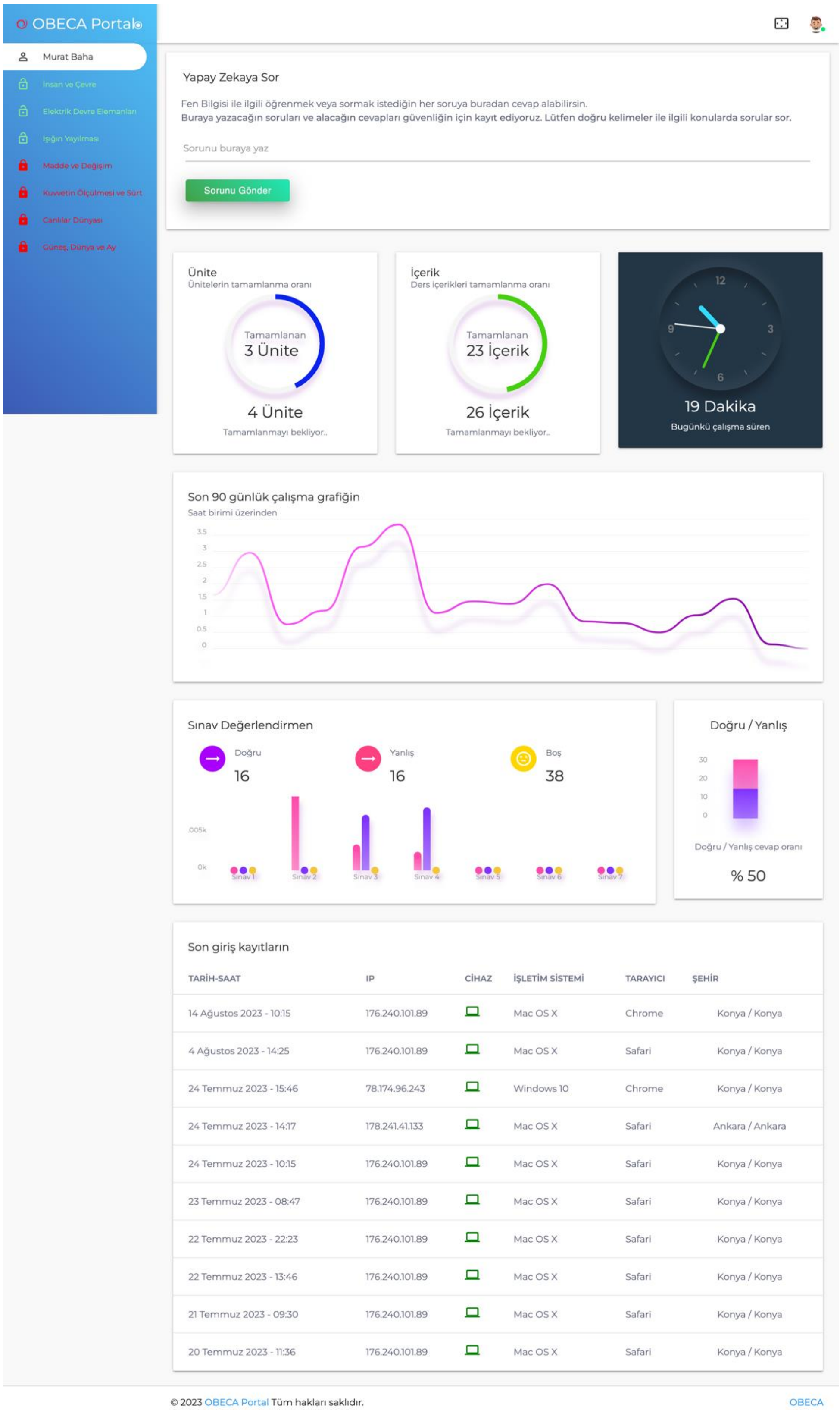


Figure 6. *Student Panel (1)*

In the left vertical menu on the student panel, there are topics designed according to the step-lock system, where the topics that are allowed to view the content are coloured green and the locked content is coloured red. According to the principle of spiralling, the student cannot switch to another topic before completing a topic

completely. In accordance with McManus' "Multimedia Design Model", the student can navigate within the same topic as much as he/she wishes. However, after completing all the content related to the subject (video, audio, lecture, animation, etc.) and after being successful in the end-of-subject exam, the other subject is unlocked and the student can switch to the new subject.
ChatGPT artificial intelligence chatbot (gpt-3.5-turbo) produced by OpenAI company has been added to the top of the page body. In this way, it is aimed that students can access information other than the content within the system. Every data/question entered by the student in the input in this section is recorded and analysed. Based on the questions asked by the students, the chatbot prompt settings are made.

There are 3 info boxes just below the artificial intelligence chatbot. The first one shows the student's progress in the course content on a unit basis, the second one shows the progress made on the basis of the course content, and the third one shows the current time and the time spent in the system that day.

Below the information boxes, at the 3rd level of the page, there is a graphical display showing the student's last 90 days of study time records graphically, and the student can visually examine the daily study status by following this graph.
Under the graphic screen, the results of the end-of-unit exams, which form the key to the step-lock system, are presented to the student as a column graphic in the context of true/false and questions left blank.

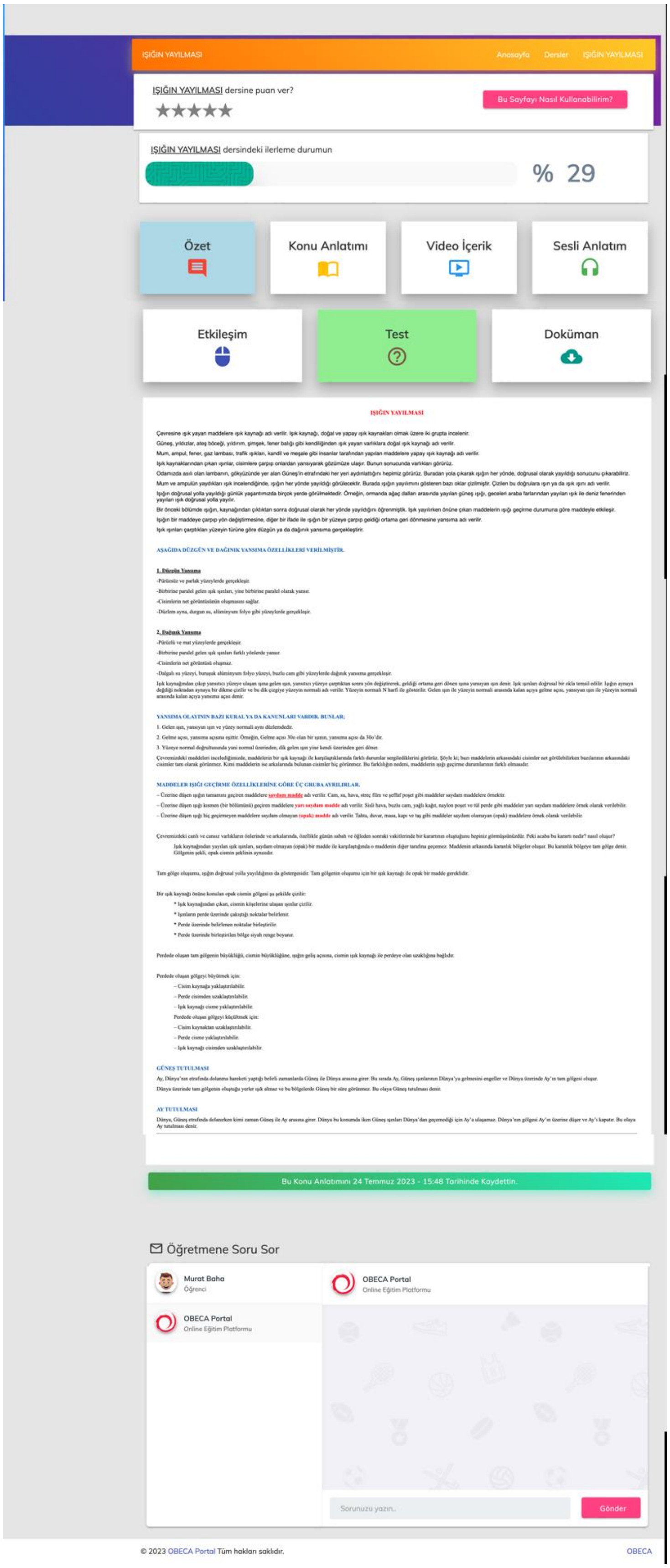
On the small screen next to it, there is an information graph that evaluates the correct / incorrect ratio of the questions answered by the student in all exams.
At the bottom of the student panel, the last 10 of the student's login records to the system are displayed, so that students can see their work tempo as well as security monitoring.

Using the Student Panel

When the student goes to the unit title that he/she is allowed to see within the step-lock system from the vertical menu, he/she goes to the page where he/she will see the subject title and the content within that subject. On this page, there are buttons for viewing the content under 7 headings (Summary-Subject Lecture-Video Content-Audio Lecture-Interaction-Test-Document) determined according to UNESCO distance education platforms standards, an information bar (infobar) showing the progress of the student in the context of the subject content as a percentage (%), a scoring system consisting of stars that the student can evaluate the course content and give feedback, and a tour/guide button that introduces the buttons and features on the page to the student and teaches them how to use them. The content selected through the buttons is presented to the student in the centre of the page body.

Under the course content, there is a chat screen that enables and facilitates the student to communicate with the portal administrators and teachers and is similar in design to current and popular chat programmes. With this chat screen, the questions or contents asked are notified to the portal administrators in the management panel with a warning. The answer given by the teacher is displayed on the same chat screen. Chat content is separated in terms of subject. With the chat feature, the student will be able to get feedback about the course content, and will not have to

look for extra and troublesome ways to communicate with the portal management when there is a question that he/she cannot understand or wants to ask.
At the end of each subject, the student is faced with the situation of leveling up or leveling down in the next step with the success score he / she has obtained after the exam he / she has taken.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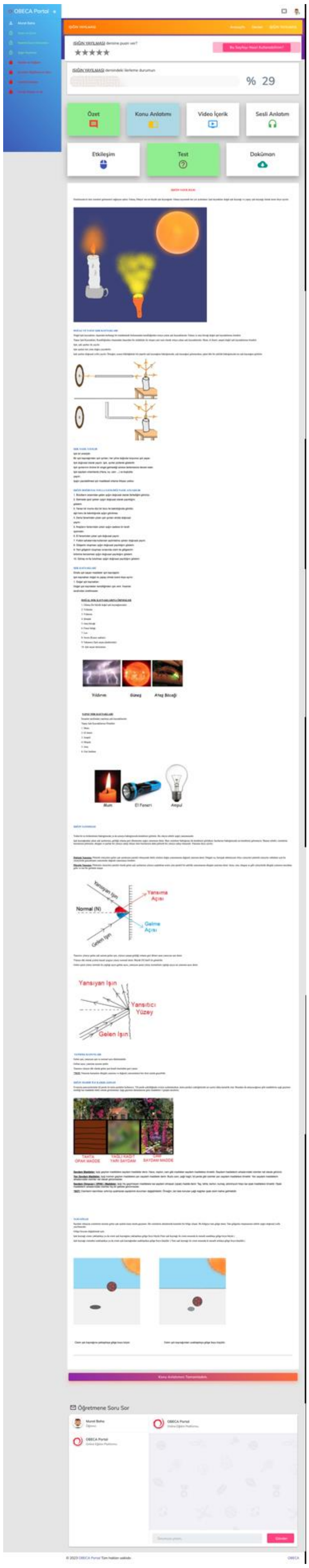
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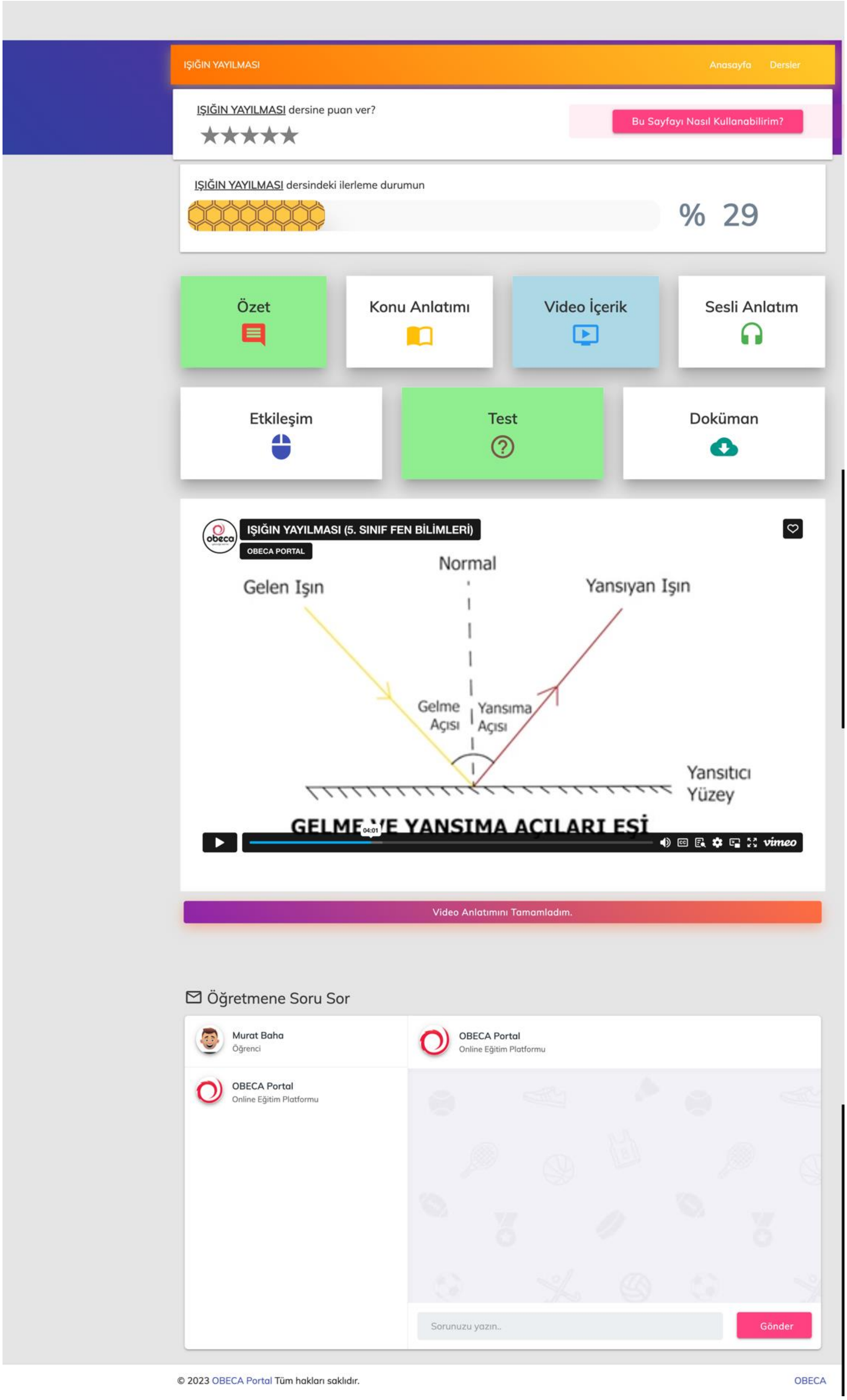
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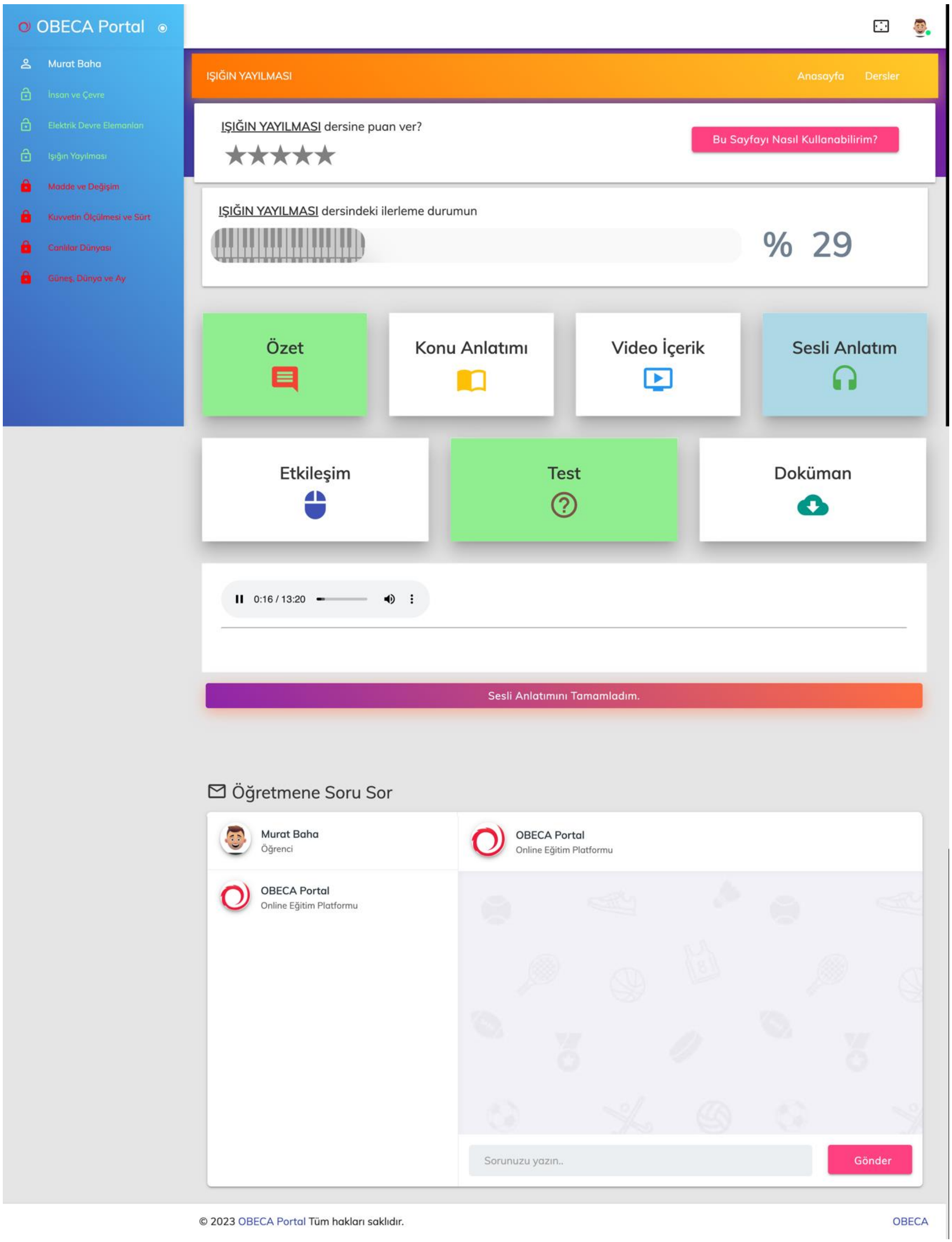
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Öğretmene Soru Sor
Murat Baha
Öğrenci
OBECA Portal
Online Eğitim Platformu
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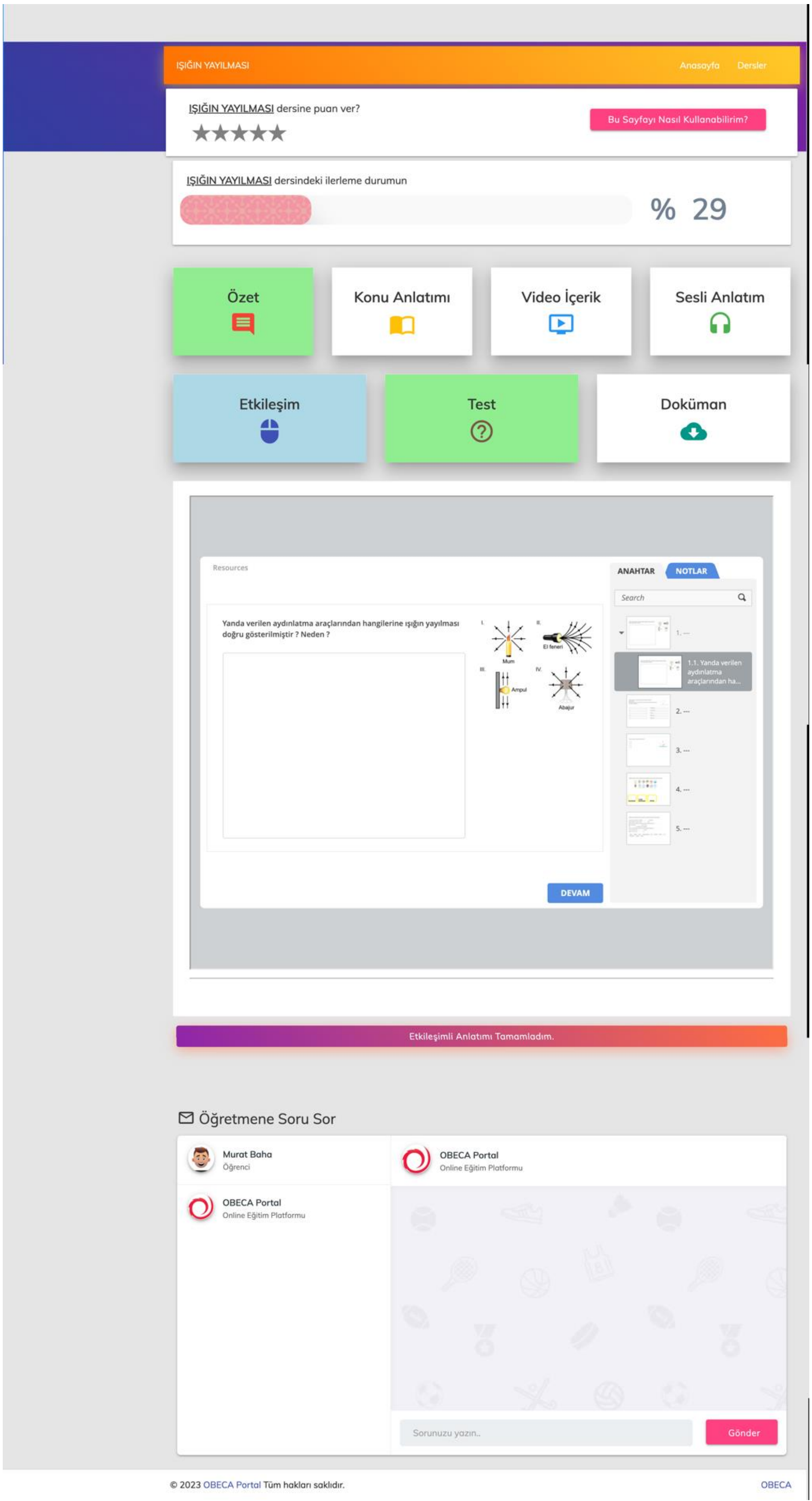
IŞIĞIN YAYILMASI
Anasayfa
Dersler
IŞIĞIN YAYILMASI dersine puan ver?
Bu Sayfayı Nasıl Kullanabilirim?
IŞIĞIN YAYILMASI dersindeki ilerleme durumun
% 29
Özet
Konu Anlatımı
Video İçerik
Sesli Anlatım
Etkileşim
Test
Doküman
Resources
ANAHTAR
NOTLAR
Search
Yanda verilen aydınlatma araçlarından hangilerine ışığın yayılması doğru gösterilmiştir ? Neden ?
DEVAM
Etkileşimli Anlatımı Tamamladım.
Öğretmene Soru Sor
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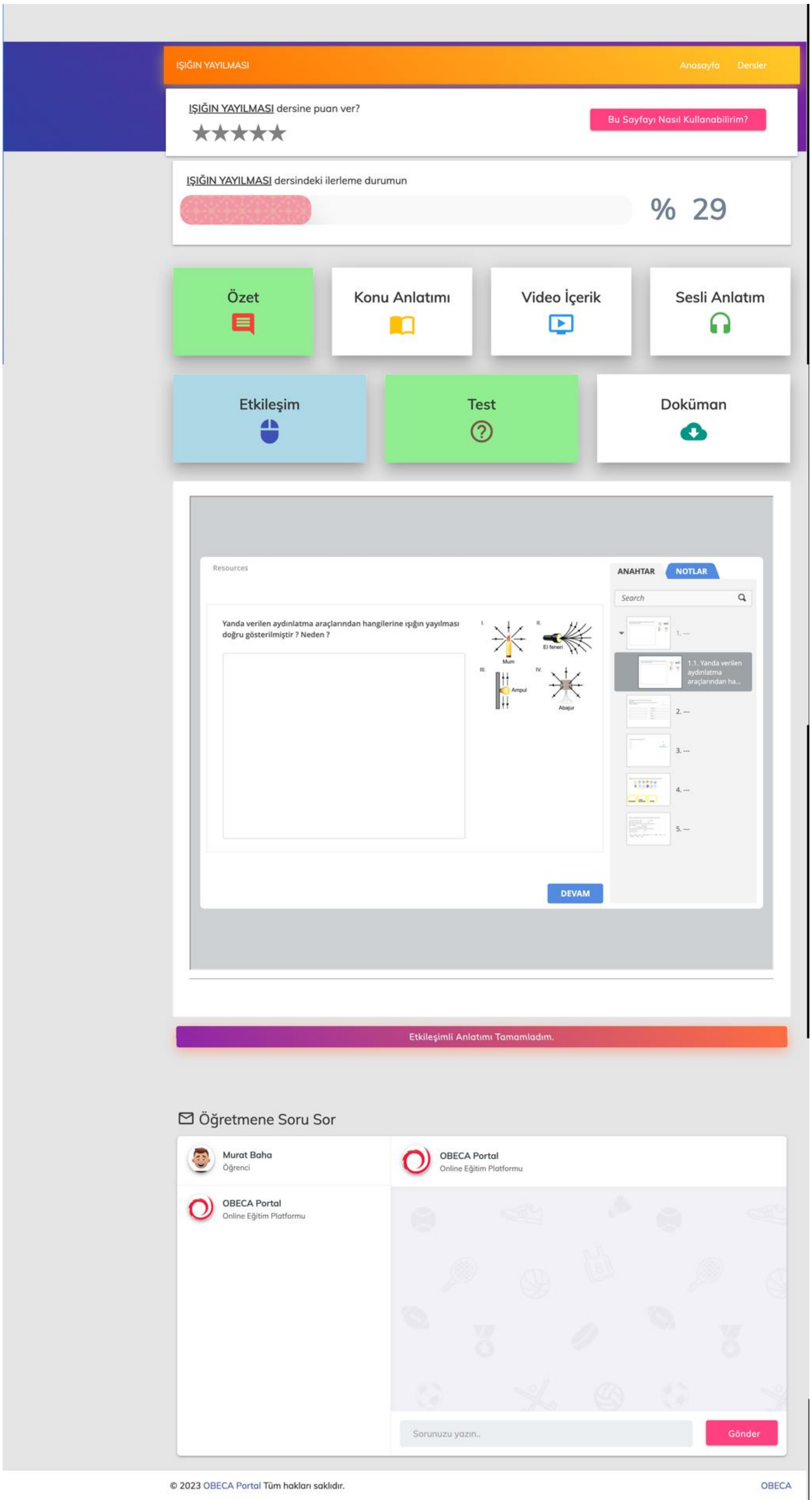
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% 29
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Etkileşim
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NOTLAR
DEVAM
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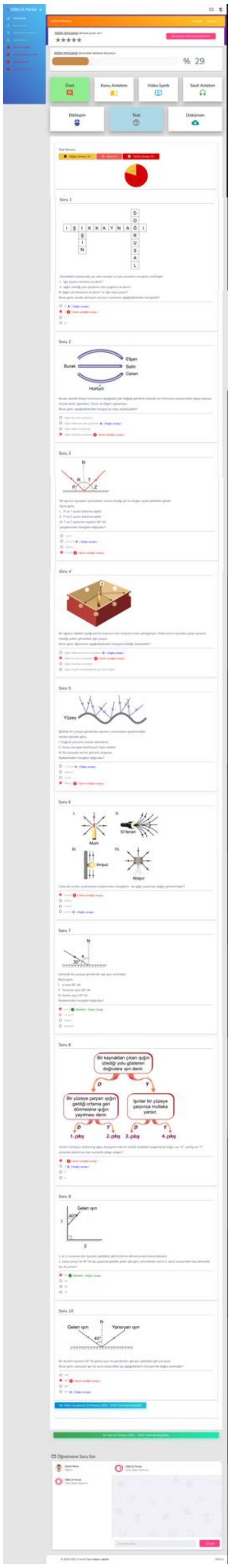

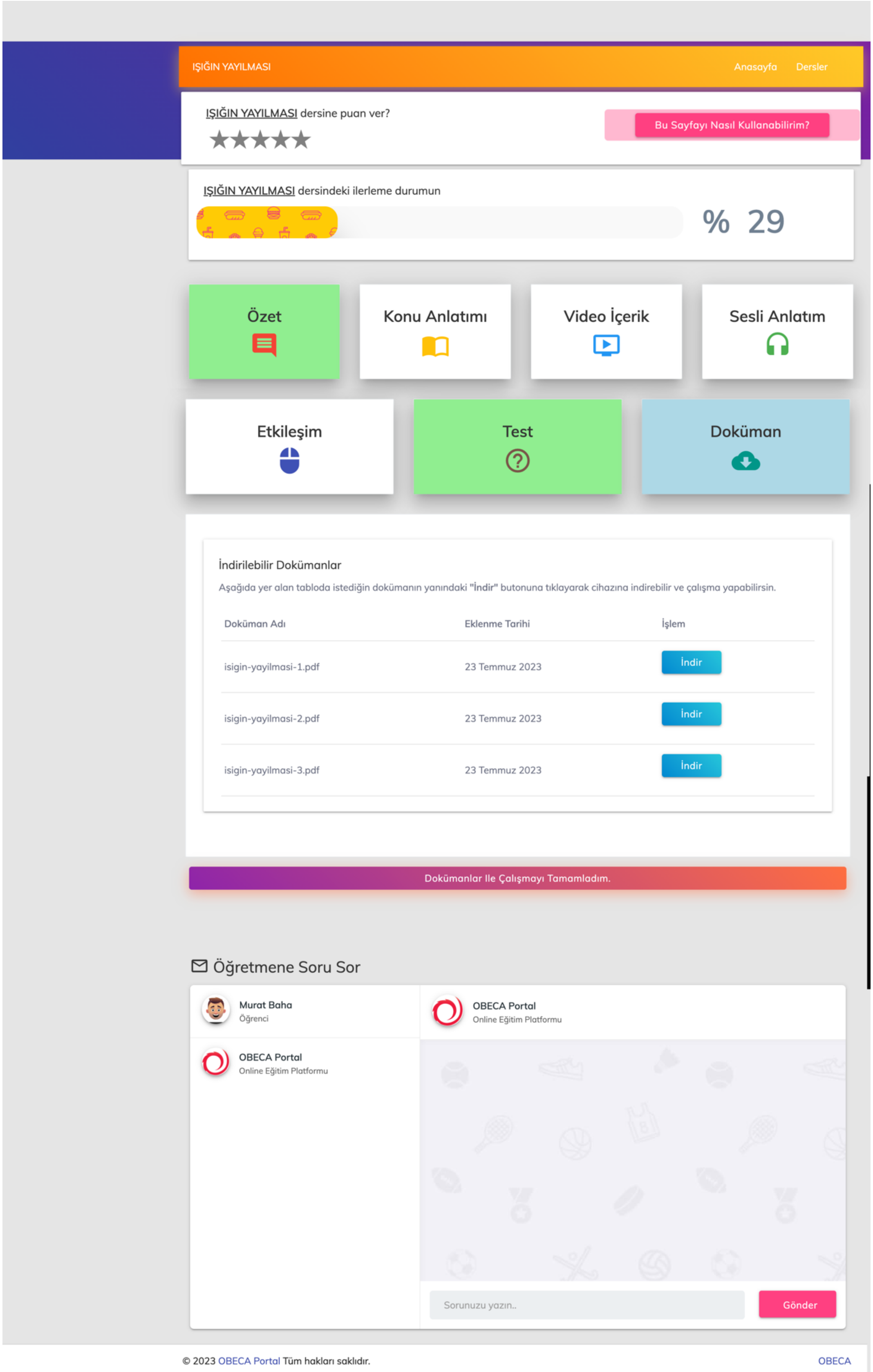
IŞIĞIN YAYILMASI
Anasayfa
Dersler
IŞIĞIN YAYILMASI dersine puan ver?
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IŞIĞIN YAYILMASI dersindeki ilerleme durumun
% 29
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Etkileşim
Test
Doküman
İndirilebilir Dokümanlar
Aşağıda yer alan tabloda istediğin dokümanın yanındaki "İndir" butonuna tıklayarak cihazına indirebilir ve çalışma yapabilirsin.
Doküman Adı
Eklenme Tarihi
İşlem
isigin-yayilmasi-1.pdf
23 Temmuz 2023
İndir
isigin-yayilmasi-2.pdf
23 Temmuz 2023
İndir
isigin-yayilmasi-3.pdf
23 Temmuz 2023
İndir
Dokümanlar Ile Çalışmayı Tamamladım.
Öğretmene Soru Sor
Murat Baha
Öğrenci
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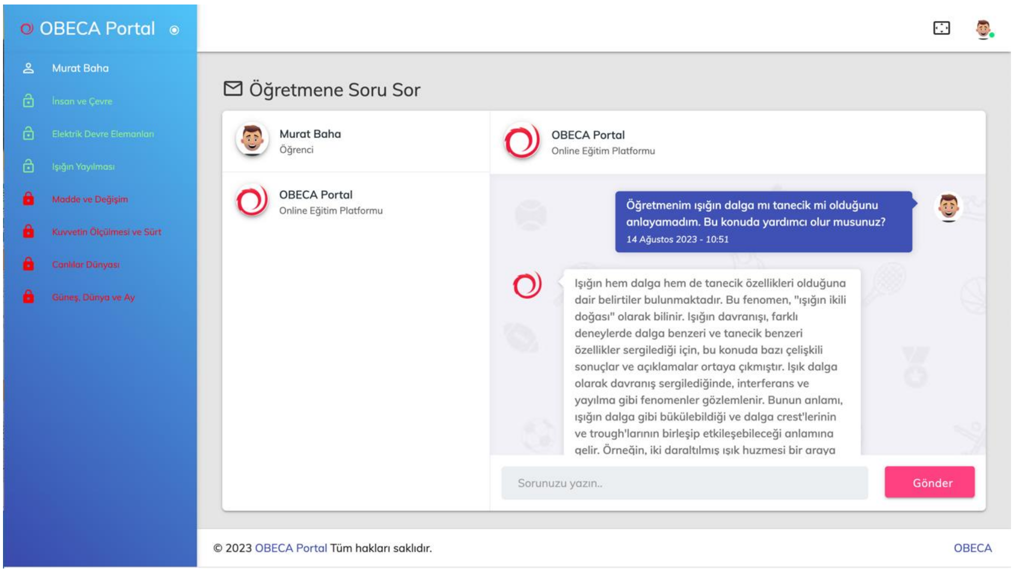
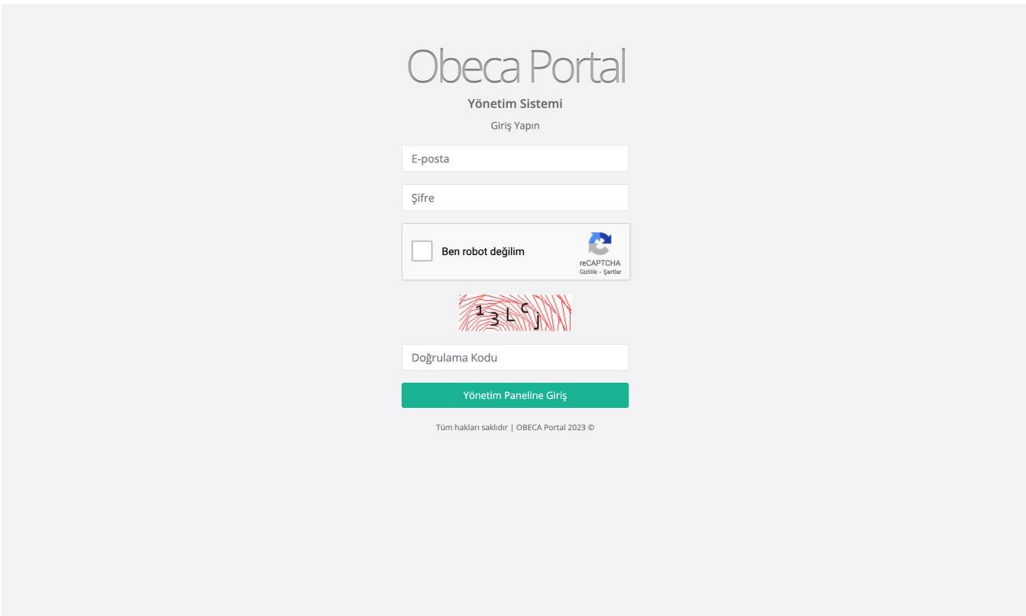


Figure 7. *Student Panel (2)*

Portal Administration Panel

All management of the portal system is carried out through the administration panel. This panel is accessed through the login screen and the login operation is protected by both captcha code and Google Recaptcha feature. When the administration panel is successfully logged in, a vertical menu and a main page containing graphics-tables and information containing portal statistics are accessed.



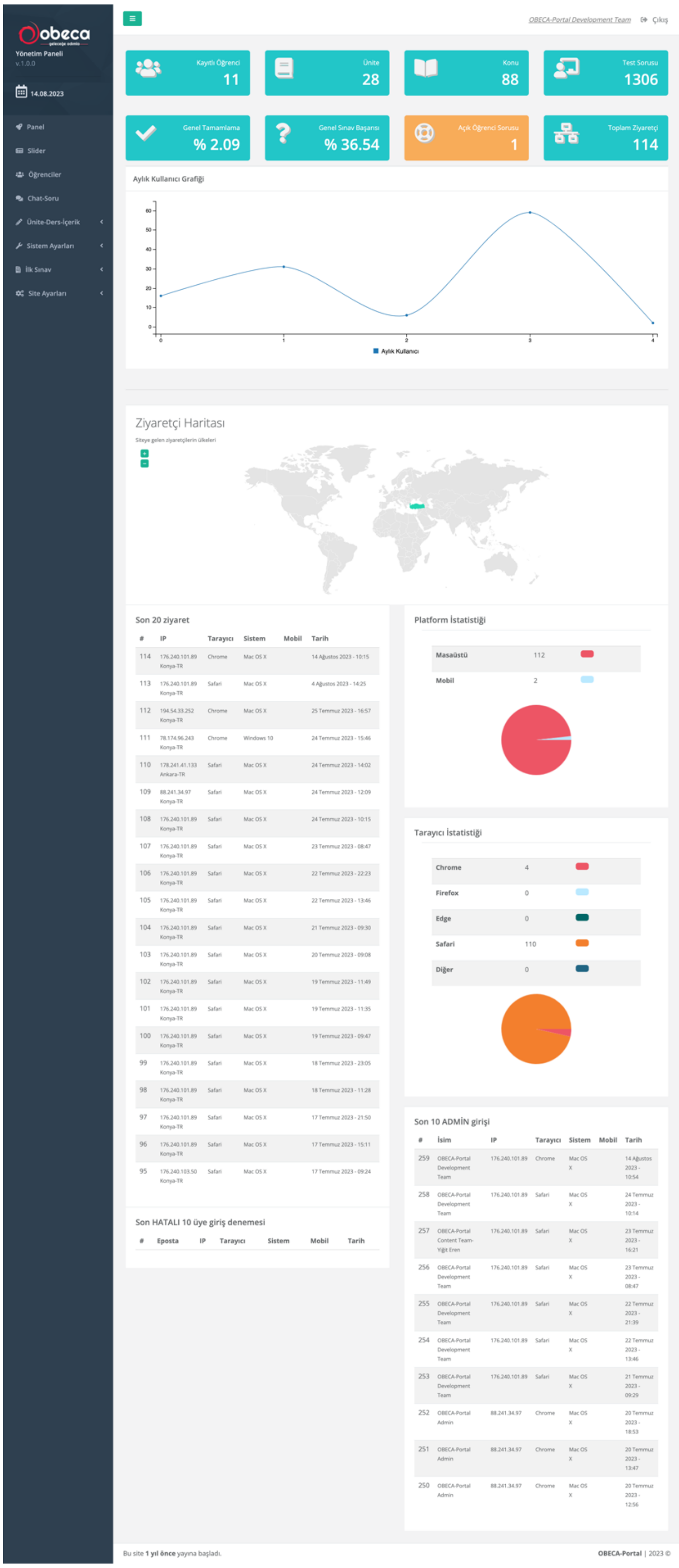
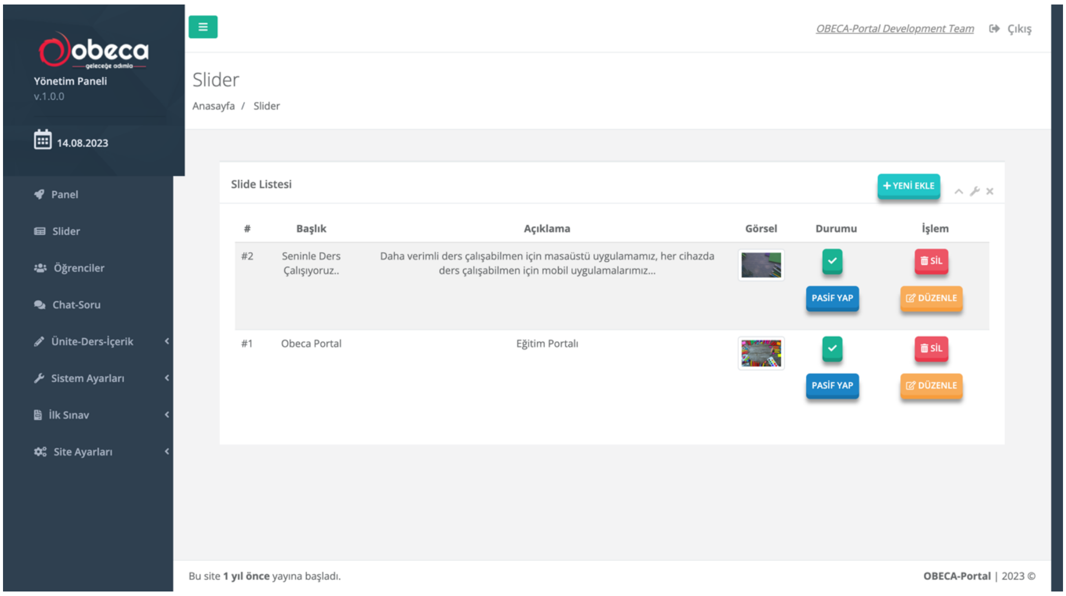
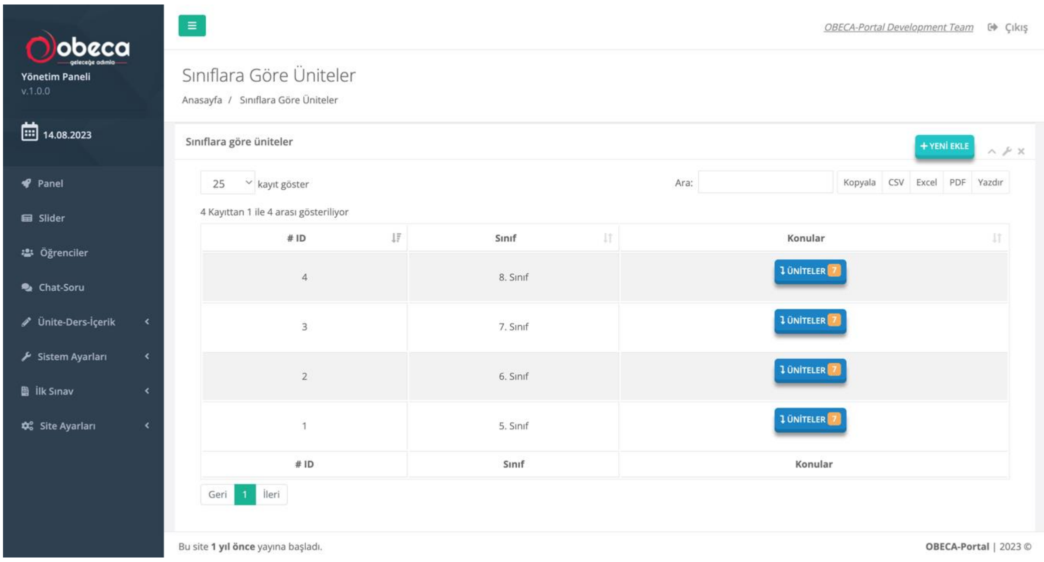


Figure 8. *Administration Panel Login Page*

In the vertical menu on the left side, there is a module for changing the slider and its features on the introduction page, a student module where registered students are listed and their details can be accessed, a Chat-Question module that shows the questions asked and answers given by the students who send questions or information with the chat screen and also allows the administration to answer, the Unit-Course Content module where the portal content can be managed, the system settings module where portal settings are made, the First Exam module that hosts the first exam setting and question pool that creates the step lock system, and the site settings menu that hosts the general settings of the system.





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Murat Baha - IŞIĞIN YAYILMASI
Anasayfa / Murat Baha - IŞIĞIN YAYILMASI
Öğrenci Sorusu
14 Ağustos 2023 - 10:51
Murat Baha
Öğretmenim ışığın dalga mı tanecik mi olduğunu anlayamadım. Bu konuda yardımcı olur musunuz?
OBECA Portal
14 Ağustos 2023 - 11:08
Işığın hem dalga hem de tanecik özellikleri olduğuna dair belirtiler bulunmaktadır. Bu fenomen, "ışığın ikili doğası" olarak bilinir. Işığın davranışı, farklı deneylerde dalga benzeri ve tanecik benzeri özellikler sergilediği için, bu konuda bazı çelişkili sonuçlar ve açıklamalar ortaya çıkmıştır. Işık dalga olarak davranış sergilediğinde, interferans ve yayılma gibi fenomenler gözlemlenir. Bunun anlamı, ışığın dalga gibi bükülebildiği ve dalga crest'lerinin ve trough'larının birleşip etkileşebileceği anlamına gelir. Örneğin, iki daraltılmış ışık huzmesi bir araya geldiğinde, dalga tepe noktaları birleşebilir veya yok edilebilir, bu da parlak ve karanlık çizgilerin oluşmasına neden olur. Diğer yandan, ışık taneciğimsi özellikler de sergiler. Fotoelektrik etki, bu özelliğin en iyi örneklerinden biridir. Fotoelektrik etkide, ışığın bir yüzeye çarptığında, yüzeyden elektronlar çıkabilir. Bu olay, ışığın enerjisinin küçük paketler (fotonlar) halinde taşındığını ve bir fotonun belirli bir enerji taşıdığını gösterir. Işığın bu ikili doğası, kuantum fiziği alanında derinlemesine çalışmaların konusu olmuştur. Işık dalga ve tanecik benzeri davranışlarını farklı durumlar altında sergileyebilir ve bu, ışığın doğasının karmaşıklığını yansıtır. Etkileşimli ders içeriğimizde bu deneyi, sonuçlarını ve açıklamaları bulabilirsin. Bana soru sorduğun için teşekkür ederim.
Cevabınızı Yazın..
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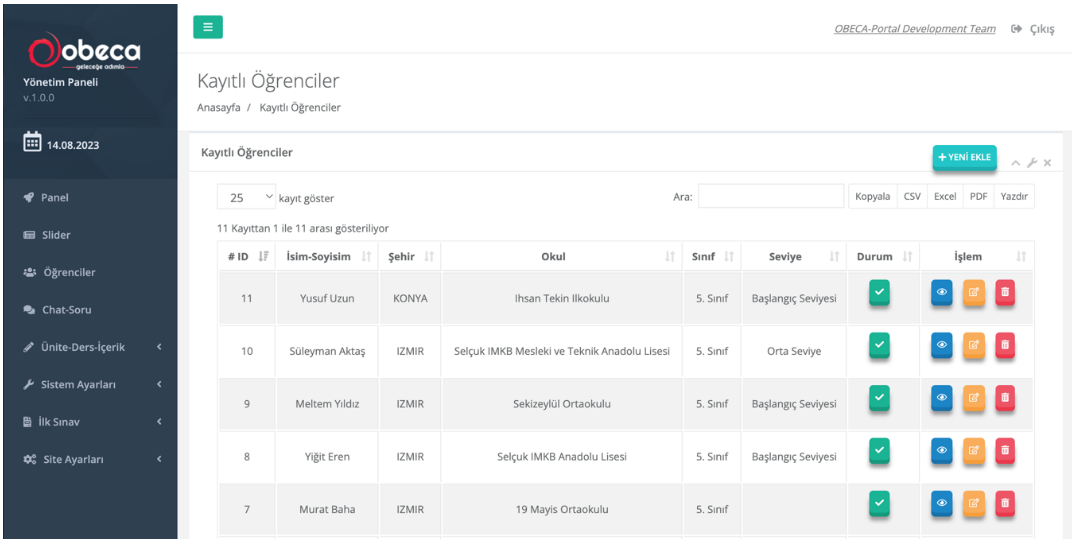

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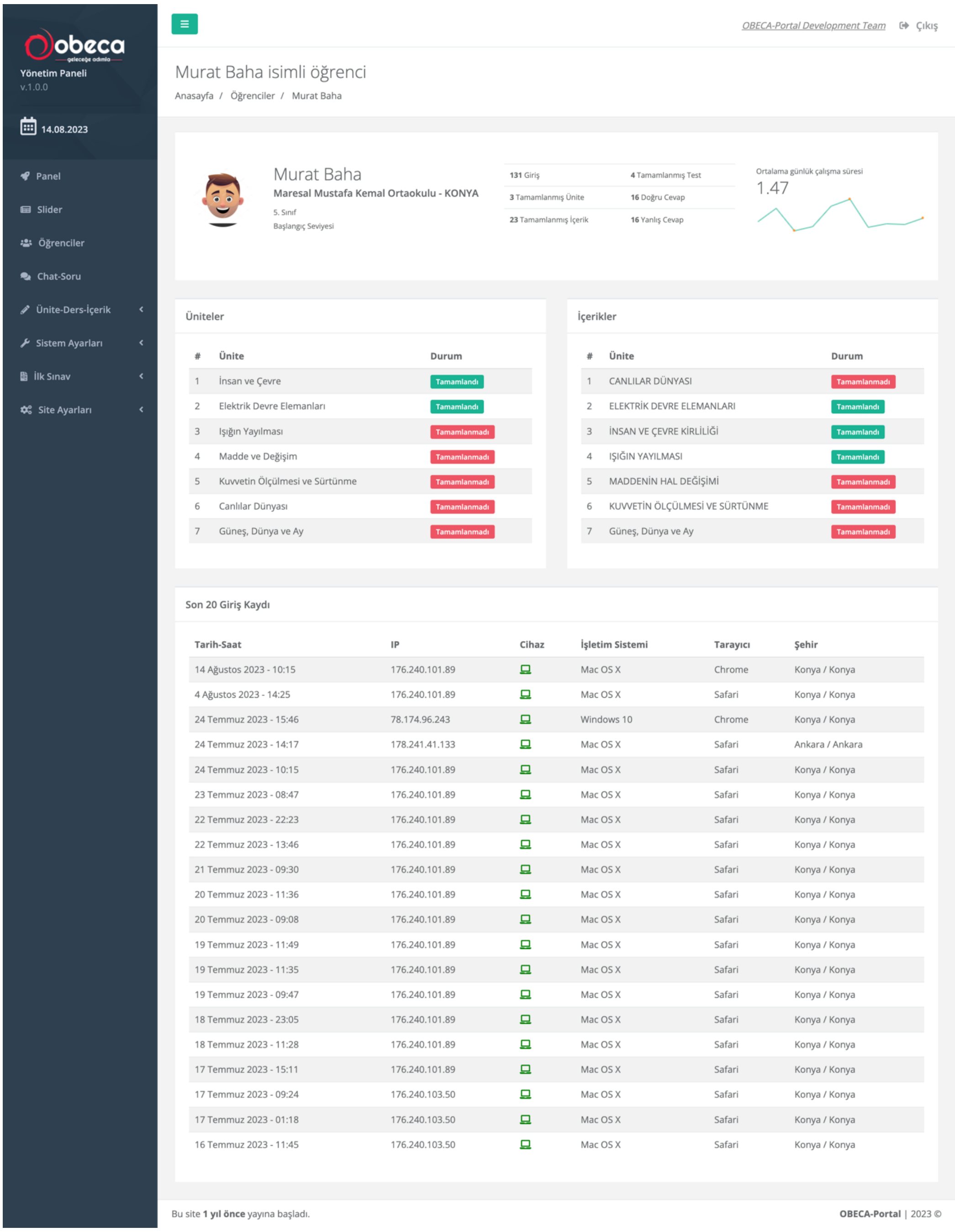
Ara:
Kopyala CSV Excel PDF Yazdır
11 Kayıttan 1 ile 11 arası gösteriliyor
ID İsim-Soyisim Şehir Okul Sınıf Seviye Durum İşlem
11 Yusuf Uzun KONYA Ihsan Tekin Ilkokulu 5. Sınıf Başlangıç Seviyesi
10 Süleyman Aktaş IZMIR Selçuk IMKB Mesleki ve Teknik Anadolu Lisesi 5. Sınıf Orta Seviye
9 Meltem Yıldız IZMIR Sekizeylül Ortaokulu 5. Sınıf Başlangıç Seviyesi
8 Yiğit Eren IZMIR Selçuk IMKB Anadolu Lisesi 5. Sınıf Başlangıç Seviyesi
7 Murat Baha IZMIR 19 Mayis Ortaokulu 5. Sınıf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Murat Baha
Maresal Mustafa Kemal Ortaokulu - KONYA
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131 Giriş
4 Tamamlanmış Test
3 Tamamlanmış Ünite
16 Doğru Cevap
23 Tamamlanmış İçerik
16 Yanlış Cevap
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1.47
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1 İnsan ve Çevre Tamamlandı
2 Elektrik Devre Elemanları Tamamlandı
3 Işığın Yayılması Tamamlanmadı
4 Madde ve Değişim Tamamlanmadı
5 Kuvvetin Ölçülmesi ve Sürtünme Tamamlanmadı
6 Canlılar Dünyası Tamamlanmadı
7 Güneş, Dünya ve Ay Tamamlanmadı
İçerikler
Ünite Durum
1 CANLILAR DÜNYASI Tamamlanmadı
2 ELEKTRİK DEVRE ELEMANLARI Tamamlandı
3 İNSAN VE ÇEVRE KİRLİLİĞİ Tamamlandı
4 IŞIĞIN YAYILMASI Tamamlandı
5 MADDENİN HAL DEĞİŞİMİ Tamamlanmadı
6 KUVVETİN ÖLÇÜLMESİ VE SÜRTÜNME Tamamlanmadı
7 Güneş, Dünya ve Ay Tamamlanmadı
Son 20 Giriş Kaydı
Tarih-Saat IP Cihaz İşletim Sistemi Tarayıcı Şehir
14 Ağustos 2023 - 10:15 176.240.101.89 Mac OS X Chrome Konya / Konya
4 Ağustos 2023 - 14:25 176.240.101.89 Mac OS X Safari Konya / Konya
24 Temmuz 2023 - 15:46 78.174.96.243 Windows 10 Chrome Konya / Konya
24 Temmuz 2023 - 14:17 178.241.41.133 Mac OS X Safari Ankara / Ankara
24 Temmuz 2023 - 10:15 176.240.101.89 Mac OS X Safari Konya / Konya
23 Temmuz 2023 - 08:47 176.240.101.89 Mac OS X Safari Konya / Konya
22 Temmuz 2023 - 22:23 176.240.101.89 Mac OS X Safari Konya / Konya
22 Temmuz 2023 - 13:46 176.240.101.89 Mac OS X Safari Konya / Konya
21 Temmuz 2023 - 09:30 176.240.101.89 Mac OS X Safari Konya / Konya
20 Temmuz 2023 - 11:36 176.240.101.89 Mac OS X Safari Konya / Konya
20 Temmuz 2023 - 09:08 176.240.101.89 Mac OS X Safari Konya / Konya
19 Temmuz 2023 - 11:49 176.240.101.89 Mac OS X Safari Konya / Konya
19 Temmuz 2023 - 11:35 176.240.101.89 Mac OS X Safari Konya / Konya
19 Temmuz 2023 - 09:47 176.240.101.89 Mac OS X Safari Konya / Konya
18 Temmuz 2023 - 23:05 176.240.101.89 Mac OS X Safari Konya / Konya
18 Temmuz 2023 - 11:28 176.240.101.89 Mac OS X Safari Konya / Konya
17 Temmuz 2023 - 15:11 176.240.101.89 Mac OS X Safari Konya / Konya
17 Temmuz 2023 - 09:24 176.240.103.50 Mac OS X Safari Konya / Konya
17 Temmuz 2023 - 01:18 176.240.103.50 Mac OS X Safari Konya / Konya
16 Temmuz 2023 - 11:45 176.240.103.50 Mac OS X Safari Konya / Konya
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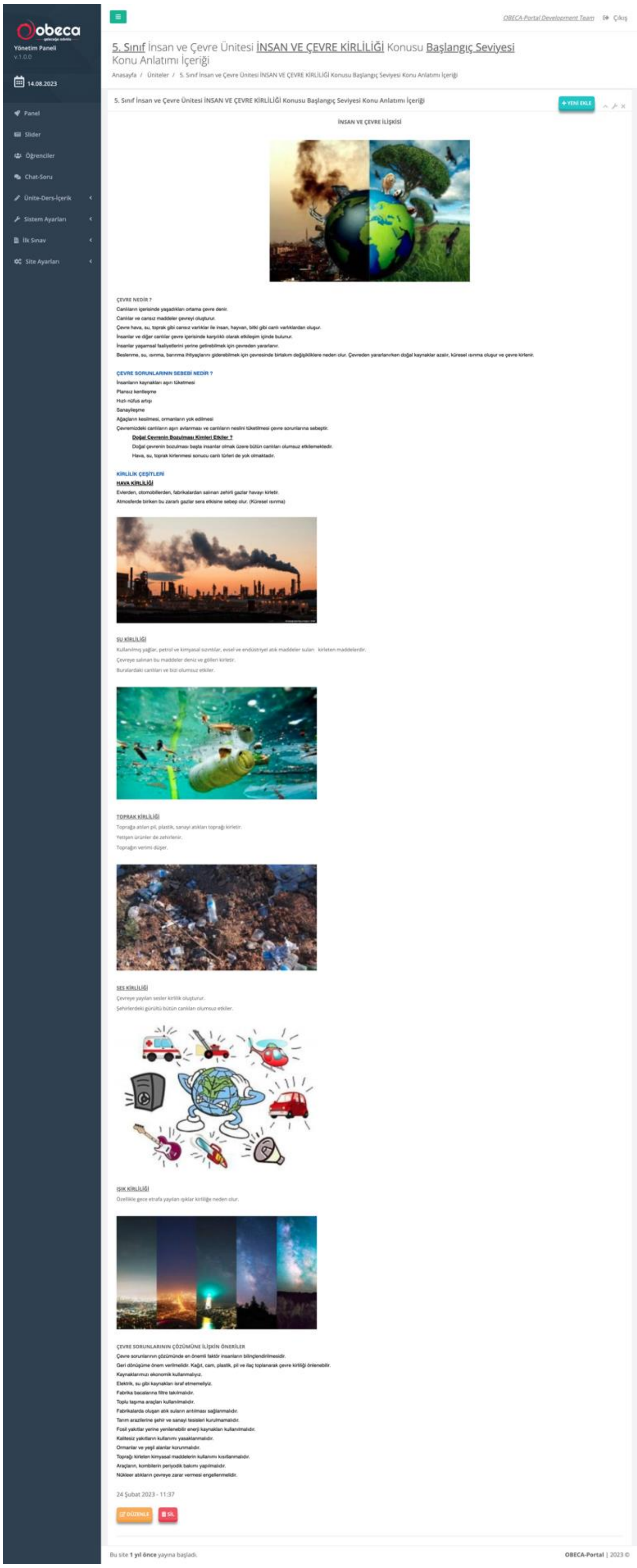
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Anasayfa / Üniteler / 5. Sınıf İnsan ve Çevre Ünitesi İNSAN VE ÇEVRE KİRLİLİĞİ Konusu Başlangıç Seviyesi Konu Anlatımı İçeriği
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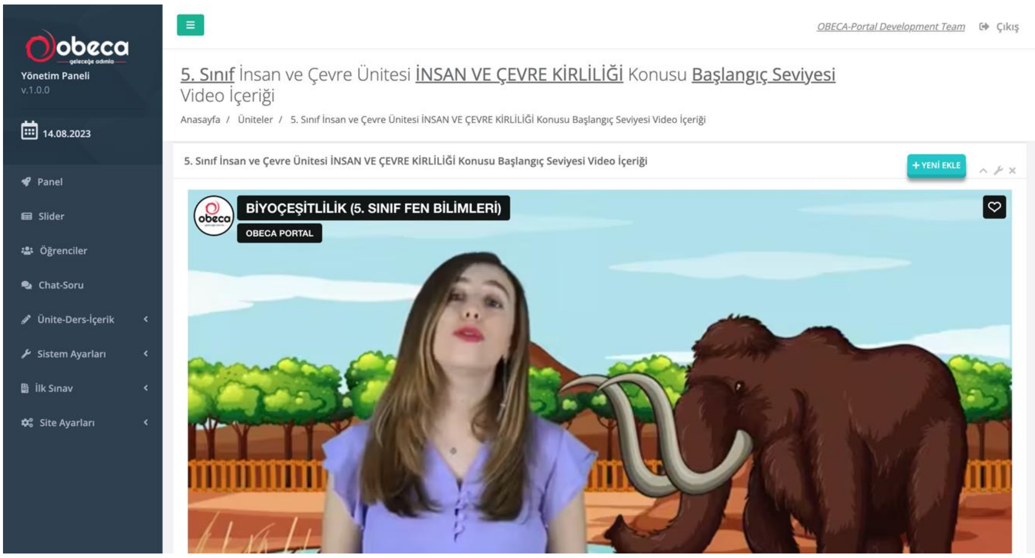
+ YENİ EKLE
İNSAN VE ÇEVRE İLİŞKİSİ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5. Sınıf İnsan ve Çevre Ünitesi İNSAN VE ÇEVRE KİRLİLİĞİ Konusu Başlangıç Seviyesi Video İçeriği
+ YENİ EKLE
BİYOÇEŞİTLİLİK (5. SINIF FEN BİLİMLERİ)
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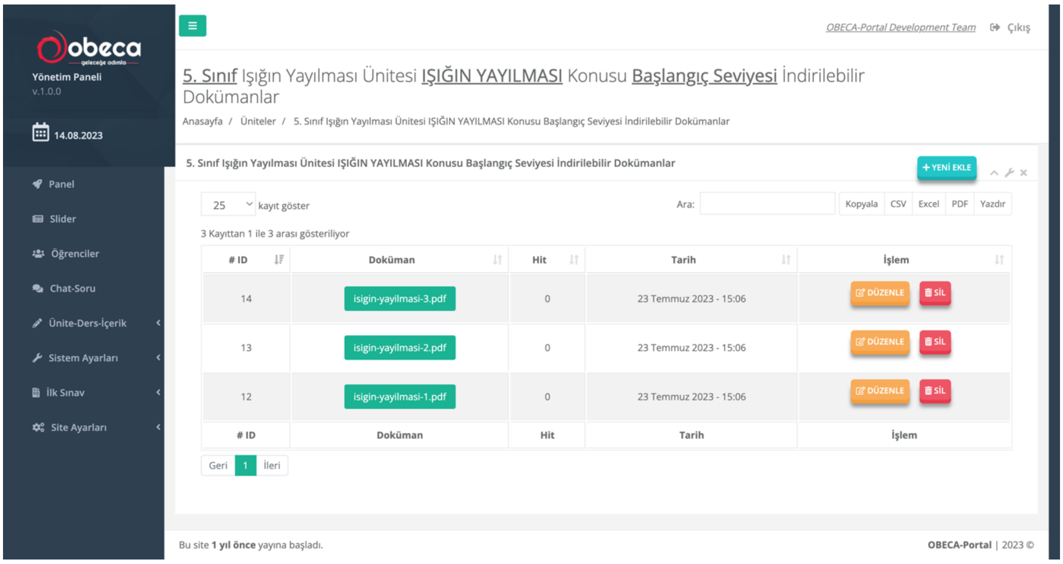
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Anasayfa / Üniteler / 5. Sınıf Işığın Yayılması Ünitesi IŞIĞIN YAYILMASI Konusu Başlangıç Seviyesi İndirilebilir Dokümanlar
5. Sınıf Işığın Yayılması Ünitesi IŞIĞIN YAYILMASI Konusu Başlangıç Seviyesi İndirilebilir Dokümanlar
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25 kayıt göster
Ara:
Kopyala CSV Excel PDF Yazdır
3 Kayıttan 1 ile 3 arası gösteriliyor
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14 isigin-yayilmasi-3.pdf 0 23 Temmuz 2023 - 15:06 DÜZENLE SİL
13 isigin-yayilmasi-2.pdf 0 23 Temmuz 2023 - 15:06 DÜZENLE SİL
12 isigin-yayilmasi-1.pdf 0 23 Temmuz 2023 - 15:06 DÜZENLE SİL
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Geri 1 İleri
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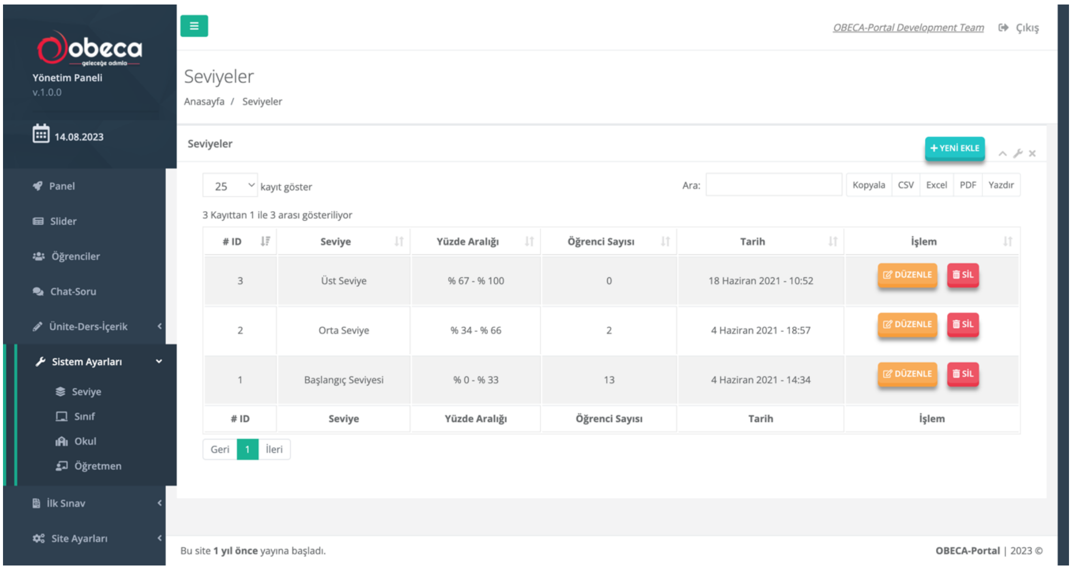
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Seviyeler
+ YENİ EKLE
25 kayıt göster
Ara:
Kopyala CSV Excel PDF Yazdır
3 Kayıttan 1 ile 3 arası gösteriliyor
ID Seviye Yüzde Aralığı Öğrenci Sayısı Tarih İşlem
3 Üst Seviye % 67 - % 100 0 18 Haziran 2021 - 10:52 DÜZENLE SİL
2 Orta Seviye % 34 - % 66 2 4 Haziran 2021 - 18:57 DÜZENLE SİL
1 Başlangıç Seviyesi % 0 - % 33 13 4 Haziran 2021 - 14:34 DÜZENLE SİL
ID Seviye Yüzde Aralığı Öğrenci Sayısı Tarih İşlem
Geri 1 İleri
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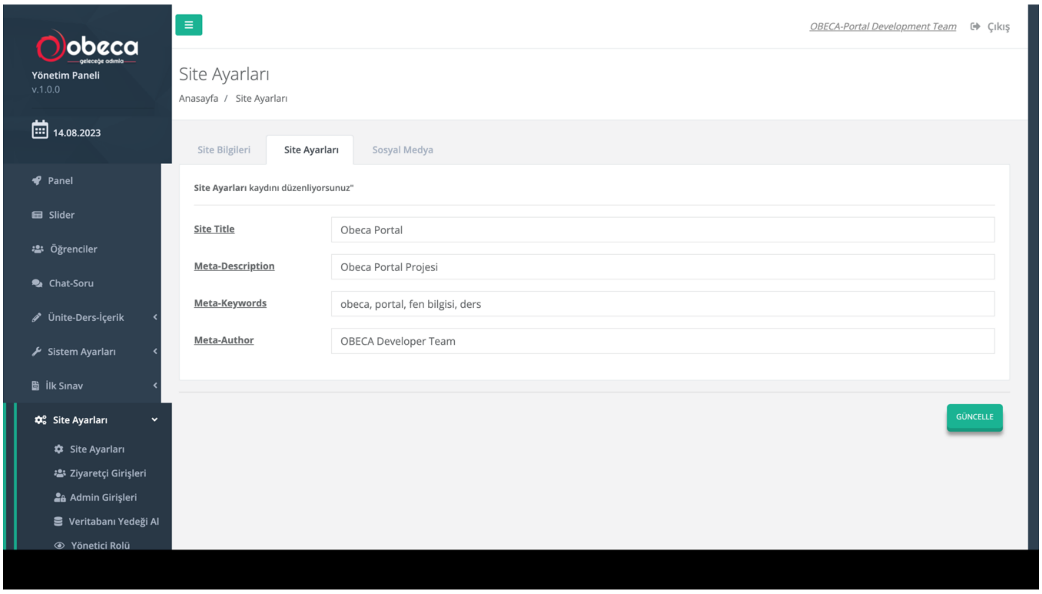
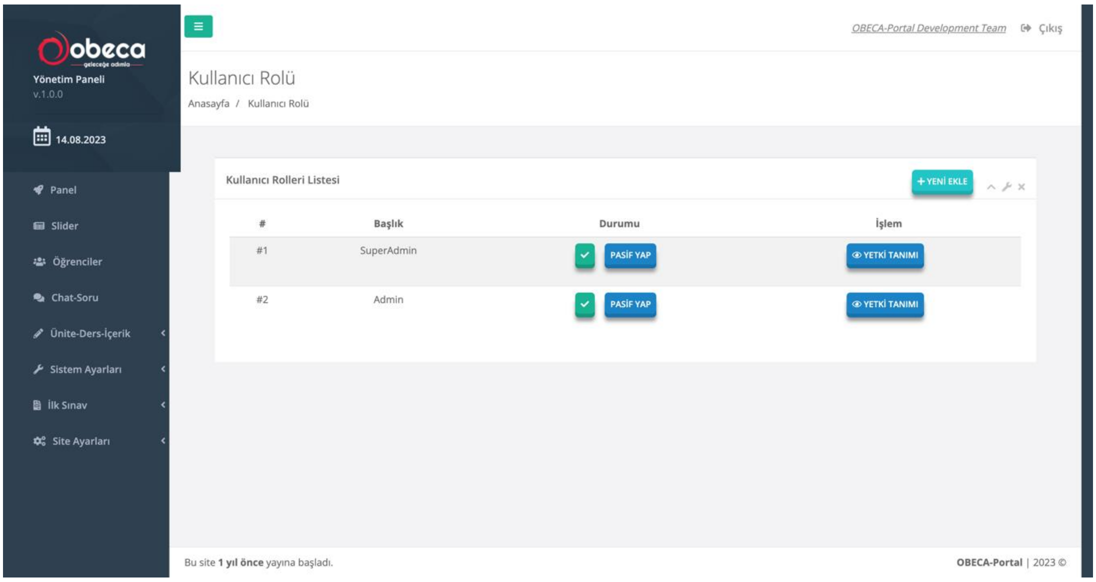


Figure 9. *Administration Panel Settings*

The portal system provides authorisation features and authorisation tracking for both administrators and users. Authorisation can be made for user groups in the administration panel and unauthorised users can be restricted from using portal features. Screenshots of this feature are shown below.



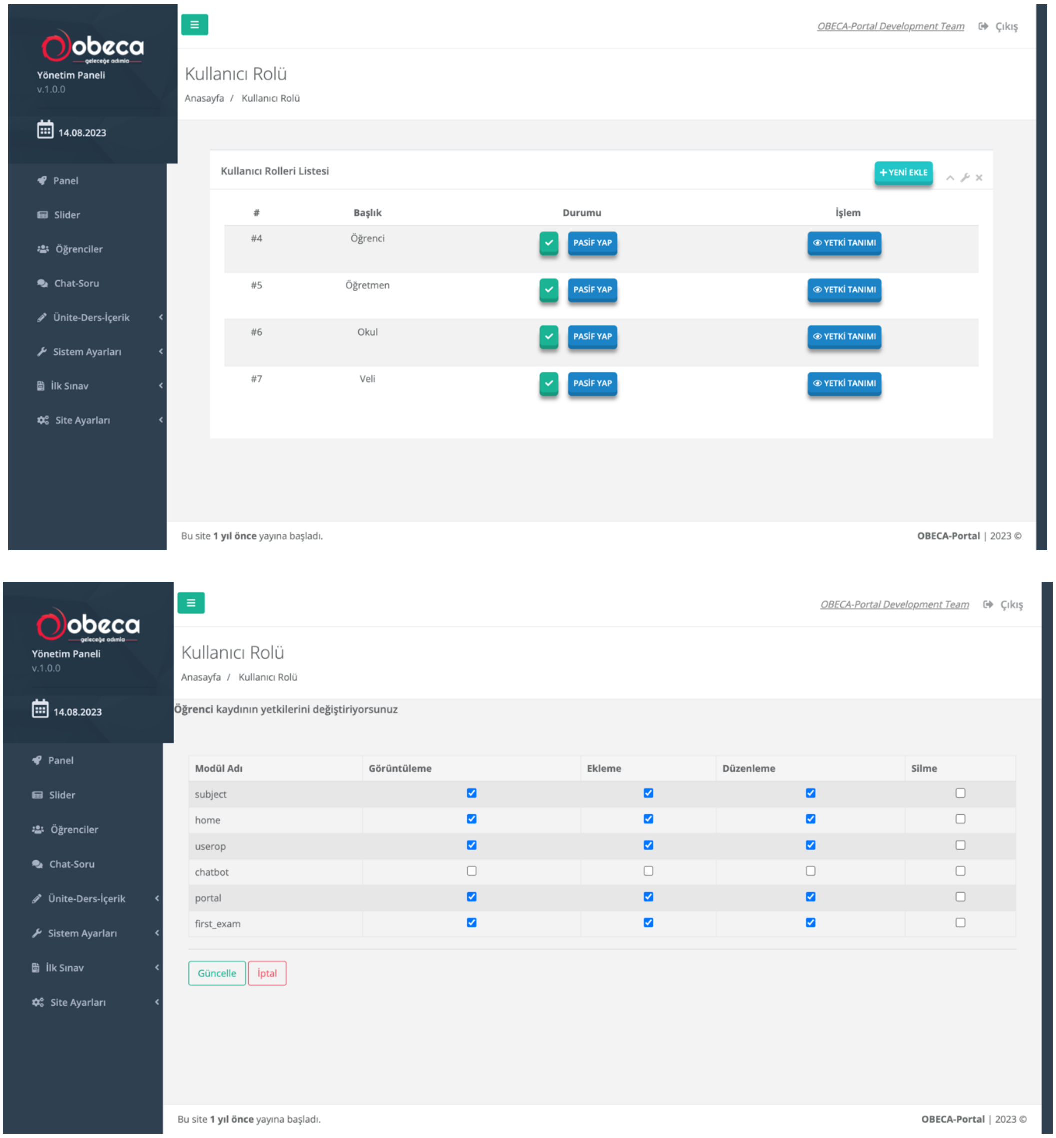


Figure 10. *Authorisation Settings*

All visits and entries within the portal are recorded, including IP-Location-operating system-ISP, etc. features are also recorded. Database backup can be taken manually with the database backup button in the menu.

Security-Speed and Improvement Aspects of the Portal

- In all login screens in the portal, security steps have been added both with the captcha code generated by the system and with Google Recaptcha.
- All passwords in the database are encrypted with 4-step encryption. Even if it is intercepted, it is impossible for a person who does not have the key data to decrypt the passwords (Hash-Salt principle).
- It is aimed to eliminate hackbots by setting honeypot traps on all login screens.
- The security features of the Codeigniter framework used as infrastructure have been activated, csrf feature, cookie and session security settings have been made.
- Measures have been taken against XSS attacks.

- All data coming from inputs are checked for harmful characters and type (string-integer etc.).
- DNS routing was made to Cloudflare proxy servers in order to control the traffic coming to the system, to eliminate possible attacks and to create an additional layer of security.
- Beta and Alpha user tests of the system were presented to the students of Konya-Selçuklu Marshal Mustafa Kemal Secondary School and feedbacks were evaluated.
- The system was subjected to speed and load tests, and speed-enhancing features such as cache, compression, minimisation were adjusted.
- Prefix feature in the database from the security features offered by the Codeigniter framework, URL manipulation is activated and controller names are hidden.
- Model files and controller files are removed from the default form and extended from different files.
- The study was developed with version management via GitHub platform from the beginning to the end.
- For the school list applied in the student enrolment screen, 53525 school records in Turkey have been added to the database.
- Hosting 1.853.080 lines of code, the portal was implemented with 1591 PHP, 250 HTML, 272 CSS, 670 JS files.

Conclusion

In the age of communication we are living in, there is no longer a need for individuals who memorise information, but for individuals who can access information, use it, synthesise it and obtain new results. Computers and the Internet, which are now almost a part of our lives, are the main sources we use to access and synthesise information. Computers and the Internet are extremely important tools that should be utilised in order to show that change is not a utopia but a part of life. The Internet, called the global communication network, is the main source of information for scientific research, productivity, global changes, global trade and education. This written, oral and visual information communication network also gives educators the opportunity to offer global distance education services.

When the Turkish market is analysed, it is seen that there are various educational platforms that serve online and are commercially marketed. The most important point that distinguishes the prepared portal from these similar platforms is that each student interacts with the content according to his/her own level and learning speed. At the same time, thanks to the step-lock system, the student cannot switch to a new subject without fully learning a subject. They can also navigate within the current active topic as flexibly as they want. For example, while one student is working with video lectures, another student can learn interactively with Web 2.0 contents including animation or simulation. In the current portal, there are activities that appeal to different sensory organs and support different learning styles. In this way, it can appeal to all students who can learn visually, auditorily or differently. This feature of the portal constitutes its unique characteristic and R&D element.

Within the scope of this study, only secondary school science course was taken as a basis in terms of educational content. And only the contents for the science course are included in the portal at four grade levels at the secondary school level. Within the scope of P&D studies, it is planned to include other course contents (mathematics, social studies, Turkish, English, etc.) in the portal, which is considered to be technically sufficient in the future. However, the quality and quantity of such digital platforms are important due to force majeure situations such as the increase in the use of technology in education, the fact that situations such as disasters and health problems have made distance education compulsory, and the fact that distance education is being used as an alternative to formal education day by day. The number of scientifically valid and reliable platforms that will contribute to the development of children, adolescents and young people who are highly exposed to the screen in daily life should be increased. In the future, it is aimed that the portal will not only be limited to computers and tablets, but also be made available as a mobile application in addition to the web browser. The integration of augmented reality applications, whose importance is increasing in technology-based educational content, into the system is also among the future plans as a P&D activity.

As stated before, UNESCO standards were taken into consideration in the theoretical infrastructure of the digital portal. Within these standards, it is stated that while presenting the course content on the portal, the "audio narration" section should also be included. The reason for this is to ensure that visually impaired students can follow the course in an auditory way. Again, within the scope of the P&D studies of the project, it is planned to expand the conditions in which disabled students can easily use the portal and follow the lessons.

Computers are used effectively in our schools as in all institutions. For this purpose, computers should have interactive education programmes and Internet connection. At the same time, the use of interactive educational software should be increased not only in computer courses where office programmes are taught but also in other courses. From this point of view, the Ministry of National Education has equipped almost all of its schools with computers and Internet. However, the efforts of the Ministry of National Education for the use of Internet in education are not at a visitable level at the moment. The efforts of other private organisations in this field are also not sufficiently supported. It can be concluded from this that the use of the Internet, which is used effectively in the field of education in the world, is not at the desired level in Turkey at the moment. Therefore, Internet and Web-based content similar to the content given in the article should be developed to serve as a resource for educators and students.

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About the Author

Dr. Oguz CETIN was born in 1980 in the Bozdoğan District of Aydın Province. He completed his primary education at Bozdoğan Central Primary School, and his middle school and high school education at Nazilli Anatolian High School. Later, he graduated from Dokuz Eylül University, Buca Faculty of Education, Department of Science Education. In 2005, he completed the Master's program in the Department of Science Education with an applied thesis on Constructivism Theory, and in 2010, he graduated from the same department's Ph.D. program with an applied thesis on Web-Based Education.

In 2002, he began working as a teacher at the Ministry of National Education. During his tenure at the Ministry of National Education, he worked full-time as an expert in the Research and Development, Projects Coordination, and Strategy Development units of Provincial and District Directorates of National Education. Between 2009 and 2011, he held managerial and coordinator positions in the

PISA (Programme for International Student Assessment), TIMSS (Trends in International Mathematics and Science Study), and ÖBBS (Öğrenci Başarılarının Belirlenmesi Sınavı) studies conducted under the Ministry of National Education, Directorate of Education Research and Development.

Throughout his service at the Ministry of National Education, he also served as a member of the Provincial and Regional Working Group in the "Bu Benim Eserim" project, a project collaboration between TUBITAK and the Ministry of National Education aimed at primary school students in the fields of Mathematics and Science. He participated in four TUBITAK-supported projects, 13 projects under Provincial Directorates of National Education, and four projects under the Ministry of National Education. He conducted over a hundred seminars as a trainer on various topics such as "Project Development," "Introduction of New Programs," "Assessment and Evaluation," "National and International Evaluation Studies," "Child Development," and "Teacher Training" within the in-service training activities for teachers. He also worked as an expert in many activities of the Ministry of National Education, such as program development and writing textbooks. He attended more than thirty courses and conferences.

After completing his doctoral studies, in 2011, he was appointed as an assistant professor at Niğde Ömer Halisdemir University, Faculty of Education. During his time at the university, he took on roles such as Department Chair and Vice Dean. Throughout his university service, he served as an instructor in over 500 educational programs. As of 2020, Dr. Oğuz ÇETİN, who holds the title of associate professor in basic education, has six international and 22 total articles, 41 presentations (21 international) in various symposiums and congresses, six book chapters, and has been involved in more than ten projects. Dr. Oğuz ÇETİN is married, has two children, and is fluent in English as a foreign language.

E-mail: oguz.cetin@windowslive.com, **ORCID:** 0000-0002-0986-5137

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of paper titled “**Web based instruction and a sample portal design that can be used in web based instruction”** belongs to the author.

Steps toward Integrating STEM Education into School Curricula

Ziad Said
University of Doha for Science and Technology

Ibrahim Al-Naimi
Ministry of Education and Higher Education

Hessa Al-Thani
Qatar University

Abdulla Abu- Tineh
Qatar University

Nasser Mansour
Qatar University

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Introduction

Digital technologies drive innovation in many different spheres of life. The level of digital skills of the population very much conditions the innovative capacity of technology. No wonder there is a strong correlation between education and skills and the uptake and use of digital technologies in various spheres of life (OECD, 2016). STEM graduates commonly continue to learn STEM skills and knowledge nearly forty years after graduation. Even many non-STEM jobs require STEM expertise—and a revised view of STEM employment (Skrentny & Lewis, 2022).

As the world changes dramatically, the future will grow mainly in education, creativity, and innovation. Innovation must be introduced in the educational system to change the economy. Academic Institutions must be enabled with pedagogies that appeal to these variables. The curriculum should be the processor to convert knowledge into skill sets. A study at Oxford says that 20 years from now, nearly half of the jobs will be automated, and we need to redefine our education system considering the challenges ahead (UNESCO 2020, WEF 2022). The study also shows that 80% of future jobs are related to careers in STEM (science, technology, engineering, and mathematics); education embraces the idea that STEM learning could include all or some of these disciplines. However, it is not as simple as that, as STEM learning also embraces the development of inquiry skills and thinking capabilities such as through project-based learning pedagogy that allows students to acquire knowledge and skills, practice inquiry across multiple disciplines, and make meaningful connections across STEM disciplines (National Science Foundation 2020).

Building 21st-Century Skills

STEM is integral to many of the required knowledge, and how they are integrated is a new 21st-century skill that students should acquire. Understanding STEM components and their connection helps students develop a better and deeper understanding of their contents. However, STEM is still taught in a traditional approach, i.e., in silos which only refers to science and math with little reference to engineering and technology (IBE UNESCO, 2020). Therefore, those developing curricula and teaching STEM subjects must also understand STEM and STEM education well.

In high-quality programs today, 21st-century skills require more rigorous content than the traditional curriculum provides. They should include skills and knowledge needed for these competencies, such as critical thinking, problem-solving, effective communication and collaboration, project–based learning with high technical skills.

Young students today need to develop a deep skillset to succeed in a world where automation is only a click away. When they become comfortable working with others, thinking creatively, and expressing their ideas persuasively at an early age, they will enter a world overflowing with opportunities.

What distinguishes STEM from traditional science and math education is the blended learning environment that is centered on teaching students how the scientific method can be applied to everyday life by connecting learning outside the classroom and using technology to engage students in scientific and engineering practices and projects that require deep science and math conceptual knowledge. (Said 2016a, Said 2016b, Said 2021, Said et al. 2023).

STEM Approach builds a strong foundation in the critical 4C skills (Collaboration, Critical Thinking, Communication, and Creativity), which they apply to solve real-world challenges grounded in science, technology, engineering, and math content (Reeve, 2016).

Early in the last decade, discussions worldwide, educators and curriculum developers in Various countries have begun to debate ways to help students understand the “island of disciplines” and “fractured disciplinary knowledge through interdisciplinary learning and curriculum integration. Interdisciplinary learning can break through academic borders to enhance students’ fundamental competencies by merging course design content with cross-border teaching and implementation (Ye, P. & XU; X., 2023).

There is also a comprehensive discussion in the literature on how STEM education is most effectively implemented (Briner et al., 2012). STEM education often implies something innovative and exciting, yet it may remain disconnected subjects (Abell & Lederman, 2007; Sanders, 2009; Wang et al., 2011). However, an integrated curricular approach could be applied to solve global challenges of the modern world concerning energy, health, and the environment (Bybee, 2010; Kelly & Knowles, 2016). Researchers agree that a real-world problem is a critical component of integrated STEM teaching (e.g., Kelley &Knowles, 2016; Moore, Stohlmann, et al., 2014; Sanders, 2009).

Sanders (2009) described integrated STEM education as "approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and between a STEM subject and one or more other school subjects." He suggested that outcomes for learning at least one of the other STEM subjects should be purposely designed in a course—such as a math or science learning outcome in a technology or engineering class (p.21).

Similarly, Moore et al. (2014) described integrated STEM education as "an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems" (p. 38). Integrated STEM curriculum models can contain content learning objectives primarily focused on one subject, but contexts can come from other STEM subjects.

While some researchers suggest integration across all four of the STEM disciplines (e.g., Burrows et al., 2018; Chandan et al., 2019), others call for integrating at least two of the STEM disciplines (e.g., Moore et al., 2020). Given the prominence of engineering, many approaches to integrated STEM specifically include an engineering context or engineering design problem as the context for learning (e.g., Berland & Steingut, 2016; Moore, Stohlmann, et al., 2014).

Mpofu (2019) suggested a continuum approach that borders on four different levels ranging from the lowest level 1 (the disconnected) to the highest level 4 (the integrated). The other possible ways of STEM integration this approach provides are connected and complementary in levels 2 and 3, respectively. In the disconnected level, individual STEM subjects are taught and learned separately. These subjects, such as chemistry, biology, physics, and mathematics, exist parallel in school curricula. Each subject is taught by teachers trained to teach it. STEM integration within this level entails introducing the subjects like engineering and technology into the school curricula, which are usually excluded in schools.

Wei & Chen (2020) synthesized various standpoints of policymakers and educators on the relationship between STEM integration and education. At the national macro level, policymakers regard STEM integration as a correlation between school education and the development of the social economy. Educators view STEM integration at the individual micro level as an educational approach that might help students become critically literate citizens and procure financially secure employment in their adult lives. Both policymakers and educators point to the interconnection between STEM integration and education.

The literal meaning of integration is combining two or more things. STEM integration naturally has this meaning; nonetheless, it is not equal to the integration of four disciplines, as the acronym of this term indicates. Thus, examining the integration of the STEM field should take a holistic and coherent view, that is, it comes to educational fields and links to areas like society and the economy. However, studying STEM practices can better understand each domain and help teachers identify key learning outcomes necessary to achieve STEM learning. (Kelley & Knowles 2016).

Framework for STEM Integration

Based on the above discussion, good STEM education is featured by enabling students to integrate knowledge and skills across different STEM disciplines as well as its connection to real-life issues and community. However, pursuing the integration of all four STEM disciplines at one time is unnecessary. Instead, the curriculum exemplifies the cross-curricular learning that is the foundation of a 21st-century curriculum. The emphasis is on raising awareness of the importance of knowledge integration and realizing the usefulness of different STEM-related subjects.

However, it is also essential to state that integrated STEM is not promoted to the exclusion of other important learning goals within a science classroom. Not all science content can and should be taught using an integrated STEM approach. Attention should also be paid to the nature of science and engaging students in learning science concepts through inquiry-based learning (Roehrig et al., 2021). Most important is that the integration should enhance understanding and achieve positive student learning outcomes, which is central to the conceptual framework for STEM (Figure -1).

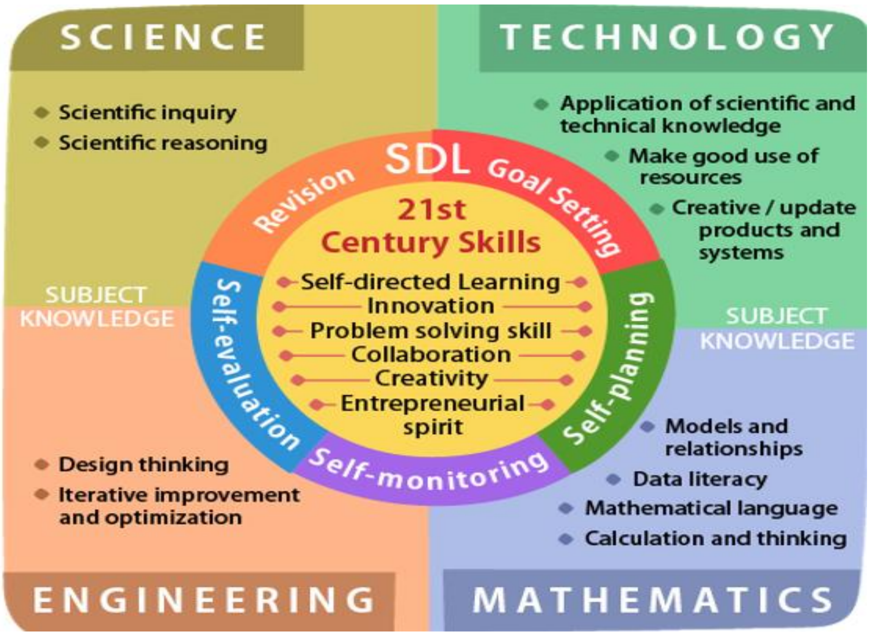

Figure-1. Framework of STEM integration (source: University of Hong Kong 2021)

To achieve these objectives of enhancing learning outcomes and raising positive students' attitudes and career aspirations in STEM, integration requires a holistic approach encompassing outstanding characteristics for successful integration. Unfortunately, the path to STEM integration remains elusive in practice and policy. Program and practice challenges remain to be addressed at national and school levels (IBE-UNESCO 2019).

This paper highlights a holistic approach based on the simplified theory of change using a logic model framework (LeCroy, 2018). The approach suggests a step-by-step implementation of STEM integration that addresses the above challenges.
A literature review was conducted to identify obstacles to STEM education; the majority were mentioned in the introduction section, with some mentioned below. Additionally, to present a specific context, we interviewed 50 science and math teachers from Qatar preparatory and secondary school teachers, equally distributed among genders, grades taught, and specialties. This interview is part of a broader project to train STEM teachers on STEM delivery through project-based learning. The main objective of this interview was to identify challenges to STEM delivery in

science and mathematics classrooms. Then we utilized the principles of the theory of change (Clark & Taplin, 2012) to suggest a roadmap to address these challenges.

Barriers to STEM Implementation in Classrooms

The above literature review identified about ten barriers; seven critical factors were identified in some studies (e.g., Ejiwale, 2013, Dong & Yang et al., 2020). These are school structure, lack of time, the impact of exams and assessments, teachers' lack of experience in engineering and Technology, Lack of professional development, poor lab facilities, lack of inspiration on the part of students, and lack of planned hands-on activities for students.

Fadelmula et al. (2022), in a systematic review of STEM research in GCC countries, and based on Van den Hurk et al. (2019) model on interventions in education to prevent STEM pipeline leakage, focused on three broad types of factors: (1) environmental factors (e.g., the social context and social environment); (2) school-level factors (e.g., instruction, teachers, and pedagogy); and (3) student-level factors (e.g., students' attitudes, motivation and aptitude). The authors recommended that to be relevant to policy-making, future studies should address identified gaps in these three broad factors.

El-Deghaidy and Mansour (2015), based on views from teachers in Saudi Arabia, believe that a direct dialogue between science teachers, mathematics teachers, scientists, and engineers about STEM applications and activities would be essential for promoting STEM education in schools. Project-based learning (PBL) can provide a vital context for such a dialogue.

As part of the results from our interview of science and mathematics teachers in Qatari schools on addressing the above gaps, teachers perceive eight persisting factors to enable successful STEM education in their classrooms. These are depicted in Figure-2.

The figure shows that the most important gap to be addressed is the teachers' lack of experience. In the second rank are the suitability of laboratories and the availability of adequate lab equipment. All other factors are important and similar to those mentioned in the previously reviewed research. Some of these are associated with the school system (e.g., Timetabling, recruitment, teachers' training) and curriculum (e.g., assessment and pedagogy). Some teachers also emphasized the importance of raising students' attitudes towards STEM and practical activities by focusing on hands-on activities and projects based-learning associated with real-life problems. Some teachers attributed students' low engagement and interest in practical activities to the low weighting of these activities in the assessment of STEM subjects.

The most important driver of change to address the above gaps is curriculum modification.

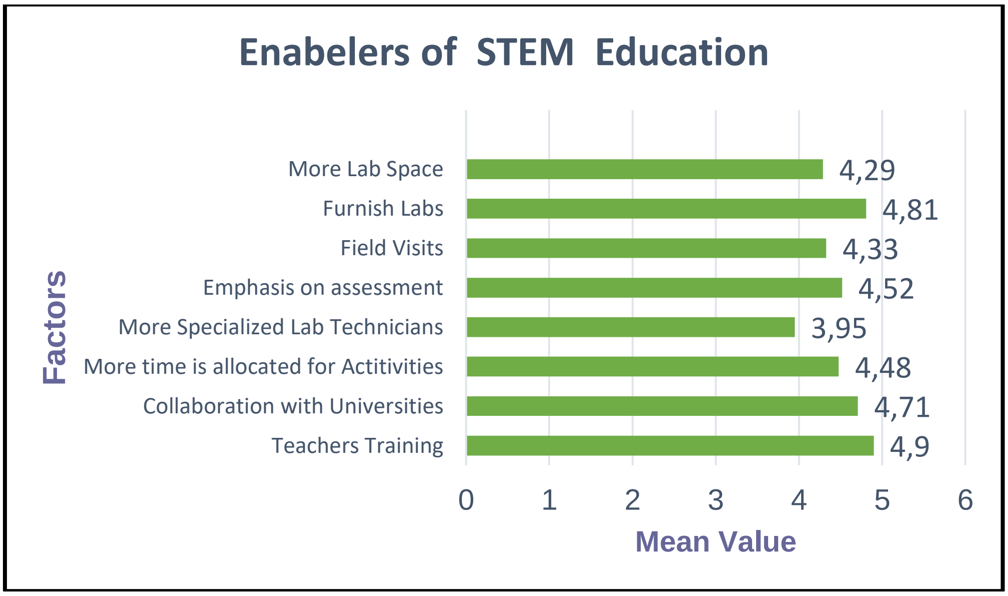

Figure2. Teachers' perceptions on factors enabling STEM Education at the school level (scale 1-5).

Theory of Change for Integrating STEM Education in School Curriculum

Theory of Change (ToC) comprehensively describes and illustrates how and why a desired change is expected to happen in a particular context. It is focused in particular on mapping out or "filling in" what has been described as the "missing middle" between what a program or change initiative does (its activities or interventions) and how these lead to desired goals being achieved. It does this by identifying the desired long-term goals and then working back from them to identify all the conditions (outcomes) that must be in place (and how these relate to one another causally) for the goals to occur. These are all mapped out in an Outcomes Framework (Clark & Tapline, 2012; Centre for Theory of Change, n.d.).

ToC is a method that explains how a given intervention, or set of interventions, is expected to lead to a specific development change, drawing on a causal analysis based on available evidence. The Theory provides a framework for learning both within and between programming cycles by articulating the causes of a development challenge, making assumptions explicit on how the proposed strategy is expected to yield results, and testing these assumptions against evidence—including what has worked well, or not, in the past. The theory of change helps ensure a sound logic for achieving change (United Nations Development Assessment Framework, UNDAF 2017).

A logic model framework provides a visual summary showing the relationship between the program's resources, activities, outputs, and outcomes. It is a tool that helps individuals see the interrelationships between the different components of a program. In addition, the tool highlights the program's underlying approach, the service activities, and the organizational structure for accomplishing program outcomes. Developing a logic model assists developers, evaluators, and other stakeholders understand a program's assumptions and evaluate the logical links between what programs are doing and the outcomes they hope to achieve. Because of their utility logic, models have become widely used in social service programs (LeCroy, 2018; McLaughlin, 2015)

UNESCO -UNEVOC (2022) recommends using the ToC logic model, stating that it helps institutions and organizations to:

1. Identify the ultimate goals and desired outcomes of a program or intervention and the underlying assumptions about how the change will occur.
2. Map out the causal pathways and the relationships between the various elements of an intervention, such as inputs, activities, outputs, and outcomes.
3. Analyze the strengths and weaknesses of an intervention and identify areas where improvements can be made.
4. Monitor and evaluate progress over time by tracking changes in intermediate outcomes, inputs, and activities and measuring the effectiveness of the intervention. (UNESCO-UNEVOC 2022).

UNESCO-UNVOC Centre (2022) developed a step-by-step template for implementing those assumptions. The template was adapted from United Nations Children's Fund (UNICEF2014) Supplementary Programme. The change process consists of five phases which include

- Identifying the problem,
- suggested approaches and strategies to solve the problem,
- the outputs (activities-enacted actions)
- short-term outcomes, and
- Long-term outcomes.

Mclaughlin and Jordan (2018) also developed a similar logic model comprising six phases; the authors added an intermediate outcomes phase (P.76). However, this is flexible and depends on the specific problem to be addressed.
Each of these phases is interlinked and helps to build a comprehensive understanding of the intervention, including the causes of the problem, the desired outcomes, the resources required, and the activities and processes that will be undertaken to achieve the desired results. The ToC approach is flexible and can be adapted to suit the needs of different initiatives, contexts, and stakeholders. However, it is essential to ensure that all phases are well-defined and that the relationships between the elements are clearly understood to achieve the desired outcomes. The template also includes the purpose and assumptions highlighting the benefits expected from the change.

The chart in the Table 1 summarizes our suggested procedure for integrating STEM into curricula. This approach of integration encompasses addressing the gaps mentioned previously.

The problem phase includes defining all factors that cause the problem, which are (the factors) not addressed, and identifying possible partnerships (e.g., a high institution, educational institute, companies, employers, etc.).

Strategies and approaches include developing teachers 'training programs, which are critical in enhancing students' learning and skills in any education aspect that requires change. In addition, continuous Professional Development (CPD) constantly upgrades teachers to enable innovative learning designs, practices, and assessments. For students to develop mastery of knowledge content, problem-solving, critical thinking, effective communication and collaboration, and self-direction, teachers must employ a variety of pedagogical approaches and teaching strategies. Therefore, effective professional development (PD) is the key to improving teachers' learning and delivery skills (Darling-Hammond et al., 2017). Thus, the foundation of the STEM Education Centre provides STEM education materials for schools, trains teachers and students, conducts STEM education research, and helps schools and education institutes revise their curricula (Carlisle & Weaver, 2018).

The outputs include evidence of implementing the planned activities, such as establishing a curriculum committee, the foundation of STEM center implementing professional development, and developing a teachers' certificate program with a stakeholder from a local university.

Short-term outcomes indicate that stakeholders completed the planned activities, and a beneficial effect becomes noticeable such as improvement in the attitude and skills of teachers; some classes start to apply. STEM integration and applying PBL pedagogy, students' attitude improvement, and attendance to STEM classes.

The long-term outcomes: STEM integration to a certain level is implemented and regularly practiced with all teachers in STEM subjects to obtain certificates and sufficient training. An increase in enrolment in STEM programs at high grades and an increase in students' achievement can measure these outcomes.

Table 1. Steps Towards Integrating STEM Education into K-12 School Curricula – Applying a Simplified Approach of the Theory of Change *(The original empty template was adapted from McLaughlin & Jordan 2018 and UNESCO-UNEVOC 2022)*

Purpose Statement	**Integrating STEM education into K-12 Curricula**			
Problem	**Strategies & Approach**	**Outputs** (1-2 years)	**Short – term Outcomes** (2-4 years)	**Long – term Outcomes** (after four years)
- STEM is still taught in a traditional approach, i.e., in silos which only refers to science and math with little reference to engineering and technology. Therefore, those involved in developing STEM curricula and teaching Science and Mathematics must also gain a good understanding of STEM and STEM education.	- Invest in teacher training and upskilling and curriculum development Using real-world problems/issues/challenges as anchors to integrate STEM and other disciplines, considering project-based learning as a teaching methodology - Promote the foundation of STEM centers where both teachers and students can be trained - Establish a STEM education certificate program for teachers	- A curriculum committee is established - Curriculum is reviewed - More teachers are being trained - More equipment is being provided - More STEM workshops are conducted	Noticeable improvement in the attitude and skills of teachers - New curriculum approved -- Some classes start to apply STEM integration and applying PBL pedagogy - Noticeable improvement in the attitude of students, improvement in attendance	- STEM integration becomes a regular unit in all subjects' components of STEM - All new Teachers in STEM subjects obtain a STEM education certificate as a requirement for teaching - More enrolments in STEM programs and

- Science and Math teachers in K-12 schools decline to teach STEM as an integrated subject based on a lack of expertise in engineering design and laboratories shortage of equipment.		- STEM education certificate program for teachers is developed	to STEM classes and workshops - STEM education program is established and offered for new teachers	courses have noticeably increased - Performance and Achievement of students in STEM subjects have increased
Key Assumptions	STEM integration across science, technology, engineering, and mathematics curricula promotes the application of these subjects in real-world contexts. As students engage in STEM education, they develop the transferable skills needed to meet the demands of today's global economy and society and become scientifically and technologically literate citizens. In addition, integrating certain STEM-related subjects can reinforce students' understanding of each subject and their interrelationships. In high-quality advanced programs today, the 21st-century skills require more rigorous content than traditional curriculum provides			

Conclusion

This paper presents a roadmap toward the gradual achievement of a certain level of STEM integration based on applying the theory of change approach. Although the term STEM integration is widely used, there is still no agreed definition and approach to STEM.; integration remains elusive in practice, and challenges remain to be addressed at national and school levels.

At the education policy level, there is a need to be a commitment to supporting all four disciplines in schools in an integrated way. This requires greater attention to be paid to the place of engineering and technology alongside, or within, science and maths. Teachers must be trained to cope with the contributory disciplines' knowledge and epistemological and pedagogical principles to embrace integrated approaches. At program and examination levels, there needs to be a commitment to defining and assessing programs that address holistic global challenges, with adequate access to teacher resources to promote active investigation and creative design of potential solutions. Finally, at the school level, timetabling and collaborative planning opportunities must be provided for teachers of different disciplines to work together.

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About the Authors

Ziad Said: Adjunct Professor of Research-Qatar University. Worked as Senior Research Scientist and UNESCO chair on TVET and Sustainable Development at Doha University for Science and Technology, and faculty staff at the Faculty of Engineering at the College of North Atlantic – Qatar. Obtained his M.SC in Petrochemicals and Hydrocarbon Chemistry from the University of Manchester-UK and Ph.D. Polymer Chemistry from the same university. He worked as a faculty staff member and researcher in many high institutions in Iraq, Libya, Jordan, and Qatar. He published about 60 scientific articles and research papers on various topics in polymer science, chemistry, STEM education, teachers' training environment, twenty-first-century skills, and TVET. He was also awarded several research grants and scholarships from UNESCO and Qatar Foundation and served as a member of the ICS-UNIDO Forum of Experts on Environmentally Degradable Plastics (1997-2004). He has recently been certified by SDN – UN Academy as a sustainability assessor in Education. He was a recipient of the President of the College of the North Atlantic - Qatar of the best researcher award.

Email: ziad.said@qu.edu.qa, **ORCID ID:** 0000-0003-3936-0567

Ibrahim Al-Naimi Currently is the undersecretary of the Ministry of Education and Higher Education in Qatar. Before that, Dr. Al-Naimi held several leadership and academic positions including Dean of the College of Science and Professor of Organometallic Chemistry at Qatar University and its President as well as President of Qatar Community College. Professor Al-Naimi earned his Bachelor of Science degree in Education with Honors in Chemistry from Qatar University, and both an MA and a PhD in Chemistry from the University of Southern California (USC).

Email: i.alnaimi@edu.gov.qa, **ORCID ID:** 0000-0003-0479-7486

Hessa Al-Thani: Assistant Professor in Education at the College of Education-University of Qatar, previously Dean of the College. Dr. Al-Thani holds a Ph.D. in Educational Policy and Social Analysis from Columbia University. in New York. Dr. Al-Thani's research focuses on educational curricula, enriching curricula and their impact on an individual's education and character building, and motivating students to learn and engage in civics. Dr. Al-Thani is involved in the development of new methods of teaching and learning and follows up with faculty members at Qatar University to improve their teaching methods.

Email: dr.Hessa.althani@qu.edu.qa, **ORCID ID:** 0000-0002-3253-4790

Abdullah Abu-Tineh: Prof. Abdullah Abu-Tineh serves as the chair of the Department of Educational Sciences at Qatar University and is a professor in the Educational Leadership Program. He served as the founding director of the National Center for Educational Development (NCED). Prof. Abu-Tineh holds a Ph.D. in Educational Leadership and Human Resource Development from

Florida State University. He has authored numerous books and research papers published in national and international journals, presented at both national and international conferences, and conducted various professional development programs. He is the recipient of the Faisal Bin Qassim Award for Educational Research and the Outstanding Faculty Service Award from Qatar University.

Email: dr-abdullah@qu.edu.qa, **ORCID ID:** 0000-0003-3908-3096

Nasser Mansour specializes in science education at the College of Education, Qatar University. Previously, he was affiliated with Exeter University, UK, where he served as a key member of the STEM Centre. Nasser is also recognized as a Fellow of the Higher Education Academy (HEA). He has played a significant role as a developer and designer for the Physics and Chemistry curricula and STEM at Cambridge International Examinations, Cambridge University, UK. His research focuses on STS Education, STEM, teacher learning, and cultural issues related to science education. Additionally, Mansour holds the position of Editor-in-Chief for the Social Science and Humanities Open Journal at Elsevier.

Email: n.mansour@qu.edu.qa, **ORCID ID:** 0000-0001-5707-7373

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of paper titled "**Steps toward Integrating STEM Education into School Curricula**" belongs to the authors.

Effects of Computer Simulation on Chemistry Learning: A Systematic Review of PhET and Vlab Use in Classroom

Eshetu Desalegn Alemneh
Bahir Dar University

Hailu Shiferaw Ayele
Bahir Dar University

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Introduction

The science of chemistry contains lots of abstract concepts that cause problems in the conceptualization of instruction in chemistry lessons (Akram et al., 2017; Gabel, 1999; Park & Oliver, 2008; Prosser et al., 1994). Chemistry teaching and learning at all levels of education have been marked with several challenges, many students have difficulties embodying chemistry lessons that contain so many abstract concepts (Nakhleh, 1992). Learning chemistry involves understanding phenomena at three levels: the microscopic level which encompasses molecules, atoms, ions, subatomic particles, and kinetic (moments of particles); the macroscopic level embraces real and observable chemical phenomena (i.e tangible, edible, and visible, etc); and the symbolic level describes chemical structures and process with graph, chemical formulas, equations, symbols, and stoichiometry (Johnstone, 1993; Tang & Abraham, 2016). Correct understanding and applying concepts of particulate nature is very essential for chemistry learning students. Nevertheless, the particulate theory of matter is one of the most difficult topics due to the abstract nature of atoms and molecules, which requires students' ability to logically operate on information and symbols beyond personal experience and concrete cases in the real world. Learning at the submicroscopic level often requires the aid of models and images. The basic concepts that are used to understand chemical phenomena would rely on how molecules are made and what molecules do (Mammino, 2008).

Chemists formulate mental visualization concepts for molecules and the changes they undergo, through this, the internal representations are expressed externally using different forms such as equations, concrete models, graphs, drawings, and tables (Al-Balushi & Al-Hajri, 2014; Gilbert, 2005; Kozma & Russell, 2005). Representing chemical molecules with a two-dimensional representation that serves as a three-dimensional phenomenon distorts mental models and hampers desirable learning outcomes (Stieff et al., 2005). Scholars pointed out that shallow experiences of students with the microscopic level of representation lead the students to miss comprehend the relationship among the three levels of representing phenomena (Johnstone, 1993; Treagust & Chandrasegaran, 2009). The students also fail to link visual and conceptual information of representations and are faced with misconceptions about chemical concepts (Al-Balushi & Al-Hajri, 2014; Özmen et al., 2009).

Scholars suggested different teaching strategies (like a computer simulation, animation, using computer-based visualization tools, and manipulation of 3D concrete models) to alleviate these epistemological problems and make students familiar with the three levels of representation in chemistry particularly in the microscopic level of representation (Kozma & Russell, 2005; Mocerino et al., 2009). Computer simulations are dynamic models that indicate simplified models of real-world components, phenomena, or processes, which include animations, visualizations, text, images, video clips, and interactive laboratories (Bell & Smetana, 2011). The greatest contribution of the computer simulations was the enhancement of learners' understanding of abstract chemistry concepts (Sentongo et al., 2013).

Computer-based animations and simulations can provide visual representations of particulate structures and processes that may help students build mental models or imaginations (Tang & Abraham, 2016). Mapping or configuring three levels of representation can be enhanced by using computer technologies that are used in the teaching-learning process as instructional media. It makes up for the deficiencies of the traditional instructional approaches concerning time, place, speed, consideration for individual differences, safety, and overall efficiencies. Oladejo (2018) emphasized the principal role of technology-based instructional media is to improve the overall efficiency of instruction by increasing the quality of learning or the degree of mastery; decreasing the time taken for learners to attain the learning outcomes; increasing the efficiency of teachers in terms of the numbers of learners taught without reducing the quality of learning; reducing cost, without affecting quality; and increasing the independence of learners and the flexibility of education and training provisions.

Technologies enhance the cognitive powers of human beings during thinking, problem-solving, and learning and hold great potential for students to develop deeper knowledge and execute reflective thoughts (Jonassen, 1996). This is why computer simulation has emerged as one of the most popular instructional tools for delivering quality instruction for the chemistry teaching-learning process. The use of realistic simulation often requires students to apply newly acquired skills while motivating them toward advanced learning (Moreno & Mayer, 2007; Weller, 2004). Different studies demonstrated that computer-based animations and simulations can increase students' conceptual understanding of chemistry and enable them to develop mental models of chemical processes at the molecular level (Abraham, 2005; Abraham et al., 2004). Other studies have shown that animations can help students develop an integrative understanding of chemical phenomena across macroscopic, submicroscopic, and symbolic representations (Kozma, 2003; Salame & Makki, 2021). Simulations have long been recognized as important in the teaching and learning of chemistry. With increased access to technology in the classroom, interactive visualization tools have emerged as powerful for transforming chemistry education. Interactive simulations deliver dynamic access to multiple representations, make the invisible aspects to be visible, scaffold the inquiry process, and allow for many trials and immediate feedback while being engaging and fun for students and teachers (Moore et al., 2014). Computer simulations have been used in different teaching situations, especially as a substitute for, or complement to, the chemistry laboratory (Akaygun & Jones, 2013). It emphasizes representing phenomena at the atomic and molecular levels. The dynamic information and character, which increases the information-processing demand is the main feature of simulation (Lewalter, 2003). Lewalter also indicated that dynamic visuals may reduce a load of cognitive processing by supporting the construction of a mental model, but they may cause a higher cognitive load because of their temporal nature (Avramiotis & Tsaparlis, 2013). Computerized simulation chemistry experiments allowed the students to correctly solve problems related to the experiments and provide feedback for the simulated experiments in a linear sequence. Another advantage of computer-simulated experiments over the traditional approach is that the students dealt with data in a controlled setting. The data obtained under the traditional laboratory conditions were not fully reliable because of uncontrolled variables or measurement errors. The students using the computer-simulated experiment might have understood the concepts and problems conducted in those experiments better because they had the option of reexamining each part of the experiment. Because of the time constraint, the traditional approaches were not reexamined (Al-Balushi & Al-Hajri, 2014; Geban et al., 1992).

Having this background, the researcher attempted to review the effects of computer-based simulation on the chemistry instructional process. In this regard, my review was guided by the following research questions:

1. What is the most commonly used research design?
2. How many of the reviewed articles were done via PhET simulation and Vlab simulation?
3. To what extent does simulation-based instruction enhance the chemistry teaching-learning process?

Data to address the stated research questions were collected via the narrative review method. This was done by conducting a literature search to gather published articles on the effects of simulation-based teaching and learning chemistry. Google Scholar and CORE search engines were used to search relevant articles published between 2003 and 2022. Initially, 32 articles were collected from these database sources in the restricted time frame. After doing some preliminary analysis of the downloaded articles, some articles were excluded because of at least one of the following reasons:

1. If the article was published before 2021 and hadn't been cited or has very small citations.
2. The article hadn't been published in a reputable journal and publishers are not indexed by Scopus.
3. The articles were done with a qualitative research approach.

By using the above exclusion criterion, 23 research articles were removed and only 9 articles that satisfy the inclusion criteria were retained to conduct the review process. The researcher identified the included articles' purpose, study design, target groups, country of the study, publication year, and the chemistry concept catered for.

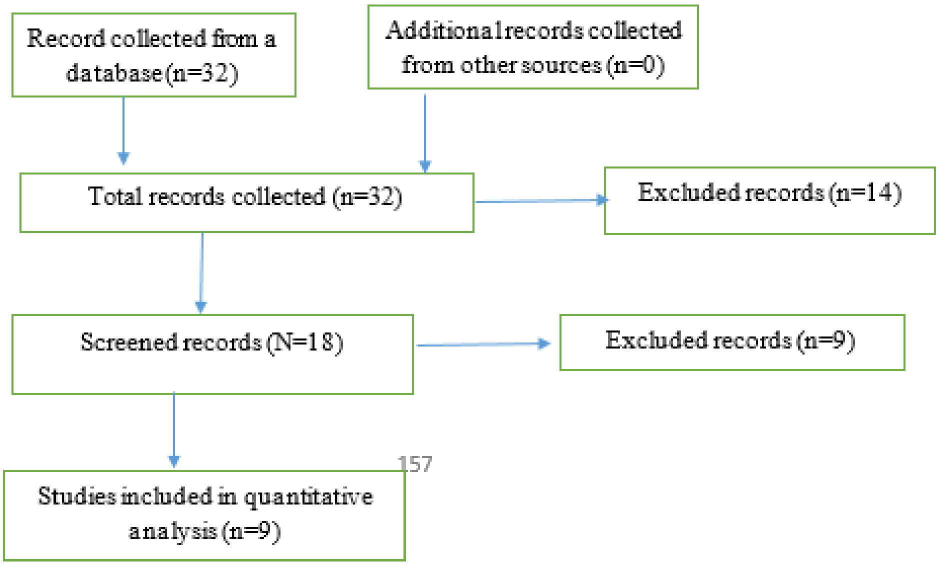

Figure 1. Exclusion steps of downloaded articles

Table 1. *General Description Of Included Articles*

	Purpose of study	publisher	# cite	Study area	Research design	Research analysis	Targeted group	Sample size	Chemistry concepts
1	Enhancing students' understanding of the macroscopic level of matter using computer simulation (**Tang & Abraham, (2016).**)	ACS	31	USA	Quasi-experimental	t-test	university students	170	Macroscopic level and particulate level of matter
2	Investigating the Effectiveness of Computer Simulations on Chemistry Learning **(Plass, Milne, Homer, Schwartz, Hayward, Jordan, & Barrientos, (2012).)**	Wiley	146	USA	Quasi-experimental	ANOVA	High school students	718	Kinetic molecular theory of gases
3	Comparing virtual and traditional laboratories for teaching electrochemistry (**Hawkins & Phelps, 2013**)	RSC	140	USA	Quasi-experimental	t-test, ANOVA	University students	167	Electrochemistry
4	examine the effect of using computer simulations in teaching chemical bonding **(Sentongo Kyakulaga, & Kibirige, 2013)**	Tayler & Francis	26	Uganda	Quasi-experimental	Mann Whiteny U-test, ANCOVA	High school students	115	Chemical bonding
5	To examine the influence of computer-assisted instruction on students' conceptual understanding of chemical bonding and attitude toward chemistry (**Ozmen 2008**)	ELSEVIER	161	Turkey	Quasi-experimental	percentage, t-test	High school students	50	Chemical bonding
6	To explore the impact of associating animations with concrete models on students' comprehension of different visual representations in organic **(Balushi & Al-Hajri, 2014).**	RSC	66	Sultanate of Oman	Quasi-experimental	ANCOVA	High school students	50	Organic chemistry

7	To examine the effects of virtual laboratories on students' achievements and attitudes toward chemistry (**Tuysuz, 2010)**	acarin dex	477	Turk ey	Quasi-experime ntal	Paired-sample t-test and independe nt-sample t-test	High school students	341	Separation of matter
8	To determine the effect of a virtual chemistry laboratory on student achievement in chemical changes (**Tatli & Ayas, 2013)**	jstor	294	Turk ey	Quasi-experime ntal	t-test, one-way ANOVA	High school students	90	Chemical changes
9	To examine the effects of PhET simulation on students' attitudes and learning in general chemistry Salame and Makki (2021)	ijese	12	USA	Descripti ve survey	Likert scale Questionn aire, open-ended question	College students	158	General Chemistry II

As vividly shown in Table 1, the overviews of the descriptive features of the 9 empirical studies were included in this review. The publication year for the articles included in the review was between 2008 and 2016 and the methodology of the studies was a quantitative research approach with an experimental research design.

Regarding research question one, identify the most common research design used for simulation-based chemistry teaching. As Table 1 displays, the commonly used research design used in the screened articles was quasi-experimental. It used a non-randomization approach to select participants and used intact or existing classes as experimental and control groups. Due to the use of naturally existing classes, the two groups may not be equivalent. As a design, it has the advantage of having better external validity to generalize the results compared to the true experimental groups but faced with different extraneous variables which affect the internal validity. Most of the screened articles were analyzed using ANCOVA to reduce the effects of the extraneous or confounding variables which affect the internal validity. From the initially collected 32 articles 20 of them were done using quasi-experimental, 2 of them were done with randomization design (true experimental), 1 of them was done with descriptive survey and 9 of them were done using qualitative research designs. But eight of the screened articles were done using a quasi-experimental and 1 descriptive survey research approach.

Regarding the second research question, the articles reviewed indicated that most of them 6(66.67%) were done using PhET simulation, and the rest 3(33.33%) were done using Virtual lab visualization computer-assisted chemistry instruction. The chemistry concept (content) taught using PhET simulation was chemical bonding, the molecular structure of organic compounds, chemical kinetics (molecular theory of gases), and the particulate nature of matter (PNM). The PNM is mainly focused on representing matters at the macroscopic level, microscopic level, and symbolic level. The macroscopic level is an observable phenomenon that is narrated through everyday experiences. It can be explained by the use of theories and models. The microscopic level is an explanatory model and theory. Representing the explanatory model through interactive computer simulation provides students with an active learning experience allowing them to engage in simulations presenting visualizations of particles that might be impossible. The symbolic representation of simulation design texts, graphs, and symbols are important elements (Milne et al., 2010; Plass et al., 2012).

Regarding the third research question, varieties of researchers investigated the effects of simulation-based instruction on students' chemistry achievement. The different articles indicated that simulation-based instructions have positive effects on the achievements of the students in the chemistry teaching-learning process. Virtual laboratory applications render students active thinkers instead of passive observers and thereby construct an effective and meaningful learning process (Tatli & Ayas, 2013). Different Studies stated that virtual laboratories facilitate the formation of conceptual models by providing activities that improve cognitive skills. The virtual laboratory software was shown to be at least as effective as real chemistry laboratories. Through research, it was determined that students in the experimental group could complete the experiments with reasonable results; they felt self-confident; they could associate the experiment with daily life; and they had the opportunity to examine macroscopic, microscopic, and symbolical levels of each experiment. It is anticipated that virtual chemistry laboratories will be adopted as supplementary and supportive elements in the future. This will provide not only an effective learning environment but will also minimize school expenditures and the time spent on such activities to a large extent(Tatli & Ayas, 2013). Virtual laboratories are a tool that can be very beneficial to the teaching-learning process of chemistry, as the conclusion of the study, virtual lab simulation was as good as normal hands-on general chemistry laboratories at teaching concepts(Hawkins & Phelps, 2013).

Research articles done by Tüysüz (2010) indicated that a virtual laboratory developed by interactive computer animation about the topic of separation of matter enhances the achievements of the students. The author of the article concluded that a virtual laboratory enriched with visual representation and used to make concrete difficult and abstract concepts increases the achievement, motivation, and interests of the students. However, as the author remarked that active will of the students to participate during the instruction plays a great role to lead the process to be effective (Hawkins & Phelps, 2013; Tüysüz, 2010).

Another scholar investigated the learners' achievement when using computer simulation in addition to the manual hands-on activities to compare achievements with using only hands-on/manual/ activities during the teaching-learning process of chemical bonding. The result revealed that understanding of the chemical bonding concept was enhanced from a pre-test to a post-test in the experimental group, and any significant change in the achievement accounted for the intervention of the computer simulation instruction. Computer simulation-based teaching-learning processes enhance the recalling process, comprehension, and analysis of chemical bonding concepts. Practically, computer simulations allowed learners to visualize chemical reactions at a microscopic level (Sentongo et al., 2013). Researchers claim that computer-assisted instruction enhances the transfer of learners' alternative conception compared to the conventional teaching method and enhance understanding of scientific conceptions (Al-Balushi & Al-Hajri, 2014; Jimoyiannis & Komis, 2001).

Other reviewed articles point out that computer-assisted instructional intervention positively impacted the attitudes of the students towards chemistry, understanding, and remediation of alternative conceptions of chemical bonding(Özmen, 2008). Some studies have indicated that students exposed to simulations performed significantly better in assessments and demonstrated better conceptual understanding than students who only viewed computerized static representations

(Aldahmash & Abraham, 2009). This is because dynamic chemical processes are usually more complex than statistical phenomena and simulated visualizations can help students develop appropriate mental models to comprehend the concepts and processes. Another result in the reviewed articles indicated that computer simulations improved students' conceptual understanding at the particulate level, but more specifically indicated that dynamic simulations at the particulate level helped the students understand the microscopic nature of matter involving dynamic chemical phenomena(Tang & Abraham, 2016).

According to Salame and Makki (2021), PhET interactive simulation had an overall positive impact on student's attitudes and perceptions about learning. PhET simulations helped students to create a better understanding of chemistry concepts and the content covered in the lecture. It promotes and facilitates learning and understanding of abstract concepts and also provides clear instruction which is easy to follow. Another reviewed article indicated that animation of submicroscopic organic molecules enhanced the utilization of concrete models in the teaching of organic chemistry, animation helped the students to comprehend the spatial aspects of organic molecules (Al-Balushi & Al-Hajri, 2014).

Chemistry teachers must make an effort to create an ideal environment for teaching and learning, including technological tools. Instead of using technological tools for a short-term educational program, students will benefit more from a longer period of learning (Pekdağ, 2010).

Conclusion

This study aimed to conduct a narrative review of the use of simulations in chemistry education. Based on the article selection process of inclusion and exclusion criteria, 32 articles published from 2003 to 2022 were listed. Using the exclusion and inclusion criterion 9 research articles published from 2006 to 2016 were selected for this narrative review. The research method, data collection tools, sampling methods, sample sizes, and data analysis method of these articles were displayed in a table for the review. According to the results of the analysis, the commonly used research design was quasi-experimental with a pretest-posttest control group design method. The data analysis was inferential statistics mainly independent and paired sample t-test, one-way ANOVA, ANCOVA, and Whitney U test. Most of the results in the articles indicated that interactive simulation-based chemistry teaching had an overall positive impact on students' achievement, motivation, attitude, and perceptions about the chemistry teaching and learning process.

Another important finding from the articles, computer simulation-based instruction can be a solution for schools which has overcrowded classes and inadequate chemistry laboratory. Sometimes virtual laboratory simulation-based instruction will be an alternative approach to physical laboratories in terms of cost, safety, repeatability, and comprehension.

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About the Authours

Mr. Eshetu Desalegn has earned his BSc degree in Chemistry from Addis Ababa University (Ethiopia) and his MSc degree in Analytical Chemistry from Bahir Dar University (Ethiopia). Eshetu Desalegn is now a Doctor of Education in Chemistry fellow at Bahir Dar University, Department of Science and Mathematics Education. He has been working as a school chemistry teacher and Chemistry teacher educator at Woldia College of Teachers Education for the last 16 years in Ethiopia. He has three published articles and two other articles which are under review.

E-mail: eshetu1976@gmail.com, **ORCID ID:** 0000-0002-3250-1833

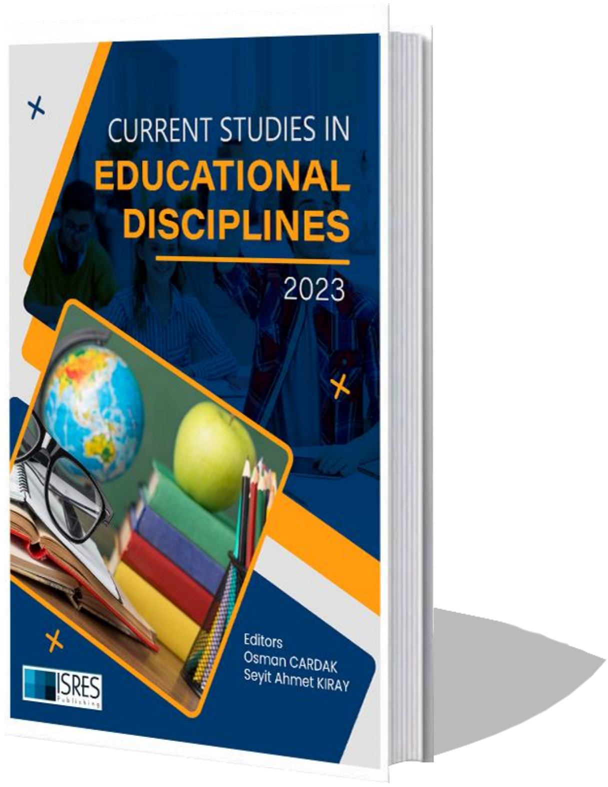
Dr. Hailu Sheferaw Ayele has earned his Ph.D. from the College of Earth Science, National Central University, Jhongli, Taiwan. He also has M.Ed (Masters of Education in Educational Psychology from Bahir Dar University Bahir Dar Ethiopia and an M.Sc (Masters of Science in Environmental

Studies from TERI University, New Delhi, India. He has earned also (B.Ed) Bachelor of Education in Chemistry from Dilla University, Dilla, Ethiopia.Dr. Hailu has worked as an educator and researcher in the Department of Chemistry, College of Science, and College of Behavioral Science and Education at Bahir Dar University, Bahir Dar. Ethiopia He has also been a visiting Researcher at the ENEA Laboratory of Biodiversity and Ecosystem Services, ENEA Research Center of Saluggia Strada per Crescentino 13040 Saluggia VC, Italy. His publications, address issues related to Environmental Science, Chemistry, and more recently teacher education. At present, He works as an Educator and researcher in the Chemistry Department, College of Natural Science, and Department of Teacher Education College of Behavioral Science and Education.

E-Mail: hayele02@gmail.com, **ORCID ID:** 0000-0002-2963-7991

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of paper titled "**Effects of computer simulation on chemistry learning: A systematic review of PhET and Vlab use in classroom"** belongs to the authors.



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