Online Journal of Mathematics, Science and Technology Education (OJOMSTE)

Vol: 6 No: 1 Year: 2025

journal homepage: https://www.ojomste.com/index.php/1

Examining the Learning Objectives Related to Sustainable Development in High School Physics Curricula Vis-À-Vis The Sustainable Development Goals and Revised Bloom's Taxonomy

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Received: June, 04, 2025 *Accepted: June, 24, 2025*

Keywords:

Sustainable development,

physics curriculum objectives,

revised Bloom's taxonomy

Paper Type:

Research

Abstract

This study determines and classifies the learning objectives related to sustainable development (SD) in the physics curricula of the 9th, 10th, 11th, and 12th grades in line with the sustainable development goals set by the United Nations (UN) and Revised Bloom's Taxonomy (RBT). The classification of learning objectives in line with RBT revealed that these objectives only focus on the cognitive domain, and no learning objectives considering the affective and psychomotor domains were present in the curriculum. Regarding the levels of cognitive learning, the objectives were mainly related to applying, analyzing, and evaluating. The classification of objectives in line with the SD goals showed that the objectives were primarily concerned with the economic pillar of sustainability, followed by the environmental and social pillars. The study concludes that SD-related learning objectives in the physics curriculum are related to the cognitive domain rather than the affective and psychomotor domains.

Erdemir, M. (2025). Examining the learning objectives related to sustainable development in high school physics curricula vis-à-vis the sustainable development goals and revised Bloom's taxonomy. *Online Journal of Mathematics, Science and Technology Education (OJOMSTE),* 6(1), 35-55.

Introduction

With the world's population increase, the need for living spaces, food, clean water, clean air, and energy has also increased. The finite nature of the world's resources has led to problems such as environmental pollution, hunger, famine, scarcity, diseases, global warming, and climate change, which in turn indirectly lead to issues such as terrorism, war, civil unrest, migration, economic problems, unemployment, income inequality, and injustice. Domestic issues have escalated to regional and global problems. For example, the impact of climate change, one of the consequences of global warming, is felt worldwide. Problems resulting from climate change, land degradation, and sea disturbance affect all living and nonliving things in nature.

Joint efforts to address global challenges should consider regional and international dynamics. The meaningful fight against these problems started in the 1940s with the Green Revolution. This initiative, which continued from the 1940s to the 1970s, aimed to increase global agricultural production to meet the population's needs. However, the increased use of chemical fertilizers and chemicals for pests, water consumption, and deforestation for farmland expansion contributed to the emergence of global problems today. The resolution agreed upon in the United Nations (UN) Conference on the Human Environment 1972 emphasized the need to place environmental issues at the forefront of development and cooperate to resolve ecological problems.

Individuals, institutions, and organizations should adopt environment-friendly policies to create a livable world for future generations and meet the needs of the current one. The Brundtland Report (1987) prepared by the World Commission on Environment and Development was presented to the United Nations General Assembly in 1987, and 'Sustainable Development (SD)' has become an important issue emphasised by the UN. In the Brundtland report, SD was defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). Then, in 1992, a roadmap for sustainability was laid out at the UN Conference on Environment and Development (Rio de Janeiro, 1992). In 1997, the Kyoto Protocol, which operationalized the UN Framework Convention on Climate Change, was signed, and the first international framework on sustainability was put into practice. In 2000, with the declaration of the Millennium Development Goals, the UN identified the "global aims of SD," and in 2015, the 2030 Agenda for Sustainable Development was adopted by all UN member states to eliminate poverty, protect the planet from degradation, and reduce equality and injustice. In this context, the sustainable development goals (SDGs) of no poverty, zero hunger, good health and well-being, quality education, gender equality, clean water and sanitation, affordable and clean energy, decent work and economic growth, industrial innovation and infrastructure, reduced inequalities, sustainable cities and communities, responsible consumption and production, climate action, aquatic life, life on land, peace, justice and strong institutions, and partnerships for the goals were adopted by UN member states (UNESCO, 2015).

Sustainable Development in Education

Countries, institutions, organizations, and individuals have a role to play in achieving SD. The UN Conference on Environment and Development (also known as the "Earth Summit") held in Rio de Janeiro 1992 emphasized that a better, peaceful, and sustainable future starts with education. The 2002 World Summit on Sustainable Development held in Johannesburg noted that education is a priority in forming a social and intellectual basis for implementing SD principles (Nasibulina, 2015). In sustainability education, students should be provided with knowledge that will enable them to build strategies that ensure our present and future well-being (Bell, 2016). Although there is no single pedagogical style for teaching sustainability, participatory and experimental approaches that lead to a change in students' opinions and actions and make meaningful differences stand out.

The 1992 Earth Summit in Rio emphasized the importance of education, training, and raising public awareness for achieving SD. At the conference, countries were called to integrate development's social, economic, and environmental dimensions into formal education curricula. Courses offered to students at school are directly or indirectly connected with different sizes of sustainability. Consequently, sustainability can be integrated into the curricula. To improve sustainability education, sustainability-related topics across all relevant disciplines can be added to the curricula (Tilbury & Wortman, 2004).

Efficiency is the ratio of inputs to outputs (Prokopenko, 2001). This definition is adequate in economics, but more is needed to express educational efficiency. Although the ratio of those entering the education system to those leaving it may indicate quantitative efficiency, it does not fully reflect the quality of education. Efficiency in education has two dimensions: "internal" and "external." Internal efficiency refers to the relationship between quantitative and nonmonetary outcomes, whereas external efficiency refers to the relationship between qualitative and monetary inputs.

Internal efficiency is represented by statistical data based on the number of students who enter and complete the educational system (Aydın, 1988) or whether the desired number of students graduate with the desired qualifications (Bülbül, 1983). Internal efficiency treats material and nonmaterial resources, pedagogical practices, and the processes related to the conduct of education as inputs. Material inputs include equipment, textbooks, teaching materials, desks, and classrooms. Nonmaterial inputs include cognitive, affective, and psychomotor domains of learning, culture, and level of readiness.

External efficiency in education refers to how an education system contributes to achieving socioeconomic and sociocultural objectives. In other words, it measures the role of education in realizing students' objective of welfare maximization. External efficiency looks at how successful the education system is in producing positive outputs and consequently enabling students to work at better jobs, get higher salaries (Santín & Sicilia, 2014), and reach higher levels of welfare. Inputs of external efficiency are nonmaterial pedagogical practices.

Positive outcomes in internal and external efficiency of education are reflected positively on SD. Accordingly, to sustainably shape the future, each individual should acquire the necessary knowledge, skills, attitudes, and values (UNESCO, 2014). Environmental, social, and economic sustainability aims to make the world more livable in the present and future. Education for sustainable development requires a new learning system that changes how we live (Ojala, 2016; Wamsler et al., 2018). An educational system's internal and external efficiencies in producing the desired outputs contribute to worldwide individuals, institutions, and countries' environmental, social, and economic development. Previous relevant studies have concluded that investments made by a government to improve the educational system contribute to its SD and economic growth (Barro and Lee, 1996, 2012; Hanushek & Kimko, 2000; De la Fuente, 2011; Hanushek & Woessmann, 2012).

Literature

The concept of sustainability came to the agenda with the 1987 Brundtland Report, and the UN started working on the subject. The studies categorized sustainable development (SD) under environmental, economic, and social headings. Two thousand fifteen, the UN set targets for sustainable development until 2030 (UN, 2015). The UN emphasized that it is essential to achieve the set targets, and countries, institutions, and organizations were asked to fulfill their responsibilities. There are studies on the limitations of the sustainable development themes identified by the UN (Washington, 2015, 2018; Bonnett, 2007, 2015; Kahn, 2010; Kopnina, 2016; Sitka-Sage et al. ve Piersol, 2017; Kopnina, H. 2020). These limitations are summarized as

follows: the themes do not meet today's expectations, some themes are prominent, economic growth and SD are contradictory, the themes are human-centered, the studies are not sufficient in achieving SD goals, the studies are at the cognitive level (the implementation aspect is weak), the themes should be structured according to cultures, although there is an awareness (awareness) for SD in education and training activities, the implementation aspect is weak.

According to Baum (2021), since the criteria for sustainable development set by the United Nations (UN) are insufficient and do not meet today's expectations, he proposed criteria for a coherent, comprehensive economy, social justice, environment, needs and rights, democracy, and long-term perspective. He stated that social issues should be prioritized. In addition to sustainable development, environmental, economic, and social dimensions should include ecocentric education, eco-pedagogy, and different financial models (Kopnina, 2020). Moreover, the SD criteria are set according to global goals and do not consider the cultural structures of nations (regions). Subject content for SD in courses should be shaped according to culture, critical pedagogy should be adopted, and it should be a lifelong learning process (Gokool-Ramdoo & Rumjaun, 2017).

Environmental studies have come to the fore in studies on sustainability. It was emphasized that sustainability is not limited to environmental protection and environmental science (Washington, 2015). It was stated that sustainable development education should be separated from environmental education, and problem-based interdisciplinary learning should be provided (Dale & Newman, 2005).

Studies have shown a contradiction between economic growth and sustainability and that sustainability and sustainable development differ. Sustainability and sustainable development are not the same thing (Washington, 2015); the leading causes of environmental unsustainability are precisely the population and consumption growth associated with economic growth and industrial development and the increasing demand for natural resources (Kahn, 2010; Kopnina, 2016; O' Neill, 2012; Washington, 2018). Social and economic priorities have been emphasized at the expense of ecological concerns in education and training (Bonnett, 2015; Fien, 2010; Kahn, 2010; Kopnina, 2016; Nocella, 2007; Sitka-Sage et al., 2017). It has been noted that economic growth to raise living standards will have a potentially devastating impact on the global ecosystem (Nemetz, 2013). They have also identified that economic growth fuels the massive expansion of industrial activities, competition for increasingly scarce resources, and associated social inequalities and turmoil (Rees, 2010; Wijkman & Rockström, 2012; Kopnina & Blewitt, 2014; Washington, 2015).

It has been stated in scientific studies that sustainable development is a human-centered approach. Sustainability is defined in the Brundtland report (1987) as meeting the needs of the present without compromising the ability of future generations to meet their own needs. Bonnett (2007) stated that sustainable development is human and economy-centered. It is noted that development aims to achieve a high quality of life for people, which will decrease biodiversity, climate change, natural resource depletion, and highly unethical relationships with nature (Washington, 2015, 2018). Molina-Motos (2019) argues that UNESCO's education and training program for a sustainable future mainly emphasizes social and economic priorities to exclude eco-philosophical principles.

Scientific studies on sustainability development practices and the goals to be achieved must be revised, and studies should focus on specific themes. In a synthesis study on sustainability, 26 of 44 were on the themes of education for sustainable development or environmental education, 12 on global citizenship or development, and six on intercultural education (O'Flaherty & Liddy, 2018). In the study on the analysis of sustainable development and its goals, goals such as

education, climate, energy, sustainable cities, natural habitat, consumption, and production came to the fore in sustainable development (Shulla et al., 2020).

Education and training on sustainable development have emphasized cognitive level knowledge, awareness, and consciousness-raising activities, and practical sustainability education and training activities need to be improved. A meta-analysis study on raising awareness for sustainable development emphasized that more research is necessary for students to promote sustainability (Gómez-Olmedo et al., 2020). There is a need to strengthen the link between formal and informal education related to sustainability (Gokool-Ramdoo & Rumjaun, 2017). A study on the formation of sustainable development awareness in students found significant differences between schools that provide sustainable development education and schools that do not, and the level of these differences is low (Berglund et al., 2014).

As education and training activities are related to broader societal goals, students must be provided with the necessary skills to overcome societal challenges such as unsustainability. In sustainability education, emphasis needs to be placed on practice. Unesco (2005) emphasized that the teacher education program should be revised to address sustainability, and the basic principles of sustainable development should be included in the teacher education program. Public institutions, private organizations, local governments, and educational institutions have a great duty to achieve SD 2030. Unesco has stated that SD should start from schools. There needs to be a clear and systematic situation about how SD and its content and applications should be in education programs.

Schools are one of the institutions that significantly impact students' behavior. Schools strongly influence students' behavior (Saunders et al., 1995). In this context, the achievements of the courses carried out in schools are essential in creating a sustainable world at the local and national levels. The outcomes of the subjects in physics courses in schools are critical in terms of having a general perspective on sustainability and the relationships between other science fields. For example, the subject of energy in the physics course is also included in courses in different fields of science. This can be achieved by creating a general sustainable perspective and by bringing together the achievements of the studies on energy in various fields of science. This study will investigate the adequacy of the course outcomes for SD by determining the learning levels of the achievements related to SD in physics courses. The learning levels will be determined according to the Revised Bloom's Taxonomy's cognitive, affective, and psychomotor themes and sub-themes. Determining the learning level of physics subject learning outcomes for SD will be important in shedding light on restructuring the physics curriculum, strengthening the relations between science fields, and developing educational strategies.

Methods

In this section, the document analysis method, one of the qualitative research methods, was used. Document analysis is the examination of written materials containing information about a subject for analysis, knowledge development, and interpretation (Bowen, 2009; Yıldırım & Şimşek, 2011). The achievements of the 9th, 10th, 11th, and 12th-grade physics curricula prepared by the Ministry of National Education (MEB) of the Republic of Turkey were examined. Tables 1 and 2 were created according to the unit and subject distributions. Physics course outcomes are coded according to the sustainable development criteria determined by the UN (UNESCO, 2005). Acquisitions were coded according to RBT (Anderson et al., 2001; Krathwhol, 2002) by high school physics teachers, university physics educators, and program developer field experts. Each expert created their coding. Table 3 and Table 4 were made by reaching a consensus in the light of the coding of three experts.

In creating Table 3, the achievements were coded according to the UN's sustainable development criteria (environment, economy, and social). According to expert opinions of the successes, the codings are distributed as three, two, and one. For example, the "*explaining the functions of simple machines used in daily life*" outcome of the simple machines subject of the force and motion unit is coded with three criteria determined by the UN. The outcome of the Waves unit on the subject of seismic waves, "*Developing solutions to prevent loss of life and property caused by earthquakes*," is coded with the economic and social criteria determined by the UN. The "*developing projects for measures to be taken against global warming"* achievement of the energy unit, its mechanisms, and energy transmission rate is coded only with the environmental criteria determined by the UN.

In creating Table 4, the most widely used adaptation of the original Bloom model was coded into the Revised Bloom Taxonomy (RBT) acquisition verbs by Anderson et al. (2001) and Krathwhol (2002). The achievements of the physics course were included only in the cognitive process of RBT. According to expert opinions, the outcomes were distributed as three, two, and one in coding the mental process's sub-themes. For example, in the energy unit, the sub-themes of *remembering*, *understanding*, and *analysis* of the cognitive process were coded for the acquisition of the subject of energy conservation and energy conversion, "*comparing the energy that living organisms obtain from food with the energy they spend daily*." In the Pressure and Buoyancy unit, the *application* and *evaluation* of the achievement of the buoyancy subject "*proposing solutions to problems related to buoyancy in daily life by using buoyancy and Bernoulli's Principle*" are coded with sub-themes. The "*understanding the health and safety precautions that must be taken against the dangers of electric currents*" achievement of the electrical circuits subject of the electricity and magnetism unit is coded with the sub-theme of *understanding*.

Data Collection

The distribution of the learning objectives in the high school physics curriculum by units, grades, and the number of objectives is given in Table 1. The table shows 213 learning objectives from 18 units of the 9th-, 10th-, 11th-, and 12th-grade physics curricula (MEB, 2018).

Table 1. Learning objectives in the high school physics curriculum.

Grade	*Unit name*	*Number of learning objectives*
9th grade	*Introduction to Physics*	*4*
	Properties of Matter	*4*
	Motion and Force	*11*
	Energy	*8*
	Heat and Temperature	*13*
	Electrostatic	*4*
10th grade	*Electricity and Magnetism*	*9*
	Pressure and Buoyancy	*4*
	Waves	*12*
	Optics	*14*
11th grade	*Force and Motion*	*33*
	Electricity and Magnetism	*29*
12th grade	*Circular Motion*	*15*
	Simple Harmonic Motion	*5*
	Wave Mechanics	*8*

Grade	*Unit name*	*Number of learning objectives*
	Introduction to Atomic Physics and Radioactivity	*11*
	Modern Physics	*15*
	Applications of Modern Physics in Technology	*14*
Total		***213***

Among the learning objectives in the 9th-, 10th-, 11th-, and 12th-grade curricula, the SD-related ones were identified by field experts in terms of the outcomes they seek to achieve. The distribution of learning objectives related to SD by grade, unit, topic, and topic content is presented in Table 2.

Table 2. Distribution of learning objectives related to SD by grade, unit, topic, and content.

Grade	*Unit*	*Topic*	*Learning Objective*	*Topic Content*
9th grade	*Energy*	*Conservation of Energy and Energy Transformation*	*Comparing the energy living organisms gain from food with the energy they expend during daily activities*	*- How living creatures use the energy they get from food for daily activities* *- The amount of nutrients a person should consume to sustain daily activities* *- Nutritional needs*
	Energy	*Efficiency*	*Explains the concept of efficiency*	*- Mathematical expression of the concept of efficiency* *- How to increase energy efficiency (clean production)*
	Energy	*Efficiency*	*Developing suggestions to improve the efficiency of a sample system or design*	*- Identifying actions that can be taken at school and home* *- Determining the actions to be taken to increase the efficiency of a system*
	Energy	*Energy Sources*	*Evaluating the advantages and disadvantages of renewable and nonrenewable energy sources*	*- Energy need, definition, and sources of renewable and nonrenewable energy* *Comparison of renewable and nonrenewable energy* *- Saving energy*
	Energy	*Mechanisms and Speed of Energy Transmission*	*Making designs to ensure the insulation of living spaces for energy-saving*	*- Conduction of heat, conduction velocity, heat loss, slowing down heat conduction, and determination of factors affecting heat conductivity* *- Thermal insulation and energy saving*
	Energy	*Mechanisms and Speed of Energy Transmission*	*Developing projects for measures to be taken against global warming*	*- Greenhouse effect, the adverse effects of global warming, prevention of global warming, and the Kyoto Protocol* *- Development of a project against global warming*

Grade	Unit	Topic	Learning Objective	Topic Content
10th grade	Electricity and Magnetism	Electric Circuits	Explaining the health and safety precautions to be taken against the dangers of electric currents	- Measures to be taken for protection against electrical accidents - Cautions and warning signs to take heed of when using electrical devices
	Pressure and Buoyancy	Buoyancy	They are proposing solutions to the problems in daily life related to buoyancy using buoyancy and Bernoulli's Principle.	- The role of buoyancy in daily life and Bernoulli's Principle - A project on preventing roof flying accidents resulting from changes in the internal and external pressure of buildings in windy weather
	Waves	Seismic Waves	Developing solutions to prevent the loss of life and property caused by earthquakes	- The nature of earthquakes and solution suggestions to prevent the consequent loss of life and property - A project on creating a model for a building that prevents loss of life and property
11th grade	Force and Motion	Simple Machines	Explaining the functions of simple machines used in daily life	- Definition of simple machines - Function, gain, and efficiency of simple machines
	Force and Motion	Simple Machines	Designing a safe system made up of simple machines to make life easier.	- A project on a straightforward machine that will make it easier to complete a daily life task
	Electricity and Magnetism	Transformers	Explaining the intended use of transformers	- Areas where transformers are used and their intended use - Energy loss and efficiency in transformers
12th grade	Circular Motion	Regular Circular Movement	Making calculations to enable vehicles to safely perform the curve movement on horizontal, vertical, and sloping grounds	- Concepts related to regular circular movement - Horizontal and vertical curves and conditions under which curve movement can be performed safely
	Introduction to Atomic Physics and Radioactivity	Radioactivity	Explaining the effects of radiation on living creatures	- Radioactive material, stable and unstable atoms, and radioactive decay - The effect of radiation on living things - Measures to be taken for protection against radioactive materials
	Applications of Modern	Semiconductors	Explaining the importance of semiconductors in technology.	- Properties of semiconductor materials and their role in information technology

Grade	*Unit*	*Topic*	*Learning Objective*	*Topic Content*
	Physics in Technology			*- The role of semiconductors in electrical and electronic circuits*
	Applications of Modern Physics in Technology	*Semiconductors*	*Providing examples of where LED technology is used*	*- LED lighting, energy saving, and efficiency* *- Application areas of LED technology*
	Applications of Modern Physics in Technology	*Semiconductors*	*Designing a system powered by solar cells to make life easier*	*- The importance and working principles of solar cells* *- Areas of solar cell use* *-A project on a system running on solar cells that aims to make life easier*
	Applications of Modern Physics in Technology	*Superconductors*	*Providing examples of the uses of superconductors in technology.*	*- Properties of superconductor materials and their use in technology* *-Zero resistance of superconductors against electric current and reduction of electrical losses*
	Applications of Modern Physics in Technology	*Nanotechnology*	*Providing examples of the use of nanomaterials in technology*	*- Areas of use of nanotechnology and the conveniences and benefits it provides*
	Applications of Modern Physics in Technology	*Laser Beams*	*Providing examples of the use of laser beams in technology.*	*- How laser beams are produced and used* *- The use and importance of laser beams in technology*

The field experts cI sided with the topic content in determining the learning objectives related to SD. Table 2 presents the relevant objectives, grade levels, units, topics, and content. In the 9th-, 10th-, 11th-, and 12th-grade physics curricula, 20 learning objectives were identified as related to SD from a total of 213 (Table 2). These objectives are predominantly taught in the 9th-grade "Energy" and 12th-grade "Applications of Modern Physics in Technology" units.

Data Analysis

The dataset was the learning objectives related to SD in the 9th-, 10th-, 11th-, and 12th-grade physics curricula. These objectives were analyzed based on the UN SDGs and RBT. Sustainable Development: The themes and sub-themes for the UN SDGs are given in Figure 1. Classifying the learning objectives in the curricula was based on these themes. This classification will be taken into account in the analysis of the findings. At the 2005 UN World Summit, SD was defined as having three components: economic development, social development, and environmental protection (UN, 2005).

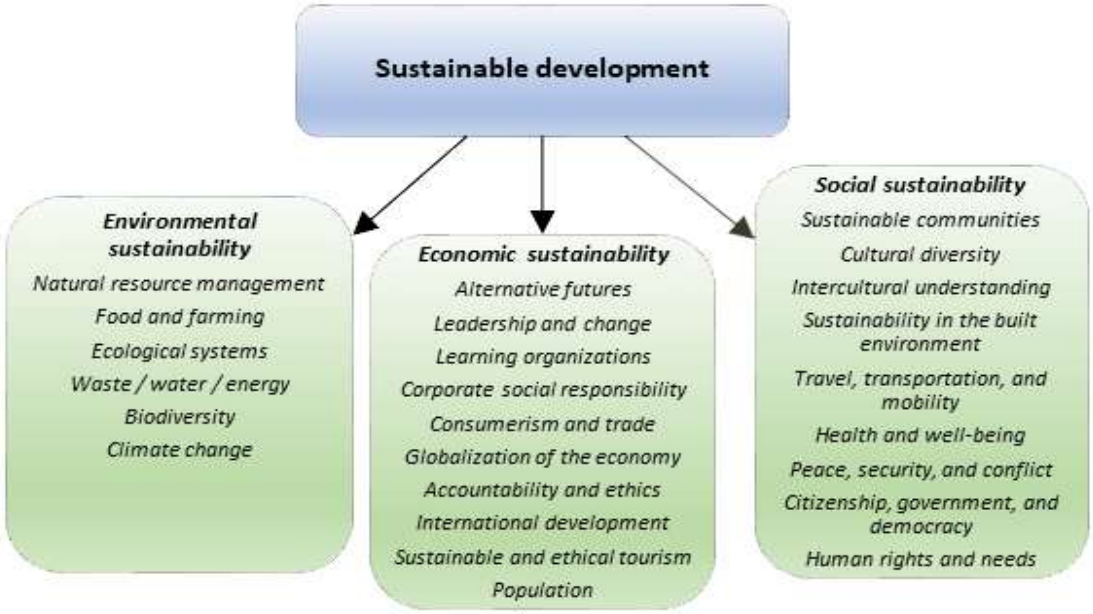

Figure 1. Dimensions of sustainable development (UN, 2005).

Environmental sustainability encompasses sub-themes such as natural resources (water, energy, agriculture, and biodiversity), climate change, rural development, sustainable urbanization, disaster prevention, and mitigation.

Social sustainability (cultural) comprises sub-themes such as human rights, peace and security, gender equality, cultural diversity and intercultural understanding, health, and co-governance.

Economic sustainability contains sub-themes such as reducing poverty, corporate responsibility and accountability, and market economy (UNESCO, 2005).

Revised Bloom's Taxonomy: The taxonomy proposed by Benjamin S. Bloom in 1956 consisted of a single domain. Updated in 2001, other domains were added. The three domains of RBT and associated levels are given in Figure 2.

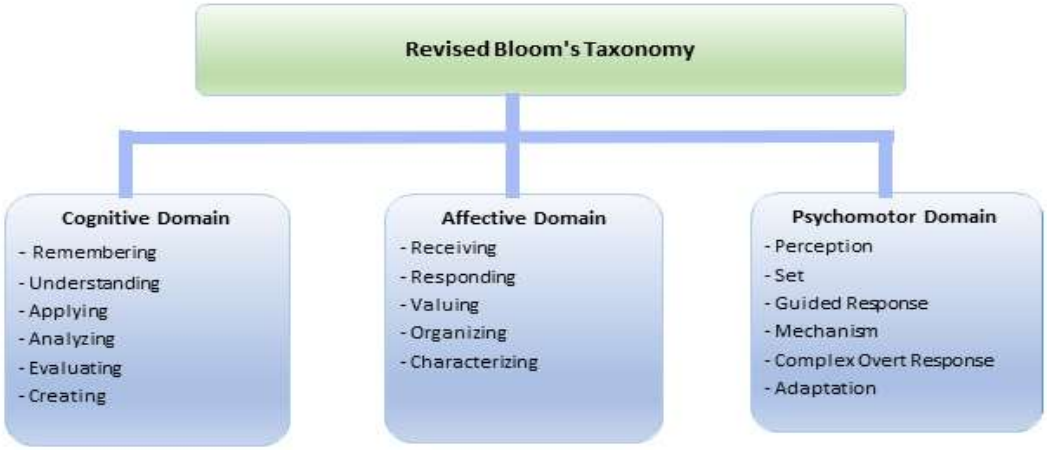

Figure 2. Revised Bloom's Taxonomy Revised Bloom's Taxonomy (Anderson et al., 2001; Krathwhol, 2002)

The RBT consists of three domains: *cognitive, affective, and psychomotor*.

The cognitive domain includes information recall, understanding meaning, deconstruction of concepts, synthesis, and evaluation.

The affective domain encompasses behaviors such as sensitivity, valuing belief, positive attitude, paying attention, reacting, and having a worldview.

The *psychomotor domain* includes behaviors that require skills related to movement, sports, and muscles.

The study findings are presented in Tables 3 and 4 regarding the learning objectives in Table 2 and the criteria in Figures 1 and 2.

Findings

SD learning objectives are classified according to the UN SDGs (Figure 1) and RBT (Figure 2).

Classification of learning objectives related to sustainable development in line with the United Nations Sustainable Development Goals

SD-related objectives are categorized according to the UN SDGs (table 3). Twenty learning objectives from nine different units of the 9th-, 10th-, 11th-, and 12th-grade physics course were classified under the three pillars of SD: environmental, economic, and social.

Table 2. Classification of achievements according to the UN SDGs.

Grade	*Unit*	*Topic*	*Learning Objective*	*Environmental*	*Economic*	*Social*
9th grade	*Energy*	*Conservation of Energy and Energy Transformation*	*Comparing the energy living organisms gain from food with the energy they expend daily.*	✓	✓	
	Energy	*Efficiency*	*Explaining the concept of efficiency*	✓	✓	✓
	Energy	*Efficiency*	*Developing suggestions to improve the efficiency of a sample system or design*	✓	✓	
	Energy	*Energy Sources*	*Evaluating the advantages and disadvantages of renewable and nonrenewable energy sources*	✓	✓	
	Energy	*Mechanisms and Speed of Energy Transmission*	*Making designs to ensure the insulation of living spaces for energy-saving*		✓	
	Energy	*Mechanisms and Speed of Energy Transmission*	*Developing projects for measures to be taken against global warming*	✓		

Grade	Unit	Topic	Learning Objective	Environmental	Economic	Social
10th grade	Electricity and Magnetism	Electric Circuits	Explaining the health and safety precautions to be taken against the dangers of electric currents		✓	
	Pressure and Buoyancy	Buoyancy	They are proposing solutions to the problems in daily life related to buoyancy using buoyancy and Bernoulli's Principle.		✓	✓
	Waves	Seismic Waves	We are developing solutions to prevent the loss of life and property caused by earthquakes.		✓	✓
11th grade	Force and Motion	Simple Machines	Explaining the functions of simple machines used in daily life	✓	✓	✓
	Force and Motion	Simple Machines	Designing a safe system made up of simple machines to make life easier.		✓	✓
	Electricity and Magnetism	Transformers	Explaining the intended use of transformers	✓	✓	
12th grade	Circular Motion	Regular Circular Movement	Making calculations to enable vehicles to safely perform the curve movement on horizontal, vertical, and sloping grounds		✓	
	Introduction to Atomic Physics and Radioactivity	Radioactivity	Explaining the effects of radiation on living creatures	✓		
	Applications of Modern Physics in Technology	Semiconductors	Explaining the importance of semiconductors in technology		✓	
	Applications of Modern Physics in Technology	Semiconductors	Providing examples of where LED technology is used	✓	✓	✓
	Applications of Modern	Semiconductors	Designing a system powered by solar cells to make life easier		✓	✓

Grade	*Unit*	*Topic*	*Learning Objective*	*Environmental*	*Economic*	*Social*
	Physics in Technology					
	Applications of Modern Physics in Technology	*Superconductors*	*Providing examples of the uses of superconductors in technology*	✓	✓	✓
	Applications of Modern Physics in Technology	*Nanotechnology*	*Providing examples of the use of nanomaterials in technology*	✓	✓	✓
	Applications of Modern Physics in Technology	*Laser Beams*	*Providing examples of the use of laser beams in technology*	✓	✓	✓
			Total	**12**	**18**	**10**

Of the learning objectives, 12 were under the environmental pillar, 18 under the economic pillar, and ten under the social pillar (Table 3). Some of the learning objectives were classified under more than one pillar. For example, the learning objective "Providing examples of the use of nanomaterials in technology" contributes to environmental sustainability because tools built using nanotechnology are more durable, cause less pollution, require less energy and water for production, and release less harmful gases and heat; these tools also contribute to economic sustainability because they are of superior quality and have a long shelf-life and social sustainability because they make individuals' lives easier and can be used in medical applications.

Classification of learning objectives related to sustainable development in line with revised Bloom's Taxonomy

Because learning objectives related to RBT's affective or psychomotor domains were not identified in the high school physics curriculum, only those that aim to enhance the cognitive domain are presented. Table 4 shows the distribution of the 31 learning objectives from 9 different units of the 9th-, 10th-, 11th-, and 12th-grade physics courses under the six levels of the cognitive domain of learning.

Table 4. Distribution of the relevant learning objectives by the levels of the RBT cognitive domain.

Grade	*Unit*	*Topic*	*Learning Objectives*	*Cognitive Domain*					
				Remembering	*Understanding*	*Applying*	*Analyzing*	*Evaluating*	*Creating*
9th grade	*Energy*	*Conservation of Energy and Energy Transformation*	*Comparing the energy living organisms gain from food with the energy they expend daily.*	✓	✓		✓		
	Energy	*Efficiency*	*Explaining the concept of efficiency*		✓				
	Energy	*Efficiency*	*Developing suggestions to improve the efficiency of a sample system or design*					✓	
	Energy	*Energy Sources*	*Evaluating the advantages and disadvantages of renewable and nonrenewable energy sources*				✓	✓	✓
	Energy	*Mechanisms and Speed of Energy Transmission*	*Making designs to ensure the insulation of living spaces for energy-saving*			✓		✓	
	Energy	*Mechanisms and Speed of Energy Transmission*	*Developing projects for measures to be taken against global warming*					✓	
10th grade	*Electricity and Magnetism*	*Electric Circuits*	*I explained the health and safety precautions to be taken against the dangers of electric current.*		✓				
	Pressure and Buoyancy	*Buoyancy*	*Proposing solutions to the problems in daily life related to buoyancy using buoyancy and Bernoulli's Principle*			✓		✓	
	Waves	*Seismic Waves*	*Developing solutions to prevent the loss of life and property caused by earthquakes*			✓		✓	
11th grade	*Force and Motion*	*Simple Machines*	*Explaining the functions of simple machines used in daily life*	✓	✓				
	Force and Motion	*Simple Machines*	*Designing a safe system made up of simple machines to make life easier*			✓		✓	
	Electricity and Magnetism	*Transformers*	*Explaining the intended use of transformers*		✓	✓			

Grade	Unit	Topic	Learning Objectives	Cognitive Domain					
				Remembering	Understanding	Applying	Analyzing	Evaluating	Creating
12th grade	Circular Motion	Regular Circular Movement	Making calculations to enable vehicles to safely perform the curve movement on horizontal, vertical, and sloping grounds			✓	✓		
	Introduction to Atomic Physics and Radioactivity	Radioactivity	Explaining the effects of radiation on living creatures		✓				
	Applications of Modern Physics in Technology	Semiconductors	Explaining the importance of semiconductors in technology		✓				
	Applications of Modern Physics in Technology	Semiconductors	Providing examples of where LED technology is used		✓				
	Applications of Modern Physics in Technology	Semiconductors	Designing a system powered by solar cells to make life easier					✓	
	Applications of Modern Physics in Technology	Superconductors	Providing examples of the uses of superconductors in technology		✓				
	Applications of Modern Physics in Technology	Nanotechnology	Providing examples of the use of nanomaterials in technology		✓				
	Applications of Modern Physics in Technology	Laser Beams	Providing examples of the use of laser beams in technology		✓				
			Total	**2**	**11**	**6**	**3**	**8**	**1**

The table shows that of the relevant learning objectives, two are related to remembering, eleven to understanding, six to application, three to analysis, eight to evaluation, and one to create (Table 4). The objectives were found to be predominantly related to the understanding and evaluation skills of the cognitive domain.

Objectives and aims were found to be determinant in classifying some objectives under multiple skills. For example, the objective “Making designs to ensure The insulation of living spaces for

energy saving" was classified under "application" because it enables energy saving in living spaces and "evaluation" because it encompasses making an insulation design.

Discussion and conclusion

According to SD criteria and RBT, this study coded learning outcomes in the 9th, 10th, 11th, and 12th-grade physics course curricula. It was determined that 20 of 213 learning outcomes were related to SD. According to the SD criteria specified by the UN, the gains are listed as economic, environmental, and social. According to RBT, it was determined that these gains were at the cognitive level and did not include gains for emotional and psychomotor areas. From the sub-themes of the mental level, the themes of understanding, evaluation, and application came to the fore.

In the Study, the identified learning objectives are represented by the cognitive domain and are oriented toward the internal efficiency of education. The outcomes related to SD in the physics course include actions such as interdisciplinary relationships and using different skills and strategies, which are insufficient for forming a high-level learning situation. This situation meets the criteria of metacognitive skills in the literature (Anderson et al., 2001; Cambridge et al., 2019; Flavell, 1979; Lokajíčková, 2014). The achievements for SD in the physics course do not provide metacognitive learning, and the learning level remains at the knowledge level. It is argued that SD education should not stay at the level of knowledge but should explore learning methods that enable the development of competencies that help individuals cope with challenges (de Haan, 2006; Papenfuss, 2019). It has been emphasized that more research should be carried out to ensure that what students learn about sustainability in the lessons turns into practice (Gómez-Olmedo et al., 2020). To achieve educational goals, the domains of RBT must be hierarchically realized. The behaviors acquired through activities aimed at improving the internal efficiency of education should also be used in work and daily life, representing external efficiency. The relevance and compatibility of the gains made by the students with the activities they carry out in their professional lives point to the external efficiency of education (Demirtaş, 1991).

According to the RBT, the achievements of the physics course are at the knowledge level, and the application aspect is weak. The study emphasized that more work should be done to encourage the transition from the cognitive level to the application stage (Gómez-Olmedo et al., 2020). It was stated that the link between formal and non-formal education for SD needs to be strengthened (Gokool-Ramdoo & Rumjaun, 2017). In another study, in the meta-analysis of 34 graduate theses and 11 articles, sustainable development awareness and views on sustainable development were predominantly included (Özerdinç, Kızılay & Hamalosmanoğlu, 2022). Physics course outcomes should be restructured for practice, and the studies should be practice-oriented. In addition, practice-oriented outcomes should be included while creating educational strategies.

This study found that the learning objectives related to SD aim to improve the internal efficiency of education (objectives representing the cognitive domain) but not external efficiency (objectives representing the affective and psychomotor domains). In other words, the identified learning objectives do not encourage students to acquire behaviors representing the external efficiency of education, such as creating a more livable world, having environmental awareness, and contributing to environmental protection. Lessons at school should encourage students to critically consider the relationships between humans and nature (Spannring, 2017). Accordingly, learning objectives that aim to raise awareness regarding sustainable development's environmental, economic, and social pillars contribute to SD. High school physics curricula should feature more learning objectives related to RBT's cognitive, affective, and psychomotor domains in a hierarchical manner. This will encourage the utilization of cleaner production processes, the production of eco-friendly products, and the use of fewer resources to ensure sustainability. In addition, increasing the number of learning objectives related to SD and aimed

at improving RBT's cognitive, affective, and psychomotor domains will ultimately contribute to the world's carrying capacity. In other words, the objectives aimed at improving the internal efficiency of education should also contribute to external efficiency and consequently create value. More learning objectives to enhance RBT's cognitive, affective, and psychomotor domains should be included in the curricula. Learning objectives are mediated by different direct outputs of the education system: cognitive skills, attitudes, and behaviors (Lockheed & Hanushek, 1994).

To achieve the UN SDGs by 2030, more learning objectives related to SD must be included in physics curricula. UNESCO emphasized the need for all learners to acquire the knowledge and skills needed to promote SD (UNESCO, 2015). Such knowledge and skills should promote sustainable lifestyles, a clean environment, human rights, equality, global citizenship, and appreciation of cultural diversity and cultural contribution to SD (UNESCO, 2015). To preserve a livable world for present and future generations, learning objectives related to sustainability and enhancing the cognitive, affective, and psychomotor domains should be taught at every stage of education. At the primary school level, SD-related learning objectives should focus on helping students gain knowledge. The relevant attitudes, behaviors, and knowledge should be promoted at the secondary school level. In undergraduate and postgraduate education, the appropriate knowledge should be reinforced with applied activities, helping students acquire the target attitudes and behaviors. Higher-order achievements should be emphasized in education, and investments in education should be made to contribute to SD. The literature stresses that a country's investment in quality education is essential for its SD and economic growth (Barro & Lee, 2012; Hanushek & Kimko, 2000; De la Fuente, 2011; Hanushek & Woessmann, 2012). Themes oriented toward sustainability education should be included in the curricula of all courses across disciplines (Tilbury & Wortman, 2004). To meet the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland, 1987), the aims of SD must be realized globally.

Conclusion

The following conclusions were drawn about the outcomes of the physics course.

1- Only 20 out of 213 objectives are related to SD.

2- 20 objectives are at the cognitive learning level, according to RBT.

3- Since 20 objectives are not included in RBT's affective and psychomotor learning levels, they cover cognitive learning levels.

Recommendations

Institutions and organizations have important roles in achieving the UN's 2030 SDGs. Time and resources should be allocated to facilitate change in students' thinking and behavior towards SD, use participatory and experiential learning, and encourage critical thinking, imagining future scenarios and practical knowledge. Educational institutions should integrate more SD-related topics into their curricula and learning processes. Lessons should include objectives related to each topic, and the objectives should reflect metacognition. The number of learning objectives in the physics curriculum that help students acquire knowledge, attitudes, and behaviors that promote SD should be increased.

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