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ORIGINAL PAPER

An effective intervention with a blended learning environment for improving cognitive learning and spiritual meaning

Emine Eren[1] · **İlbilge Dökme**[1]

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Abstract
According to cognitive and spiritual developmental theories, individuals construct and transcend their previous thought processes by incorporating more sophisticated ways of understanding the world as they progress through stages requiring efforts in different modes of thought. These theories focus on the importance of contextual variables in development and emphasize that these variables will spark a change in cognitive and spiritual development or awareness. We have investigated the effects of blended learning on cognitive learning and spiritual interpretations of science teacher candidates. The study with a quasi-experimental design had 54 science teacher candidates attending the science education department of a state university in Turkey. Our study showed that when learning Einstein's theory of special relativity, a blended learning environment affects students' cognitive learning positively. In the spiritual sense, too, significant results were found in favor of the blended learning group students. This effect that triggers spiritual change has been discussed in two contexts: "the effect embedded in the variable" and "indirect effect from the variable." If supported by further research, the results of this study suggest that the spiritual dimension can be incorporated into three domains of learning, namely cognitive, affective, and psychomotor.

Keywords Blended learning · Quasi-experimental design · Science teacher education · Science teacher candidates · Spiritual meaning

Blended learning is an effective and efficient learning method obtained by integrating the advantages of face-to-face and online learning environments (Ginns and Ellis 2007; Ng and Fergusson 2019). Russel Osguthorpe and Charles Graham (2003) state that blended learning environments may be preferred as they provide rich learning, easy access to

Lead editor: Michael J. Reiss

✉ Emine Eren
emneern1@gmail.com

İlbilge Dökme
ilbilgedokme@gazi.edu.tr

[1] Gazi Education School, Science Education Department, Gazi University, Ankara, Turkey

information, improved social interaction, good management of learning, low costs, and easy updates. Blended learning environments facilitate deep learning and improve student–student, student–teacher, and student–content interaction. In order to achieve these, effective blending is needed. In other words, both face-to-face and online environments should be well-designed, that is, various elements such as the topic to be learned, selected course materials, student characteristics, and access to learning environments should be carefully considered (Dini, Jaber, and Danahy 2019; Osguthorpe and Graham 2003). To illustrate, a course that requires higher-order thinking skills may be a good candidate for the use of an online environment (Jaber, Hufnagel and Radoff 2019; Singh 2003). Similarly, an online environment may be an advantage when teaching the higher-order cognitive skills in Bloom's taxonomy as these environments allow students to learn and repeat the topics at their own pace (Fernandes, Rodrigues and Ferreira 2020). Studies showing the positive effects of blended learning on deep (Abdul Razzak 2016; Young, Cleveland and Imms 2019) and holistic learning (Uhlig 2018; Vinnakota 2016) are especially worth noting as they may be related to the spiritual meaning findings of this study. Some of these studies have been in natural sciences which demand higher-order thinking skills.

In recent years, blended learning environments have become a focal point for researchers in physics education as well (Krasnova and Shurygin 2020; Roth, Schwingel and Rumpler 2019). These studies in the field of physics education are mostly related to the affective and cognitive learning outcomes of students in such environments. The most important factors that complicate the cognitive learning of physics topics include the difficulty of the content and the need for higher-order thinking skills (Redish 1994). In the science of physics, Newton's laws explain phenomena in the universe in which we live and which we can observe within the scope of classical physics, while quantum laws explain beings and phenomena that we cannot observe or perceive in the microuniverse within the scope of modern physics. Therefore, many topics and concepts in modern physics are not possible for students to experience directly in a science classroom. In this research, the topic of Einstein's theory of special relativity, in which the blended learning model is implemented, is one of these topics with no tangible experimental material to be used when learning and teaching. For example, the time dilation that occurs near the speed of light is not a concept that can be directly experienced; it can only be perceived through the use of mathematics and abstract principles. The main reasons why students have difficulty understanding the theory of special relativity are "they are used to classical physics paradigms," "their thought systems are more aligned with classical physics," "the topic of special relativity includes abstract thought experiments," and "the theory of special relativity paradigms is not easy to test" (Dökme and Koyunlu Ünlü 2019).

The most important motive for the present study has been our first assumption that blended learning environments would contribute to the deep and internalized learning of Einstein's theory of special relativity. The deep cognitive learning of science topics may encourage most people to think about the transcendent dimension of science topics (Bernstein 2000; Billingsley et al. 2018; Luckett 2019). Hence, the second assumption of the study is that such thoughts might trigger a change in people's spiritual interpretations. The Spiritual Meaning Scale (SMS) developed by Nathan Mascaro, David Rosen, and Leslie Morey (2004) was used as a measure of spiritual meaning in the study to find out whether there is a change in the spiritual interpretations of science teacher candidates or not with cognitive intervention. These authors constructed their scales on the following definition of measure of spiritual meaning. They define it the extent to which an individual believes that life or some force of which life is a function has a purpose, will, or way in which individuals participate, to supplement measures of personal meaning (mindfulness to a framework

or philosophy of life) and implicit meaning (engaging in activities and valuing attitudes that people typically report as comprising an ideally meaningful life) (Mascaro, Rosen and Morey 2004). As it is the crucial point about the nature of the scale, the direct quotation from the article is given below (Mascaro, Rosen and Morey 2004, p. 847):

> This definition captures the idea that many people have that they are participants in a meaning that transcends them. And inasmuch as we are all participants in, or parts of whatever is believed to be life's meaning, we each have particular purposes or functions to play in manifesting that meaning. This links the construct of spiritual meaning to one of calling, or of feeling called on by Life (or Tao, God, Being, or whatever Force it is in which one believes oneself to be a participant) to proceed in a certain direction.).

The present research is important not only because the blended learning method is used for teaching Einstein's theory of special relativity and the cognitive learning of teacher candidates, but also because it is the first investigation of its effects on spiritual meaning cited in the literature. This study contributes to the literature with the following research question guiding the study: "What are the effects of blended learning method on teacher candidates' cognitive learning and spiritual interpretations during teaching Einstein's theory of special relativity?" The Special Relativity Topic Achievement Test (SRTAT) as an indicator of cognitive learning and the Spiritual Meaning Scale (SMS) as a measure of spiritual meaning were used in the study. With these data collection tools, the sub-questions of the study to compare the two groups following blended and traditional learning are listed below:

- Is there a significant difference between the SRTAT post-test mean scores of blended and traditional learning groups?
- Is there a significant difference between the SRTAT pre-test mean scores and SRTAT post-test mean scores of students in the blended learning group?
- Is there a significant difference between the SRTAT pre-test mean scores and SRTAT post-test mean scores of students in the traditional learning group?
- Is there a significant difference between the SMS post-test mean scores of blended and traditional learning groups?
- Is there a significant difference between the SMS pre-test mean scores and SMS post-test mean scores of students in the blended learning group?
- Is there a significant difference between the SMS pre-test mean scores and SMS post-test mean scores of students in the traditional learning group?

Blended learning

Blended learning was defined as one of the 10 tendencies that emerged in 2003 from the information distribution industry as identified by the American Society for Training and Development. Blended learning has several definitions; however, in the most general sense, it is defined as the use of traditional learning environments (e.g., face-to-face) together with "e-Learning" (e.g., from Internet sources or other electronic devices). According to Diann Wilson and Ellen Smilanich (2005), blended learning is the use of the most appropriate in-class approach and the most effective and applicable educational methods together with online learning tools. Similarly, Osguthorpe and Graham (2003) defined blended learning as a coherent and balanced integration of face-to-face and online learning environments.

Harvi Singh and Chris Reed (2001) classified the components of a blended learning environment into three formats: synchronous physical, synchronous online, and asynchronous self-paced. Synchronous physical formats comprise teacher-led classrooms and lectures, hands-on laboratories and workshops, and school-guided field trips. Synchronous online formats comprise e-meetings, virtual classrooms, web seminars and broadcasts, tutoring, and instant messaging. Asynchronous self-paced formats comprise documents and webpages, computer/web-based educational modules, assessments, tests and surveys, simulations, electronic performance support systems, recorded live events, online learning communities, and discussion forums.

Margaret Driscoll (2002) has defined blended learning as four different processes:

- combining and using web-based technologies (live virtual classroom, self-learning, collaborative learning, and streaming video or text) to accomplish educational goals;
- combining various pedagogical perspectives (constructivist, behaviorist, or cognitive) to reach optimal learning outcomes with/without using instructional technologies;
- combining any form of instructional technologies (videotape, CD-ROM, web-based learning, movies) with teacher-led face-to-face education; or
- combining instructional technologies with actual job tasks to create a harmonious interaction of learning and working.

Based on these definitions, it is difficult to propose that the literature presents a clear-cut definition of blended learning or explains how to blend various methods. At this point, a course is needed in which the blended learning environment is the determining factor. It is not possible to recommend a specific application; however, emphasis can be put on the dimensions that are necessary to consider while blending that are in line with the course content and objectives.

Badrul Khan (2005) proposed eight dimensions that should be considered while designing an effectively blended environment. The institutional dimension refers to the need to prepare students and administrators for the organization of the method and to stress that the method must be applicable to the institution where blended learning is conducted. The pedagogical dimension points out that the learning environment should be suitable for subject content goals and includes the design of the instructional technologies used. The technologies used for blending to be accessible, usable, and supportive for the learning content are addressed in the technological dimension. The interface design includes the dimension of the usefulness of all elements to be used in blended learning and their adaptability to different situations. The evaluation dimension includes both the evaluation of learning and blending and explains the selection of appropriate evaluation techniques. The management dimension contains the management of learning or concepts, such as infrastructure and logistics evaluation. Resource support includes the organization and accessibility of topic contents that are used online or offline in blended learning environments. The ethical dimension includes determining the topic contents to be used while designing the blended learning method, considering ethical concerns such as the equality of opportunity and cultural differences.

Elaine Allen and Jeff Seaman (2015) have suggested that the percentage to be used to blend traditional face-to-face courses with online courses should be between 30 and 80%. If the percentage of the course conducted online is $< 30\%$, the course can be considered as face-to-face. If the ratio is $> 80\%$, it can be considered an online course. In blended or hybrid learning environments, the percentage of the contents covered by online and face-to-face environments can vary. The most preferred situation for blended learning is that

the percentages of face-to-face and online courses are equal to each other (Osguthorpe and Graham 2003; Singh 2003).

Spirituality in cognitive learning perceptive

Spirituality, which has been a growing focus across disciplines over the last three decades, is not considered in this study as an invalid way of knowing that cannot be proven, unlike science (Carrington 2014; Hodge 2009). Cognitive thinking in the capacity of transcendence represents a certain peak in human cognitive and emotional development as a sign of access to thinking and feeling associated with wisdom (Hogan 2009; Pascual-Leone 2000).

Cognitive development in Jean Piaget's theory (Lawson 2009; Piaget 1965) has four different stages: sensorimotor (from birth to 2 years), preoperational (ages 2 to 7), concrete operational (ages 7 to 11), formal operational (ages 12 and up). Cartwright (2001), in her study titled "Cognitive developmental theory and spiritual development," has reviewed some representative theories of spiritual development and highlighted the important features of these theories to facilitate a discussion of potential connections between spiritual and cognitive development in adulthood. While some theories on spiritual development have focused on "development of autonomy and self-awareness (Conn, 1993; Fowler, 1981), and the development of moral understanding (Fowler, 1981; Mitchell, 1988)," "some theories (Elkind, 1997; Fleck, Ballard and Reilly 1975) have showed correlation between children's understanding of religious or spiritual concepts and Piagetian stages of cognitive development" (Cartwright 2001, p. 215).

Individuals at Piaget's sensorimotor stage have no awareness of an abstract spiritual level of reality, "because for infants are bound to their own perceptual and sensory realities and are not able to differentiate the self from the other, the only 'knowable' information is what is directly detectable by their sensory or motor experience" (Cartwright 2001, p. 217).

According to Piaget, individuals at the preoperational stage start reasoning, even if not within the framework of logic principles; however, sorting, classification, and preservation skills have not yet developed effectively (Lawson 2009; Piaget 1972). Children at this stage begin to contemplate their relation to a higher power without logical explanation, only at a mythical level, and "may tacitly accept that there is 'something out there' beyond the self that defies explanation" (Cartwright 2001, p. 217). "As individuals make the transition to concrete operational thinking, they begin to incorporate conventional explanations into their spiritual understanding and to devalue their subjective experience (Labouvie-Vief, 1990)" (Cartwright 2001, p. 218).

During Piaget's concrete operational stage, children with normal mental development in the 7–11 age range begin to use simple sequencing, classification, and conservation skills. For example, children can line up items of different lengths from short to long; they can group pens of different colors according to their color and can reason using their conservation skills (Lawson 2009; Piaget 1972). For example, they can reasonably state that by pouring water from a narrow glass into a wide glass of the same length, the amount will not change even though its height decreases. This is a simple conservation law. Individuals at this stage may spiritually seek a logical explanation or concrete means for their relationship to a higher power, being dissatisfied with their preoperational understanding (Cartwright 2001). Their logical explanations often form socially transmitted traditions, values, or beliefs from the norm of social reciprocity (Cartwright 2001).

According to Piaget's cognitive development theory, individuals can move into the formal operational stage from the concrete operational stage after the age of 11. This stage indicates that individuals have reached the maturity to perceive abstract concepts and to carry out more complex mental activities (Piaget 1965). Every child with normal mental development catches the path from concrete to abstract after the age of 11. This is a gateway to the abstract world, and behind this gateway, there is a path from sensations to perceptions, from perceptions to concepts, from concepts to judgments. The reasoning skills that individuals can learn and develop in this stage are "determining and controlling variables by hypothetical thinking," "probabilistic thinking," "combinational thinking," "relational thinking," and "proportional thinking" (Adey, Shayer and Yates 2001).

Individuals at the formal operational stage can "begin to consider the abstract principles that govern the behaviors" they experienced spiritually in the concrete operational stage (Cartwright 2001, p. 218). As "young adults and adolescents at this stage tend to value universal laws and are often tied to concrete traditions (Labouvie-Vief, 1990; Ormer & Fowler, 1993) … they may still be constrained by the conventional social norm of reciprocity that governs their understanding at the concrete operational level" (Cartwright, 2001, p. 218). Although their thinking has "shifted to abstract principles," these individuals, who "still view their relationship with the" high power as dependent "on their own behavior," cannot progress their spiritual thinking unless they examine or critically evaluate the "culturally transmitted conventions in which they are embedded (Ormer & Fowler, 1993)" (Cartwright 2001, p. 218).

As detailed in the "studies of Conn (1993), Fowler (1981) and Sinnott (1998), many varied relationships between self, others, and an external Power are all vital components of spirituality" (Cartwright 2001, p. 218). According to cognitive and spiritual developmental theories, individuals construct and transcend "their previous thought processes by incorporating more sophisticated ways of understanding the world" as they progress through stages requiring efforts in "different modes of thought" (Cartwright 2001, pp. 216–217). "The transcendence of previous modes of thought that is characteristic of cognitive development provides a formal mechanism by which spiritual development may also occur" (Cartwright 2001, p. 217). Individuals' spiritual progress is claimed to proceed through stages parallel to the original Piagetian stages (Fleck et al. 1975). However, "as suggested by Sinnott (1998), individuals need to have thought processes beyond the formal operational mode of reasoning to develop an understanding of their relationship with an External Power" (Cartwright 2001, p. 217). The spiritual understanding of an individual at each stage transcends their prior understanding by incorporating additional cognitive skills; however, "their understanding is also constrained by their current stage of cognitive development" (Cartwright 2001, p. 217). Spiritual development stages are not limited to certain age ranges as in Piaget developmental stages, and stage transitions can occur at any point in a person's lifetime, depending on individual experiences, awareness, and motivation (Cartwright 2001, p. 217). Theories of spiritual development suggest that individuals' subjective experiences within contextual variables stimulate the process of transcendence "by forcing individuals to move beyond prior cognitive processes and engage with new modes of thought" (Cartwright 2001, p. 217).

Methods

Our study was designed as a pre-test/post-test with comparison group within the scope of quasi-experimental research (Table 1). Quasi-experiments are most likely to be conducted in education studies in which random assignment is difficult or impossible. They are

Table 1 Symbolic design of the study

Group	Pre-test	Method	Post-test
1	$O_{1.1}$	Blended learning	$O_{1.2}$
2	$O_{2.1}$	Traditional learning	$O_{2.2}$

Table 2 Results of the Mann–Whitney *U* test on the blended and traditional learning groups' SRTAT and SMS pre-test scores

	N	Sum of Ranks	*U*	*p*
SRTAT				
Blended	28	683.5	277.5	0.112
Traditional	26	801.5		
SMS				
Blended	28	780	354	0.862
Traditional	26	705		

SRTAT the Special Relativity Topic Achievement Test; *SMS* Spiritual Meaning Scale

usually conducted to evaluate the effectiveness of a treatment as an educational intervention (Cook and Campbell 1979). In a quasi-experimental design, the research substitutes statistical "controls" for the absence of physical control of the experimental situation.

Participants

The study was conducted on second-year students from the science education department at the educational faculty of a public university in Turkey. The blended learning group consisted of 28 students, and the traditional group contained 26.

The data obtained using SRTAT and SMS as a pre-test are provided in Table 2.

The results of Mann–Whitney *U* test indicated no significant difference between the SRTAT and SMS pre-test scores of blended and traditional learning groups ($p > 0.05$). Here, Mann–Whitney U test was used because the distribution in the groups was not normal.

Data collection

A cognitive achievement test developed by Gülnur Önsal (2016) for Einstein's theory of special relativity was used in the study as an indicator of cognitive learning. Önsal (2016) found the Cronbach's alpha reliability coefficient of the scale to be 0.74. The cognitive achievement test comprising 27 multiple-choice questions was used to measure cognitive thinking skills related to the consequences of special relativity (time dilation, length contraction, and mass variation), observation frameworks and transformation factors, the changes in energy and mass with respect to speed, and the mass–energy relationship.

SMS was developed by Mascaro, Rosen and Morey (2004) and adapted into the participants' language by Rukiye Şahin, Yusuf Sarıkaya, and Mustafa Baloğlu (2017). The scale involves a single dimension that explains 41% of the total variation. SMS comprises 13 five-point Likert-type items ranging from completely disagree (0) to completely agree (5). The minimum score is 14 and the maximum is 70. The Cronbach's alpha reliability

coefficient of the scale was noted as 0.81; however, we calculated the Cronbach's alpha coefficient again and found it to be 0.82. The SMS aims to assess a single construct related to individuals' perceiving themselves as participants in the purpose of some transcendent Life Force and deriving meaning from such participation (Mascaro, Rosen and Morey 2004). Within this assessment purpose, in SMS, there are items about the individual's beliefs on existence, spiritual bonds, whether there is a point in existence, and whether our existence on earth is re-established.

Implementation

Implementation within the scope of this study was conducted with 54 second-year undergraduate students and lasted four weeks. SRTAT and SMS were first applied to blended and traditional learning groups as a pre-test. The theory of special relativity was then taught to blended and traditional learning groups for four weeks. The participants in both groups performed SRTAT and SMS as the post-test at the end of the course. Implementation course hours and topics in blended and traditional learning groups are provided in Table 3.

Students in the blended learning group were informed about the blended learning method before implementation. The method was then applied in two stages—within the virtual environment and face-to-face. The virtual environment was accessed through Google Classroom. Prospective teachers were instructed on how to use this platform before implementation. Videos selected and created in line with the course content were presented to prospective teachers in the virtual classroom, and the course contents were shared by the researcher. In this environment, the students accessed the researcher's shared posts on special relativity without going through face-to-face teaching. The virtual classroom environment was designed to facilitate student–researcher interaction and student–student interaction. It allowed students and the researcher to share, comment, tag or message relevant videos, movies, documentaries, and articles, like other social networks. Each week, the researcher shared videos and other tools on special relativity topics and assigned related homework to the students. The students were asked to complete this homework until the next task; therefore, the students could access this environment at any time and place. The students were encouraged to participate in the virtual environment, comment, and share. The link list of the videos, documents, and other tools shared by the researcher (implementer) each week, and materials and methods/techniques used in the face-to-face classroom is provided in Tables 4 and 5.

The most important difference between the implementation in the blended learning group and the traditional group was that students in the blended learning group had

Table 3 Topics learned in the blended and traditional learning group and course hours

Topics	Duration
Introduction to Special Relativity, Reference Systems	2 course hours
Special Relativity Principals and Lorentz Transformation	2 course hours
Time Dilation and Length Contraction	2 course hours
Relativistic Mass–Energy and Momentum	2 course hours
Total	8 course hours

prior knowledge when they came to the classroom because of their work within the virtual environment. For example, students in the blended group who had been tasked to learn the theoretical details of Einstein's time dilation would already bring ideas to a real classroom environment based on a movie/documentary they had watched or an article they had read within the virtual environment. The researcher conducted the teaching within the scope of the students' engagement within the virtual environment to ensure readiness. Teaching in the real class was deductive and the students were allowed to take notes and resolve problems related to the topic to comprehend mathematical relationships.

Related to the content of links shared within the virtual environment, some questions were posed to the students to discuss with each other and the researcher. These questions included "what are your thoughts about ether?", "is it actually the substance that is known as the lost mass of the universe?", "what is time?", "what do the past, future, and now mean to you?", "is time absolute or is it a result of human perception?", and "is travel in time possible?". It was determined that 28 students in the blended learning group logged into the links and participated in the discussions about the questions, and three students shared films, documentaries, etc.

The special relativity topic was taught to the traditional learning group each week during regular course hours using the materials, methods, and techniques specified in Table 6. The instruction, as in the blended learning group's face-to-face method, was deductive and the students were encouraged to take notes and resolve problems related to the topic to comprehend the mathematical relationships. In addition, the democratic climate of the classroom encouraged the students to share their opinions on the topics. The list of the links in the online environment activated by the teacher in the blended learning group was given to the traditional group students as homework. Students were asked to enter these links, read related articles, and watch related videos. Few students received feedback from classroom discussions about the content of the links.

One particular concern in the present study was that the first author as a researcher was also the instructor of blended and traditional learning groups; thus, she might have affected the implementation by manipulating the participants to accept her biased expectations. However, having a single instructor also offered the advantage of eliminating the peripheral variables on students' cognitive learning and spiritual meaning. The researcher as an instructor was able to keep all conditions constant in both blended and traditional learning groups during the face-to-face course, except for the virtual learning environment in the blended learning group.

Data analysis

The data obtained were analyzed using SPSS 22 considering $p = 0.05$ as the level of significance. Considering the numbers of participants, the normality of the data was tested using the Shapiro–Wilk test, which was used because the sample size was < 50 (Razali and Wah 2011). Results of the normality analysis of the intergroup post-test data for the data collection tools used are presented in Table 7.

Based on these results, the analysis type used for each data collection tool is given in Table 8.

Table 4 Summary of the implementation in the blended learning group

Topics	Environment	Date	Material (shared by researcher)	Approach/method and technique
Introduction to Special Relativity and Reference Systems	Virtual Course	April 8–11, 2018	https://www.youtube.com/watch?v=KZDEoQyC-lE https://www.youtube.com/watch?v=fYEn_Fg03RQ https://www.kuark.org/2015/06/uzay-zaman-nedir/ https://www.kuark.org/2013/12/einstein-ozel-gorelilik-ilkesi/	Indirect guided approach/Exploratory methods, Question–answer techniques
	Face-to-face course	April 11, 2018; 80 min	Books: *Concepts of Modern Physics* (Beiser, 2002), *Physics For Scientists and Engineers with Modern Physics* (Beichner, Jewett and Serway, 2000)	Direct Approach/Expository methods, Question–answer techniques
Special Relativity Principals and Lorentz Transformation	Virtual Course	April 13–18, 2018	https://www.kuark.org/2014/01/lorentz-daralmasi-uzunluk-buzulmesi/	Indirect guided approach/Exploratory methods, Question–answer techniques
	Face-to-face course	April 18, 2018; 80 min	Books: *Concepts of Modern Physics* (Beiser, 2002), *Physics For Scientists and Engineers with Modern Physics* (Beichner, Jewett and Serway, 2000)	Direct Approach/Expository methods, Question–answer techniques
Time Dilation and Length Contraction	Virtual Course	April 21–25, 2018	https://www.kuark.org/2017/07/gelecek-gecmisi-etkileyebilir-mi/ https://www.youtube.com/watch?v=ZNJ9GRkmeY4 https://www.youtube.com/watch?v=JMdO5KyjwAw	Indirect guided approach/Exploratory methods, Question–answer techniques
	Face-to-face course	April 25, 2018; 80 min	Books: *Concepts of Modern Physics* (Beiser, 2002), *Physics For Scientists and Engineers with Modern Physics* (Beichner, Jewett and Serway, 2000)	Direct Approach/Expository methods, Question–answer techniques

Table 4 (continued)

Topics	Environment	Date	Material (shared by researcher)	Approach/method and technique
Relativistic Mass–Energy and Momentum	Virtual Course	April 28–May 2, 2018	https://www.youtube.com/watch?v=XiR5JPHtuuQ https://www.kuark.org/2014/01/ve-kutle-enerji-denkligi-emc2/ http://www.kuark.org/2014/01/evrenin-hiz-limiti-isik-hizi/	Indirect guided approach/Exploratory methods, Question–answer techniques
	Face-to-face course	May 2, 2018; 80 min	Books: *Concepts of Modern Physics* (Beiser, 2002), *Physics For Scientists and Engineers with Modern Physics* (Beichner, Jewett and Serway, 2000)	Direct Approach/Expository methods, Question–answer techniques

Table 5 Links shared in the virtual environment

Links shared by researcher	Link content
https://www.youtube.com/watch?v=KZDEoQyC-lE	A video explaining the Michelson-Morley experiment and the results of this experiment
https://www.youtube.com/watch?v=fYEn_Fg03RQ	A video explaining what the reference system means in physics at the entry-level
https://www.kuark.org/2015/06/uzay-zaman-nedir/	An article explaining the concepts of space and time shared on a quark science community website published by a group of young researchers
https://www.kuark.org/2013/12/einsteinin-ozel-gorelilik-ilkesi/	An article describing the emergence of Einstein's special relativity principle and basic postulates
https://www.kuark.org/2014/01/lorentz-daralmasi-uzunluk-buzulmesi/	A video explaining the mathematical expressions of Lorentz transformations and why length contracts at speeds close to the speed of light
https://www.kuark.org/2017/07/gelecek-gecmisi-etkileyebilir-mi/	From the point of view of quantum mechanics; an article describing the concepts of time in the past, present, and future
https://www.youtube.com/watch?v=ZNJ9GRkmeY4	A video explaining the twin paradox that describes time dilation related to the theory of special relativity special theory of relativity
https://www.youtube.com/watch?v=JMdO5KyjwAw	A video called *Will we able to teleport?*, prepared by Sajan Saini for Ted-Ed, that explains, with animations, the speed of light and teleportation
https://www.youtube.com/watch?v=XiR5JPHtuuQ	A video in which the mathematical expressions showing that mass increases as a result of movement at speeds close to the speed of light are explained in an understandable form
https://www.kuark.org/2014/01/ve-kutle-enerji-denkligi-emc2/	An article explaining how the formula $E=mc^2$ came about and what this formula means
http://www.kuark.org/2014/01/evrenin-hiz-limiti-isik-hizi/	An article explaining why the speed of light is considered the speed limit in the universe
Links shared by students	
https://youtu.be/MaHRqTz5nn8	A section from the movie *Einstein and Eddington*, discussing special relativity
https://youtu.be/qcNaPevSGvQ	Documentary film *Einstein's Big idea:* $E=mc^2$
https://youtu.be/cOw5wX402S8	A TV program where the theory of relativity is discussed from a philosophical perspective

Results

The first sub-problem of the study was related to determining whether there is a significant difference between the SRTAT post-test scores of the groups in which the blended and traditional learning methods were used. The results of the analyses of blended and traditional learning group SRTAT scores are presented in Table 9. To test the hypothesis on the first sub-problem, an independent samples t test was applied to the SRTAT post-test scores of blended and traditional learning groups.

The difference between the scores of the blended and traditional learning groups on the SRTAT post-test was significant ($p < 0.05$), which indicates that the blended learning environment positively affects the cognitive learning achievement of the students

Table 6 Implementation process in the traditional learning group

Topics	Environment	Date	Material	Method and technique
Introduction to Special Relativity and Reference Systems	Real class	April 12, 2018, 80 min	Books: *Concepts of Modern Physics* (Beiser, 2002), *Physics For Scientists and Engineers with Modern Physics* (Beichner, Jewett and Serway, 2000)	Expository Approaches and methods, Question–answer techniques
Special Relativity Principals and Lorentz Transformation	Real class	April 19, 2018, 80 min	Books: Concepts of Modern Physics (Beiser, 2002), Physics For Scientists and Engineers with Modern Physics (Beichner, Jewett and Serway, 2000)	Expository Approaches and methods, Question–answer techniques
Time Dilation and Length Contraction	Real class	April 26, 2018, 80 min	Books: Concepts of Modern Physics (Beiser, 2002), Physics For Scientists and Engineers with Modern Physics (Beichner, Jewett and Serway, 2000)	Expository Approaches and methods, Question–answer techniques
Relativist Mass–Energy and Momentum	Real class	May 3, 2018, 80 min	Books: Concepts of Modern Physics (Beiser, 2002), Physics For Scientists and Engineers with Modern Physics (Beichner, Jewett and Serway, 2000)	Expository Approaches and methods, Question–answer techniques

Table 7 Results of the Shapiro–Wilk analysis on the individual pre-test and post-test scores of the blended and traditional learning groups

Group	SRTAT pre-test	SRTAT post-test	SMS pre-test	SMS post-test
Blended (*Z*)	0.778	0.947	0.966	0.919
p	0.000	0.138	0.508	0.037
Traditional (*Z*)	0.793	0.955	0.855	0.941
p	0.000	0.302	0.002	0.291

Table 8 Tests used for the analysis of between groups and in-groups for data the blended and traditional learning groups

Comparison between groups		Group	Normality of the data	Comparison in-group
Mann–Whitney U-test	Blend.-SRTAT-pre Trad.-SRTAT-pre	Blended SRTAT pre-test	Not normal	Wilcoxon Signed-Ranks Test
		Blended SRTAT post-test	Normal	
t-test	Blend.-SRTAT-post Trad.-SRTAT-post	Blended SMS pre-test	Normal	Wilcoxon Signed-Ranks Test
		Blended SMS post-test	Not normal	
Mann–Whitney U-test	Blend.-SMS-pre Trad.-SMS-pre	Traditional SRTAT pre-test	Not normal	Wilcoxon Signed-Ranks Test
		Traditional SRTAT post-test	Normal	
Mann–Whitney U-test	Blend.- SMS-post Trad.- SMS-post	Traditional SMS pre-test	Not normal	Wilcoxon Signed-Ranks Test
		Traditional SMS post-test	Normal	

Table 9 Results of the independent samples *t* test of the SRTAT post-test mean scores of the blended and traditional learning groups

Group	*N*	$\overline{X}$	SD	*df*	*t*	*p*	η^2
Blended	28	0.37	0.099	52	6.20	0.00	0.42
Traditional	26	0.19	0.114				

studying special relativity. The r value, which was calculated to determine the dependence of this effect on the learning environment, was $\eta^2 = 0.42$, which shows that 42% of the variance observed in the mean scores on the SRTAT pre-test and post-test depends on blended learning, and that r is medium for the significance between the learning environment and achievement.

The second sub-problem of the study was related to determining whether there is a significant difference between the scores of the students in the blended learning group on SRTAT pre-test and post-test. To test the hypothesis on the second sub-problem, a Wilcoxon signed-ranks test was applied to the achievement test data of the students in the blended learning group before and after the implementation; the results are presented in Table 10.

As Table 10 shows, the results revealed that blended learning positively affected the students' cognitive learning achievement on the topic of special relativity. That is, the cognitive learning achievement of the students in the blended learning group was significantly higher in the post-test than in the pre-test ($p < 0.05$). In this analysis, $r = 0.61$ indicated that the learning environment had a substantial effect on cognitive learning.

The third sub-problem of the study was related to determining whether there is a significant difference between the scores of the students in the traditional learning group on the SRTAT pre-test and post-test. To test this hypothesis, a Wilcoxon signed-ranks test was applied to the achievement test data of these students before and after implementation; the results are presented in Table 11.

As Table 11 shows, no significant difference was found among traditional learning students' pre-test and post-test SRTAT mean scores ($p > 0.05$), which indicated that the traditional learning environment had no effect on achievement.

The fourth sub-problem of the study was related to determining whether there is a significant difference between the scores of blended and traditional learning groups on the SMS post-test. To test the hypothesis regarding the fourth sub-problem, a Mann–Whitney U test was applied to the post-test SMS data on blended and traditional learning groups; the results are presented in Table 12.

As indicated in the table, there was a significant difference between the SMS post-test scores of the blended and traditional learning groups ($p < 0.05$), which shows that the level of students' spiritual interpretation in the blended learning environment was higher. The significant difference was calculated as $r = 0.092$, which means that blended learning had a small effect on students' spiritual interpretation.

The fifth sub-problem of the study was related to determining whether there is a significant difference between the mean scores of the students in the blended learning group on the SMS pre-test and post-test. To test the hypothesis regarding the fifth sub-problem, a Wilcoxon signed-ranks test was applied to the pre-test and post-test SMS data on the students in the blended learning group; the results are presented in Table 13.

Table 10 Results of the Wilcoxon signed-rank test on the SRTAT pre-test and post-test data of the blended learning group

Pre-test–post-test	*n*	Sum of ranks	*z*	*p*	*r*
Negative Rank	0	0.00	−4.546	0.00	0.61
Positive Rank	27	378			
Equal	1	–			

Table 11 Results of the Wilcoxon signed-ranks test on the SRTAT pre-test and post-test data on the traditional learning group

Pre-test–post-test	*n*	Sum of ranks	*z*	*p*
Negative Rank	8	115	−1.567	0.117
Positive Rank	18	273		
Equal	0	–		

Table 12 Results of the Mann–Whitney U test on the SMS post-test data on the blended and traditional learning groups

Group	*N*	Sum of Ranks	*U*	*p*	***r***
Blended	28	897.5	236.5	0.027	0.092
Traditional	26	587.5			

Table 13 Results of the Wilcoxon signed-ranks test on the SMS pre-test and post-test data on the students in the blended learning group

Pre-test–post-test	*n*	Sum of Ranks	*z*	*p*	***r***
Negative Rank	7	61	2.34	0.019	0.31
Positive Rank	16	251			
Equal	5	–			

Table 14 Results of the Wilcoxon signed-ranks test on the SMS pre-test and post-test data on the students in the traditional learning group

Pre-test–post-test	*n*	Sum of Ranks	*z*	*p*
Negative Rank	13	176.5	0.758	0.449
Positive Rank	11	123.5		
Equal	2	–		

As Table 13 shows, there is a significant difference between the SMS data on the students in the blended learning group before and after the implementation ($p < 0.05$). The calculated r value for this significant difference, $r = 0.31$, showed that blended learning had a medium-sized effect.

The sixth sub-problem of the study was related to determining whether there is a significant difference between the scores of the students in the traditional learning group on the SMS pre-test and post-test. To test the hypothesis regarding the sixth sub-problem, a Wilcoxon signed-ranks test was applied to the pre-test and post-test SMS data on the students in the traditional learning group; the results are presented in Table 14.

As Table 14 shows, there was no significant difference between the SMS data for the traditional learning group before and after implementation ($p > 0.05$).

Discussion

It was found from the quasi-experimental study that when learning about Einstein's theory of special relativity, the blended learning environment affected students' cognitive learning positively. In spiritual meaning, too, significant results were found in favor of the blended learning group students.

Studies in the literature focusing on the reasons for the benefits of blended learning on cognition have shown that these environments increase students' *readiness* (Ginns and Ellis 2007) and motivation and conditioning levels (Schober and Keller 2012; Van Der Merwe 2007). Another important reason in our research for effective cognitive reflections in students was online interaction (Wilson and Smilanich 2005). The list of the links in the online environment activated by the teacher in the blended learning group was given to the traditional group students as homework. However, reflections comparable to those obtained from blended group students were not observed in this group. For this reason, effective student reflections in our study originate from the virtual environment and the interaction of the students in this environment with each other and with the teacher. In this environment, students shared the posts that would encourage and appreciate each other, just like on Facebook and Instagram. This situation enabled them to search for both deep learning and enjoyment.

After the study, the SMS post-test findings showed that the spiritual interpretations of the students in the blended learning environment differed significantly from those of the students in the traditional learning environment. In addition, SMS post-test scores of the blended learning group were significantly higher than their pre-test scores. Theories of cognitive and spiritual development focus on the importance of contextual variables in development and emphasize that these variables will spark a change in cognitive and spiritual development or awareness. The variable that aids cognitive and spiritual development of the students in this study is blended learning practices. Although many studies revealing the positive effects of the blended learning method on cognitive learning can be clearly found in the literature, there is a lack of sources that directly document a relationship between blended learning and spiritual reflections. Therefore, more research findings may be needed to generalize the relationship between blended learning and spiritual reflections. However, the effect that triggers this spiritual change has been discussed here in two contexts: "the effect embedded in the variable" and "indirect effect from the variable." A representation of the research findings for discussion is illustrated in Fig. 1.

The effect embedded in variable is the knowledge content of blended learning practices for Einstein's theory of special relativity. The theory of special relativity requires higher-order thinking skills and is a rather abstract and hard-to-understand topic in physics. At the same time, it requires students to change their knowledge and perceptions of time, space, mass, and energy which they acquire over years, drawing on classical physics (Dökme and Koyunlu Ünlü 2019). The different meanings of the concept of "time" in classical and modern physics can be explained as follows: One of the main assumptions of Newtonian mechanics is that time is the same for all observations; that is, time is "absolute." According to Einstein, the time elapse between two events depends on the reference system by which they are measured. For example, the time that elapses between the ticks of a watch moving at a speed close to that of light and the time that elapses between the ticks of a watch at rest are different. The "twin paradox" in modern physics is the most popular example of this. The time dimension of my twin that travels close to the speed of light is different from mine. In my twin's reference frame, the time, compared to mine, is dilated. That is, the time elapsed between the ticks of my twin's watch is longer than that of my watch; for example, if 30 years have passed according to me, this period might be only 10 years for my twin and, thus, my twin becomes younger than me, as I age.

It is thought that during blended learning practices, students were able to enrich their existing meaning of time, space, mass, and energy which they had previously gained within the scope of classical physics with the help of the online videos and articles on the theory of special relativity. For example, it was seen from their online posts that those who complete the cognitive learning of Einstein's theory of special relativity with blended learning

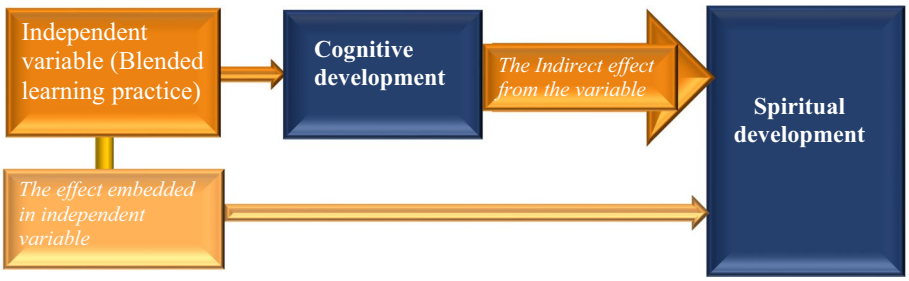

Fig. 1 Representation of research findings

started to ask themselves questions such as "What is time?", "Does the universe have a beginning and an end?", "What is the aim of existence?", "What is the meaning of life?". These questions were considered a sign of their deep learning (Berger, Eylon and Bagno 2008; Chandra and Watters 2012).

Knowledge in the natural sciences is acquired through systematic construction from the concepts of everyday life to higher-order concepts requiring deep learning. As a powerful knowledge, the upper boundary of this knowledge provides epistemological or spiritual access by bringing big questions with it (Billingsley et al. 2019; Luckett 2019). This is analyzed in detail as a semantic density and gravity in Bernstein's theoretical framework. When evaluated from a subjective point of view, this analysis of knowledge has revealed the concept of epistemic insight for the knower. Proceeding from Bernstein's concept of classification and framing (Bernstein 1999), epistemic insight arises from frames and bridges that require thinking deeply in one discipline and making the connection between different disciplines. The core idea of Bernstein's theory is that modernity has not resulted in a decline in the sacred, but rather its abstractions beyond knowledge as a means to encode and frame new meanings (Bernstein 2000; Hodgkins 2014; Wheelahan 2006). In other words, knowledge transmission remains embedded in a fundamental and universal cosmological relationship that exists between the esoteric and the mundane (Hodgkins 2014). The distinction between esoteric and mundane knowledge is the means through which society navigates between the concerns of everyday life (the mundane) and a "transcendental" realm (Bernstein 2000; Wheelahan 2006).

The indirect effect from the variable is related to progress in the cognitive development process, which is due to deep learning with blended learning practices. In other words, this finding shows that deep cognitive learning in modern physics contributes also to spiritual development. Despite the lack of sources in the literature that directly document such a relationship between blended learning and spiritual reflections, there are many studies—mostly in children's spirituality (De Souza and Hyde 2007; Solomon 2003; Solomon and Hunter, 2002)—which argue that learning has a spiritual dimension in addition to its cognitive and affective dimensions (Bin Yussof and Bakar 2016; Chastain 2017; Mudge 2009). In fact, according to developmental psychologists who suggest the spiritual dimension of learning as well as the cognitive and affective dimension, the effects of blended learning on spiritual meaning that also emerged in this study have cognitive sources (Harris 2007; Scheindlin 2003).

The spiritual dimension in higher-level learning is one dimension beyond the cognitive and affective (Buchanan and Hyde 2008; Scheindlin 2003; Solomon 2003). Recently, some scholars have started to conceptualize the terms "spirituality" and "science" as distinct but overlapping constructs (Solomon 2003; Watts 2019). Overlapping constructs of science and spirituality actually suggest that there is an interface between science and spirituality. Hodge and Derezotes (2008) point out two themes related to the concept of spirituality among a wide array of themes used to flesh out this conceptual skeleton (Canda and Furman 1999; Hodge and McGrew 2006). First, various understandings of spirituality typically assume the existence of a transcendent reality in a nontemporal dimension (Gallup and Jones 2000; Harlos 2000; Hodge and Derezotes 2008). Secondly, spirituality connotes the idea of relationship, connection, or even union with the nontemporal dimension (Hodge 2005; Hodge and Derezotes 2008). It is possible that this transcendent dimension is encountered in a personal, existential, subjective manner (Cowley and Derezotes 1994; Hodge and Derezotes 2008).

Deep and holistic learning experiences that provide spiritual enlightenment can be defined here as the spiritual dimension of learning rooted in cognitive origins. Peter Mudge

(2009) has pointed out two complementary ways of "knowing" in spirituality and education. These are expressed as follows: Kataphatic knowing acknowledges what is visible, imaged, apparent, and quantifiable in the material world; and apophatic knowing points to what is beyond the world and image, to what is invisible, mysterious, ineffable, unmanifest, and unquantifiable in and beyond the material world (Mudge 2009). Mudge also referred to the strategies of questioning, guessing, hypothesizing, predicting, contemplating, and lateral thinking for apophatic knowing in the classroom context as more complex and challenging operations. Those strategies require higher thinking skills in science education, such as reasoning, and creative, critical, and reflective thinking.

The findings of this research, and the above discussions, suggest that due to the nature of knowledge in science, the spiritual dimension can be incorporated into the three domains of learning – cognitive, affective, and psychomotor. In the cognitive dimension of learning, the reasons for any natural phenomenon are investigated and learned within the scope of determinism. In the spiritual dimension of learning, any natural phenomenon is investigated within the scope of finalism (for what purpose does any natural phenomena happen?). To illustrate, the reasons for the Earth's motion around the Sun may be explained with a cause–effect relationship with the Laws of Newton and Galileo. This is the cognitive dimension of learning. However, questions regarding what wills the motion of the Earth, and whether it has a beginning or end may bring spiritual expansion. This expansion may be philosophical or spiritual, but the fact that it can take place upon deep and holistic learning (cognition) has been supported with the findings of this study.

In fact, if human existence is taken as a whole, knowledge and cognition nurture the human mind, while art and esthetics nurture the emotions affectively. Contemplating existence, life, and the soul, and engaging in moral and spiritual activities all nurture the spiritual side of humans.

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Emine Eren is a doctoral student in science education at Gazi University and works as a science teacher. She received her Bachelors's Degree (2014) and Master's Degree (2019) in Science Education from Gazi University. Her research interests include learning environments, and science teacher training.

İlbilge Dökme is a Professor at the Department of Science Education, Gazi University, Ankara, Turkey. She received her Bachelor's Degree (1990) and Master's Degree (1995) in Physics Education from Gazi University, and received her Doctoral Degree (2002) in Semiconductor Physics. She began her career as a science and physics teacher in a public school after completing her undergraduate education. Seven years later, she worked as a member in the commissions of the Board of Education at the Ministry of National Education, where she took part in writing science textbooks, examining science and physics textbooks, and developing science and physics curriculum. She has been working as a faculty member at the Department of Science Education, Gazi University since 2003. She has 30 years of experience teaching physics to middle school, high school, and college students. She has many publications in distinguished international and national journals in the fields of Science Education and Physics.