JOURNAL OF BALTIC SCIENCE EDUCATION

ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

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INCREASING STUDENTS' EMPATHY LEVELS IN SCIENCE EDUCATION: A THEMATIC REVIEW

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Abstract. *K-12 education as an enterprise always has two main aims; to teach basic skills and knowledge and to cultivate moral citizenry. There is substantial evidence that empathy can promote morality and character development through education. To shed light on what has been done and to identify the pathways already established, a thematic review of research focused on empathy development in K-12 science education has been conducted. A systematic examination of literature published before January 2024 resulted in 28 publications being analyzed in terms of their general characteristics and the specifics of the designed interventions. Results show that educational interventions can improve empathy skills; these studies use collaborative learning environments, take 3-10 weeks to implement, and the most preferred strategy is recognizing different perspectives of a given situation with reflective exercises. All of the studies reviewed positively affected students' affective and cognitive domains. For future research, more interventions designed to improve empathy skills in parallel with the science curriculum are proposed to supply teachers with new comprehensive resources to implement.*

Keywords: *empathy development, empathy skills, science education, thematic review*

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Introduction

K-12 education as an enterprise always has two main goals; to teach basic skills and knowledge and to cultivate moral citizenry. Although the perceived importance of the second half of this equation has fluctuated over time, affective outcomes of education have gained accelerated attention recently because humanity has faced an unequivocal number of issues with unprecedented complexities in the last decades. The world needs scientifically literate global citizens with moral values to feel responsible, make informed decisions with limited available data for the greater good, and be motivated to take action against a plethora of real-life issues, from climate change to abandoned animals.

The integration of empathy in science education takes on heightened significance when viewed through the lens of cultivating moral citizenry. In an era where scientific advancements wield considerable influence over societal structures, it is imperative to nurture scientists who not only possess technical expertise but also have a strong ethical compass. Moral development is described as "*transformations that occur in a person's structure of thought"* by pioneering of character development researchers (Kohlberg & Hersh, 1977). That is why the integration of values into the science education curriculum necessitates empathy skill research as the first necessary step to be taken since it is often seen as a precursor to prosocial behavior and moral development by changing students' structure of thought (Hoffman, 1981; Sokol et al., 2010; Zaki, 2018).

Empathy is a crucial human ability to understand what other people are experiencing (Titchener, 1909), and it has been identified as one of the most important competencies a future global citizen can have (Risberg, 2022). It has cognitive and emotional components. Empathy has become an umbrella term throughout the years, encompassing numerous synonyms referring to different components. Cognitively, understanding what others think and feel is known as *theory of mind* (Premack & Woodruff, 1978). Affectively, feeling what others are feeling can be experienced by a series of complex mechanisms such as the action-reaction impulse involving 'mirror neurons' and the emotion contagion phenomenon (Ferrari & Coudé, 2018).

https://doi.org/10.33225/jbse/24.23.914

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Moral Development in Education

Cultivating moral citizenry as an explicit aim of the curricula has become widespread over the last 50 years (Lovat et al., 2010; Nucci & Narvaez, 2008). Over the years, a vast amount of research has been done, and numerous initiatives have been implemented (Berkowitz et al., 2008; Fullick & Ratcliffe, 1996; Rodriguez, 2016). In two comprehensive studies aimed at elucidating what works in moral development education, 87 research studies and 45 character education programs were examined (Berkowitz et al., 2008); later, 42 evidence-based effective character education studies were analyzed (Berkowitz et al., 2017). These effective studies reported significant positive outcomes on socio-moral cognition, pro-social behaviors, and attitudes, problem-solving skills, school behavior, knowledge/attitudes about risk behavior, emotional competency, academic achievement, attachment to school, and a meaningful decline/amelioration in drug use and violence/aggression (Berkowitz et al., 2008, 2017).

There is also substantial work on two specific approaches; moral dilemma discussions (Kohlberg, 1976) and cooperative learning. One of the effective cooperative learning initiatives is "Teaching Students To Be Peacemakers," which uses real-life conflict scenarios to teach students how to manage conflicts constructively (Johnson & Johnson, 2002). Meta-analyses of 16 conflict resolution studies implemented in two countries (the USA and Canada) with kindergarten to ninth-grade students showed that students can learn conflict resolution procedures and apply them to real life situations both in school and out-of-school settings (Johnson & Johnson, 2002).

Schools have three pathways to implement effective moral development programs as specified in the Next Generation Science Standards and the National Curriculum of England (NGSS, 2013; Department for Education, 2014); adopt them as an add-on program, integrate them into academic classes, and carry out a schoolwide approach (Sokol et al., 2010). The integration of moral development into science classes plays a crucial role in developing an ever-increasing need for scientific literacy, which involves applying scientific decision-making to real-life issues that require recognizing controversy, examination of available information, careful consideration, and an understanding of the social ramifications of the decisions made (Çepni et al., 2003; Kahn & Zeidler, 2014). In science education, to foster scientific literacy for citizenship, Science-Technology-Society (STS), later Science-Technology-Society-Environment (STSE), and Socio-Scientific Issues (SSI) movements were developed and implemented (Chowdhury, 2016). Various scientific topics that have societal consequences were introduced through interdisciplinary approaches. When STS education was first envisioned, it planned to emphasize scientific facts and skills in sociological and technological concepts (Çepni et al., 2012; Solomon & Aikenhead, 1994), but during implementation, the cultivation of moral development and the consideration of emotional aspects of learning science fell short (Zeidler et al., 2005). With the SSI movement, students are expected to make informed decisions about a controversial issue, requiring them to consider multiple stakeholders' perspectives (Kahn & Zeidler, 2019). Furthermore, there are several recent endeavors to incorporate social-emotional learning and design thinking strategies into STEM (science, technology, engineering, and mathematics) and STEAM (STEM with arts) curricula to enhance the classroom practices in order to reach the goals mentioned above (Kijima & Sun, 2021; McCurdy et al., 2020).

In an increasingly interconnected and diverse global landscape, the cultivation of empathy within educational frameworks has become essential. Empathy not only enhances interpersonal relationships but also fosters a profound sense of moral responsibility and social awareness among students. As future citizens, K-12 learners must be equipped with the capacity to comprehend and appreciate diverse perspectives, which is critical for addressing complex societal challenges. The integration of empathy development into the curriculum not only enriches students' emotional intelligence but also promotes a more inclusive and compassionate educational environment, thereby contributing to their comprehensive development as responsible and ethical citizens.

Empathy Development in Education

The significance of developing empathy levels through educational programs has predominantly been emphasized in medical education, particularly in training doctors and nurses to improve relationships with patients and achieve better patient health outcomes (Kelley et al., 2014; Teding van Berkhout & Malouff, 2016). Empathy education programs historically rely on self-reports and empathy questionnaires. Recently, it has even been demonstrated with brain functional magnetic resonance imaging that the empathy levels of individuals can be increased through educational programs (Tholen et al., 2020).

K-12 education in the United States aims to achieve educational excellence as a nationwide guideline (US Department of Education, 2011). The Institute of Educational Sciences under the US Department of Education

https://doi.org/10.33225/jbse/24.23.914

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

offers the What Works Clearinghouse platform to analyze and report on programs, workshops, and research that have been implemented. Within this platform empathy development is addressed under Social-Emotional Development Programs. For the first time, empathy became an explicit goal in the Strategic Plan of the Department of Education in the US (Education, 2022). The UK curriculum aims to foster students spiritually, morally, socially, and culturally (Hawkes, 2010). There is an emphasis on ethics in science education (Department for Education, 2014). Additionally, the UK has the STEM Learning initiative, which collaborates with the Department for Education and provides many resources incorporating social-emotional learning, values attainment, and ethical considerations, including specific activities for empathy development ("STEM Learning", 2024). In Turkey, empathy is identified as a key competency of future citizens in the latest national curricula (MEB, 2018, 2024b). The 2024 curriculum emphasizes empathy in a specific manner in science education and advises educators to use classroom discussions as a means to foster this competency (MEB, 2024a).

Within K-12 education, SEL (social-emotional learning) programs and SSI research focusing on the affective domain report empathy developments in students (CASEL, 2019; Durlak et al., 2011; Herman et al., 2020; Fortus, 2022; Schonert-Reichl et al., 2012). These programs have five main approaches; teacher training, role-play and discussions, decision-making, using historical case studies, and work placement/service learning. The main strategy is to use collaboration which enhances students' academic success, cognitive abilities, self-confidence, social skills, metacognitive levels, problem-solving skills, proficiency in group work, positive attitudes toward learning and courses, and internal motivations (Bosch et al., 2019; Davidson, 1995).

Incorporating empathy into the context of science education (or any context) can contribute to the social-emotional development of students, fostering emotional intelligence, including emotion awareness and emotion regulation (Matthews, 2004; Schonert-Reichl et al., 2012; Lunn et al., 2022). Additionally, it has the potential to reduce anxiety and depressive symptoms (Peifer & Taasoobshirazi, 2022), work to ameliorate aggressive behavior (Castano, 2012) and combat cyberbullying (Beatty-Cipoletti, 2020; Kokkinos & Kipritsi, 2018). Emerging literature shows a strong correlation between empathy and reflective thinking (Soodmand Afshar & Rahimi, 2016) and critical thinking skills (Hasanpour et al., 2018). Developing empathy in the science education context can enhance student motivation and contribute to more effective teaching (Zeyer & Dillon, 2019). It serves as a platform for holistic learning (Pajak, 2021) and facilitates altruistic behavior, aligning with the ultimate goal of environmental education: promoting pro-environmental attitudes and behavior (Berenguer, 2007; Gladwin, 2020). Furthermore, there is a connection between empathy and scientific inquiry ability, as well as group creativity (Yoon et al., 2020). A recent study revealed a strong positive correlation between emotional experiences and achievements in cognitive and psychomotor areas, highlighting that the emotional context of learning is a key factor in student success (Kuo et al., 2024). This finding emphasizes the importance of considering all relevant factors when designing effective instructional strategies (Kuo et al., 2024).

The research up to date on this matter underscores the importance of developing empathy skills, highlighting its beneficial integration into educational curricula. It points out that the development of empathy within K-12 science education is often neglected, and existing research is fragmented. Although there are clear connections between empathy and related concepts such as ethics, humanitarianism, emotional intelligence, and perspective-taking, these areas have not been associated with empathy gains in the literature. The definition of empathy itself lacks clarity, leading to the use of various terms to describe the skill. Consequently, when researchers, policymakers, and practitioners review publications in the context of science education, they find it challenging to discern a coherent picture of interventions, recent trends, and the outcomes of implemented programs. As a result, a common understanding in this area has not yet been established.

Research Aim and Research Questions

Although empathy interventions are researched vastly, research on science education is still limited. No thematic review on fostering students' empathy levels in K-12 science education has yet been conducted. This effort aimed to shed light on what has already been done on the subject, identify the carved pathways to follow and determine what can be a logical next step in this matter. Therefore, this study aimed to perform a detailed analysis of the studies concerning the improvement of students' empathy levels in K-12 science education in terms of general features like research methods, samples, and results, and with specific attention to the design of interventions that had been implemented. The research questions for the review of the literature were as follows:

1. What is the distribution of studies according to their general characteristics (year, geographic location, and publication type)?

https://doi.org/10.33225/jbse/24.23.914

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

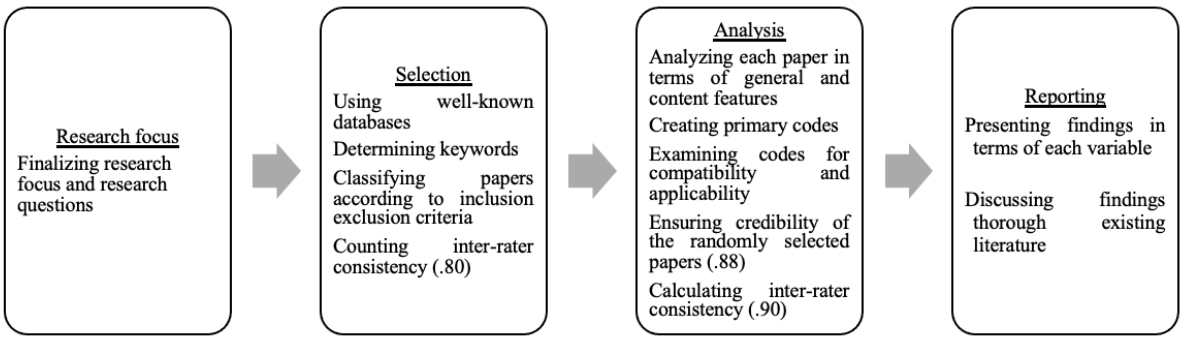
2. What are the common trends for effective interventions, in terms of strategy, length, and preferred course subject?

Research Methodology

General Background

This study meticulously synthesized the literature on empathy development within K-12 science education, establishing overarching themes and constructing a framework (Çalık & Sözbilir, 2014; Çepni- , 2021). Its aim was to highlight the prevailing patterns, commonalities, and distinctions within the research on empathy, with the goal of analyzing findings and providing insights to researchers, policymakers, and practitioners. A detailed review process was followed (Figure 1).

Figure 1
Review Process



The study utilized the document analysis approach, a key technique within the realm of qualitative research, to examine academic papers concerning models and modeling in science education. Document analysis serves as both a standalone research instrument and a means of data collection (Creswell, 2012). It entails the examination of written materials to gather insights about the specific phenomena or events being investigated.

Data Collection

Education Resources Information Center (ERIC), Academic Search Ultimate (EBSCO), Taylor & Francis Online Journals, Web of Science, Wiley Online Library, Springer, ProQuest Dissertations and Theses, Taylor and Francis Journals, Emerald, Open Dissertations, and YÖK Tez databases were examined. "Empathy" and "Science Education" keywords were used. The keywords were written in English in all databases except the YÖK Tez database (Turkish).

The preliminary search yielded 2,122 articles (all databases except ProQuest and YÖK tez), and 32 theses (ProQuest). For the YÖK Tez database, the "science education" and "empathy" keywords did not yield any results, the "empathy and "education" keywords were used instead, which yielded 675 theses. A specific time constraint wasn't set; the selected articles were published before January 2024. Upon applying the screening steps shown in Figure 1 and the inclusion and exclusion criteria (Table 1), a total of 28 publications were chosen (see Supplementary Document).

Table 1
Inclusion and Exclusion Criteria

Inclusion	Exclusion
The publication implemented a strategy to develop/foster/imbue empathy	The focus of the publication is not empathy, and if it includes empathy is about the effect of empathy rather than its development

https://doi.org/10.33225/jbse/24.23.914

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Inclusion	Exclusion
Publications where the primary focus of the research was K-12 students	Publications where the primary focus of the research was undergraduate or graduate students, faculty, practicing clinicians, teachers or children younger than 5.
Publications where empathy is developed during a science or related class/workshop/program	Publications where empathy is developed in settings that are not related to science (i.e., healthcare setting, history course)
Publications in English or Turkish	Publications in any other languages
Publications include clear research questions or hypothesis-driven inquiry, where a study was conducted, or a description of a course.	Publication describes an idea or presents an argument without background or research, and no study is conducted.

Publications were ineligible for inclusion if they lacked empirical studies, or if their content primarily revolved around discussions regarding potential implementation options or recommendations for enhancing empathy. This criterion led to the exclusion of numerous book chapters, given their tendency to provide broader overviews of the subject matter. While there could be connections between empathy and related subjects like ethics, humanitarianism, emotional intelligence, perspective-taking, etc. articles addressing these topics were incorporated only if the researcher explicitly mentioned empathy. The pivotal aspect of the data analysis involved determining whether the paper presented both pre-intervention and post-intervention data on student empathy levels, using either quantitative or qualitative measures. Papers were included in the analysis regardless of whether the primary focus of the intervention was on empathy development.

Data Analysis

Research on students' empathy levels was analyzed in terms of general characteristics (year of publication, type of publication) and content characteristics (methods, sample, data collection tools, intervention specifics, results). These variables are summarized in Table 2 with a matrix. This matrix has been used to define studies, point to general trends, explain similarities and differences, and show the unique features of significant studies (Çepni, 2021).

Table 2
Matrix

Themes	Codes	Explanations
General Features	Years of publication	Year of published study
	Geographic Location	The country in which intervention is applied
	Type of publication	Articles, theses, etc.
Content Features	Methods	Preferred research method
	Sample	Grade level or age of students
	Data collection tools	Tools used to obtain data
	Intervention specifics	Applied time length, preferred strategies and chosen course subjects for the intervention
	Results	Empathy and other outcomes under study

Utilizing the matrix variables as a guide, the authors developed a preliminary code for each article, classifying the findings accordingly. This initial set of codes underwent a collaborative review process for accuracy and relevance assurance. Thereafter, inductive analysis of these primary codes led to the extraction of secondary themes. Through this methodical approach, a clear depiction of commonalities, differences, and distinctive characteristics emerged from the collected research.

Research Validity and Reliability

To ensure comprehensive data reliability, two researchers independently analyzed 28 studies in terms of variables listed in Table 2. This process yielded an inter-rater agreement of .80. Any discrepancies in classification

https://doi.org/10.33225/jbse/24.23.914

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

were addressed and resolved through discussion. Additionally, to verify the reliability of the coding system, a team of expert reviewers, including the authors and a science educator, independently coded four randomly chosen articles. This resulted in an inter-rater agreement score of .86, indicating an excellent level of concordance in the coding process (Landis & Koch, 1977).

Research Results

General information regarding the studies is presented in Table 3

Table 3
General Information About the Studies

Themes	Codes	*f*	Total
Years of Publications	2008	1	28
	2010-2013	4	
	2015-2019	4	
	2020-2023	19	
Geographic Location	USA	10	28
	Turkiye	8	
	Korea	3	
	China	2	
	Colombia	1	
	Chile	1	
	Japan	1	
	Italy	1	
	Morocco	1	
Type of publications	Article	20	28
	Conference Proceeding	1	
	Thesis	7	

When the studies' general characteristics were examined, it was seen that most of them were conducted from 2020 to 2023. The articles involve K-12 students from 9 countries. Ten of the twenty-eight articles focused on students in the United States. Turkiye was with the next-highest number of articles (8). Journal articles are published three times more than these. Table 4 shows the distribution of studies according to preferred research methods.

Table 4
Distribution of Studies According to Preferred Research Methods

Methods	*f*	%
Experimental Research	7	25
Mixed-Method Research	7	25
Case Study	4	14
Action Research	4	14
Qualitative Research	3	11
Ethnography	2	7
Community-based Research	1	4
Total	28	

https://doi.org/10.33225/jbse/24.23.914

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Publications tend to favor experimental (23%) and mixed-method research (23%) approaches, with qualitative research (16%) closely following suit. Additionally, action and case studies (13%) are frequently used, and there are two studies of ethnographic and one community-based research. Table 5 shows the studies' distribution according to their preferred data collection tools.

Table 5
Distribution of Studies According to Preferred Data Collection Tools

Data Collection Tools	Examples	*f*	%
Interviews and Surveys	Structured interviews, semi-structured interviews, in-depth conversations, open ended question surveys	23	26
Discussions	Group or class discussions, video and/or voice recordings	13	15
Structured tools	Attitude scales, Knowledge tests	13	15
Observations	Participant observation, researcher interaction, video-recording of events	11	13
Project outcomes	Design schemes, artifacts, products, informative pamphlets, presentations	10	11
Student work	Worksheets, project proposals, narrations, homework	9	10
Reflective notes	Journals, sheets, survey answers	7	8
Academic grade	Year-end course grade	1	1
Q method	Participant ranking of 33 self-referenced statements	1	1
	Total*	88	100

Note: *All studies used several data collection tools.

As seen in Table 5, researchers preferred interviews and surveys (26%) the most, followed by class or group discussions (15%) and structured instruments (15%). Documented observations (13%) are followed by project outcomes (11%) and student work (10%). Moreover, studies benefit from reflective activities (8%), fewer studies used student grades (1%), or the Q method (1%). The distribution of the studies according to preferred sample groups in terms of grade level and the number of students is given in Table 6.

Table 6
Frequencies of Studies by Grade Level and Number of Students

Level	Number of Students	*f*	%
Primary School	20-48	5	23
	139-262	2	
	745	1	
1 to 8th Grade	30 and 499	2	7
Lower Secondary	4-8	2	53
	17-32	5	
	56-94	4	
	100-172	5	
Upper Secondary	10-26	2	13
	121-132	2	
Total		30	100

*Since Sarıkoç (2022) reported 3 separate groups, the total number of groups is 32.

Researchers preferred to focus on lower secondary school students the most (53%) with varying numbers of students; primary school samples were the next preferred sample by 23%. Upper secondary school students were the least preferred group by 13% of the studies. Table 7 shows study frequencies by intervention length.

https://doi.org/10.33225/jbse/24.23.914

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 7
Frequencies of Studies by Intervention Length

Length	*f*	%
1 Unit (4 to 24 Class hours)	8	29
3 to 10 weeks	7	25
11 to 14 weeks (1 semester)	4	14
8 to 9 months (1 school year)	6	21
3-day workshop	1	4
4 field trips	1	4
After School and Summer Camp	1	4
Total	28	100

Most of the studies were conducted in 3 to 10 weeks (25%) or a science unit (29%), which also takes about the same time interval. This trend is followed by interventions for a school year (21%) or a semester (14%). Studies in the form of workshops, field trips, or camps (4%) were also present. Table 8 shows the preferred subjects for the interventions and whether they were integrated into the science education curriculum.

Table 8
Frequencies of Preferred Course Subjects

Integration to Curriculum	Yes		No	
	Course Subject	*f*	Course Subject	*f*
Science Education	Force and Motion	2		
	Sustainability	1		
	Nature of Science	1		
	Environment	1		
	Matter	1		
	Human Growth and Development	1		
STEM / STEAM	Arthropods	1	Different projects	7
	Engineering for Sustainable Communities	1	Culturally sustainable communities	1
			Senior Citizen Needs	1
			Ecosystem	1
			Environment	1
SSI	Genetic Engineering	2		
	Abandoned Animals	1		
	Interrelation of species and environment	1		
STSE	Living Organisms	1		
Education for Sustainable Development			Life Lab and Wall Climbing	1
Outdoor Education			Environment	1
Involvement of multiple courses			Environment	1
	Total	14		14

Science Education in Table 8 refers to standard science classes. Out of the 7 research initiatives, all of them are aligned with the curriculum mandated by the respective country. STEM/STEAM research, for the most part, pursued distinct objectives (11 out of 14), often featuring unique projects for each group or varying projects throughout the course. Integration of SSI discussions into the curriculum occurred when genetic engineering, abandoned animals, and the interrelation of species and environment were the subjects of the course. The STSE

https://doi.org/10.33225/jbse/24.23.914

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

approach facilitated conversations on living organisms. Courses on education for sustainable development and outdoor education adopted an environmental education perspective in certain interventions. Notably, there is one initiative that demands the involvement of multiple courses and clubs to promote pro-environmental behavior. Table 9 delineates the social aspect of these interventions.

Table 9
Distribution of Studies According to Their Social Aspect

The social dimension of intervention	*f*	%
Group activities	24	86
Class discussions (when no collaboration present)	3	8
Individual activities	1	4
Total	28	100

All but one research was designed to be practiced with interaction with peers or involve discussions in class as a whole. Table 10 examines the distribution of studies according to selected strategies for empathy development.

Table 10
Distribution of Studies According to Selected Strategies for Empathy Development

Strategies for empathy development	*f*
Collaboration with peers and/or community	20
Group and/or Class discussion	13
Design thinking	12
Perspective-taking/Recognition	11
Stories from real life or historical characters	9
Self-reflection	9
Decision making	7
Action taking	4
Understanding animals and arthropods	4
Direct experience with nature/animals	3
Positive psychology/SEL incorporated	3
Dilemma stories	3
Web-based games and coding	1
Role-playing	1
Total	100

Note: * All studies used several strategies to promote empathy.

The most preferred method to promote empathy is the use of collaboration (20%), which is followed by group or class discussions (13%), design thinking (12%), and perspective-taking (11%). It is also possible to find studies that used reflective exercises (9%) and the use of contemporary or historical stories (9%). Decision making (7%), action taking (4%) and enabling understanding of animals and arthropods (4%), direct experience with nature (3%), incorporation of positive psychology or SEL principles (3%), and dilemma stories (3%) were also used within selected work. One study developed a video game to facilitate perspective-taking and systems thinking. Table 11 summarizes the studies' effect on empathy in the sample.

https://doi.org/10.33225/jbse/24.23.914

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 11
Frequencies of Studies by the Effect on Empathy

Data Collection Tool	Effect on the Empathy Component		*f*
	Improvement	No change	
Empathy Scale (pre and posttest)	6	1	7
Qualitative data	21	0	21
Total	27	1	28

All but one study (Pirchio et al., 2021) observed a significant increase in the empathy levels of students. Table 12 examines studies based on their results other than empathy.

Table 12
Distribution of Studies by Measured/Observed Themes

Themes	Codes	Number of articles	Total	*f*
Social-Emotional Development	Character development and values	16	30	42
	Dispositions	14		
Skills and Competencies	Competencies	15	19	27
	Behavior	4		
Cognitive development	Knowledge and understanding	18	18	25
Academic Outcomes	Achievement	4	4	6
		Total	71	

Note: * Most studies reported results from different themes.

In the course of examining the results other than the effect on empathy, four overarching themes emerged: (1) social-emotional development (encompassing character development and values also dispositions); (2) skills and competencies (competencies and behaviour); (3) cognitive development (knowledge and understanding); (4) academic outcomes (achievement). The context encompasses a comprehensive model that extends beyond mere academic performance. Cognitive development serves as the foundational pillar, which includes knowledge—a broad awareness and content knowledge about scientific concepts, the interconnectivity between nature and humans, sustainability, and physics. It also involves a deep understanding of the environment and a holistic view of learning that integrates these intra-disciplinary knowledge areas. The second pillar, social-emotional development, focuses on character and values. It emphasizes self-awareness, self-management, responsible decision-making, respect, cooperation, and honesty, which are fundamental to developing a sensitivity to the moral and ethical dimensions of science and technology. This domain also includes dispositions such as a genuine interest in science, motivation, appreciation for teamwork, creative confidence, a feeling of connectedness to the natural world, and specific attitudes towards entities like arthropods. At the skills and competencies level, learners are expected to acquire a host of critical abilities, including problem-solving, empathic listening, higher-order thinking, effective communication, leadership, decision-making, and innovation in engineering designs. These competencies are vital for the creation and conceptualization of new artifacts and contribute to a student's creative aptitude. Behaviorally, students are encouraged to engage in empathy-driven actions, exhibit positive leadership, organize activities, motivate peers, and practice pro-social behaviors that reinforce their learned competencies and character values. Academic outcomes, the fourth pillar, focus on achievement, which is demonstrated through academic performance and success in science education.

The distribution of research themes within the corpus of analyzed literature reveals a substantial emphasis on the impact of educational interventions on students' social-emotional development, with nearly fifty percent of the publications examining effects beyond the dimension of empathy. The domains of skills and competencies, as well as cognitive advancements, are also well-represented, each constituting approximately a quarter of the scholarly contributions. Furthermore, a minority of studies, specifically four, have concentrated on measuring improvements in academic achievement as an outcome of the interventions in question. All but 3 studies report a positive impact

https://doi.org/10.33225/jbse/24.23.914

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

across all intervention themes. Talan (2020) reported a chaotic classroom environment during the group project. Türköz (2018) observed increased stress in students due to upcoming nationwide tests during the implementation of the intervention. Lastly, Idrissi (2020) did not observe an intervention effect on students' responsibility.

Discussion

As a result of a thorough search, the authors selected 28 publications. All the reported studies are interventions designed within the scope of K-12 science education. When the general characteristics are examined, it is evident that in recent years, more studies have been published; this indicates that interest in, and the importance of, empathy in science education is growing exponentially. This situation can be due to the ever-increasing social role of the school environment in students' everyday lives, where other social interactions are dramatically decreasing (Hardy, 2022). Therefore, the affective domain growth of the students primarily has to take place in the school setting. Also, social problems are aimed to be addressed because bullying has been a prominent issue in recent years (Beatty-Cipoletti, 2020).

Science education is a stakeholder in this regard that can make a change in the perspectives of students either towards their peers through group work (e.g., Greenstein, 2010) or animals through a selection of units regarding animals in science education (e.g., Castano, 2008).

It was interesting that during the search, the authors came across Solomon and Duveen's (1994) paper, which mentions that in the late 1980s, the British National Curriculum and two other researchers found empathy to be an unhelpful idea. This might explain the uncharted territory for empathy in science education before those years.

Since English and Turkish were the authors' search criteria, it was not surprising to find the frequency of Turkish publications as high as 8 out of 28. However, for European countries, only one publication from Italy was included in the selections; the others were either more inclined to report the effects of including empathy during interventions (Henriksson, 2023), or failed to provide intervention specifics (Andrikopoulou & Koutrouba, 2019). European publications may have been written in their native languages as well.

Because of the diverse definitions of empathy and the abundance of synonymous terms, we excluded studies that researchers might perceive as empathy but were not explicitly labeled as such by the authors. Nonetheless, we did not exclude studies in which authors identified empathy while also using alternative terms to describe it. These alternative terms included empathetic listening, empathic problem solving, transformative perspective-taking, pro-social behavior, emotional intelligence, and compassion.

Intervention Design

Most of the interventions were implemented for 3 to 10 weeks. Studies implemented for one curriculum unit took about the same amount of time. Both periods make up about half of the selected studies. Therefore, it can be concluded that this duration is sufficient to observe effective positive results (e.g., Greenstein, 2010; Toraman, 2013). This time length is followed by interventions lasting for the whole school year (e.g., Kouvara et al., 2019), which is suitable for extracurricular programs using STEM education approach (Bush et al., 2020), or for school-wide ESD selective courses (Ampuero et al., 2015).

Although the selected subjects (Table 8) are numerous, the interventions conducted have been notably limited in addressing subjects that fall within the broader spectrum of science education curricula globally. When interventions are designed for traditional science courses, alignment with curriculum attainment goals is the preferred approach. STEM/STEAM methodologies often pursue their own objectives, as they primarily involve projects that embrace interdisciplinary perspectives. SSI discussions have been sparingly used, with a focus on aligning genetic engineering topics within the curriculum (Gao et al., 2021; Lee et al., 2013).

All of the interventions except one were designed to have group work either for guided inquiry (Greenstein, 2010), design projects (Kijima et al., 2021), co-production (Calabrese Barton et al., 2021), or opening space for dialogue for culturally sustainable STEM activities (King et al., 2023). When the class was not divided into groups, whole class discussions took place (Table 9). This allowed students to interact with some of the peers they had never interacted with before and listen to their perspectives on the selected topic (e.g., Castano, 2008, Greenstein 2010). Group work also encouraged them to take responsibility (Talan, 2020; Türköz, 2018).

Table 10 shows other strategies implemented. Most activities required students to consider other perspectives by researching their position or recognizing it (Gao et al., 2021). Design thinking is utilized within STEM projects which starts with understanding the need (Huang et al., 2022; McCurdy et al., 2020). Some of the interventions

https://doi.org/10.33225/jbse/24.23.914

ISSN 1648–3898 /Print/
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required students to collaborate with community members, enabling them to work with elders (Kijima & Sun, 2021) or experts like veterinarians (Gao et al., 2021) . This also led students to grasp the notion of an essential aspect of problem solving; "here and now", furthermore enabled students to feel in power for change (Calabrese Barton et al., 2021). Some even had to take action for the presented problem (Çavdar, 2020; Toraman, 2013) or at least propose a solution for the given task (Idrissi, 2020; Sarıkoç & Ersoy, 2022). These activities required the utilization of critical, analytical thinking, and decision-making skills that enabled transformative perspective-taking (McCurdy et al., 2020).

All of the strategies can be claimed to put students in a situation that they have to experience by listening to others' stories (Emir, 2021), seeing by field trips (Garner et al., 2017) , or considering different (people, historical characters, nature, or animals) perspectives (Ingram et al., 2022)—enabling them to have a broader perspective (Bush et al., 2020), achieving a holistic understanding (Pajak, 2021), and use this gained skill in a given project or problem to find solutions which also required them to use their scientific knowledge (McCurdy et al., 2020). These findings are parallel research that shows story-telling positive impact on students' values and attitudes (Sali & Aydın, 2023).

Results

While this review was mainly designed to shed light on outcomes relevant to K-12 students in the context of empathy development in science education, it additionally gathered data on associated findings during analysis. Summarizing the outcomes documented in peer-reviewed literature indicates a predominantly positive impact of the incorporation of empathy on K-12 students in all specified domains.

Designed interventions had broad effects on the student's cognitive and affective abilities. Students related science topics to real life (Greenstein, 2010), developed a better understanding of sustainability concepts (Jensen, 2016) and understanding of abandoned animals (Kim & Lee, 2021), and incorporated a variety of STEM content or practices into the problem (McCurdy et al., 2020). Interventions promoted students' understanding of the nature of science (Güney & Seker, 2012) and the interconnected nature of humans and the environment (Castano, 2008). This substantial effect on the knowledge domain is predicted by Zeyer and Dilon (2019) who claimed incorporating empathy into science teaching enables effective science learning by increasing motivation and contributes to unlocking its complete potential, where he also highlights the vitality of incorporating values.

The domain of character development and values is the second most frequently observed, with only three studies reporting no effect. This area is experiencing heightened attention in science education due to a growing emphasis on fostering scientific literacy (NGSS, 2013) and human-centered design (Pande & Bharathi, 2020). Both of these objectives require socio-emotional development and moral reasoning skills. As it is established in social psychology and moral philosophy, empathy has precursor links to moral development, moral reasoning, and altruistic behavior (Hoffman, 1981; Stueber, 2017; Zaki, 2018). This effect also can explain the comparable impact on disposition and competency domains where students' interest and motivation (Garner et al., 2017; Greenstein, 2010), also higher-order thinking skills (Ampuero et al., 2015; Sarıkoç & Ersoy, 2022) improved. These effects are in line with the findings of Almers (2013), who identified empathy as one of the pathways that enables action competence for sustainability. Also, the relationship between attitudes and knowledge is reciprocal, as attitudes can both result from and impact science performance; when students express interest in science and harbor positive perceptions of their competencies, they tend to approach science topics with greater confidence and employ more effective learning strategies (Schneider et al., 2016). Lastly, socio-emotional and psycho-physical well-being go hand in hand with the development of emotional intelligence which leads to better academic performance (Quílez-Robres et al., 2021).

Regarding the long-term sustainability of empathy development outcomes, only Pajak (2021) conducted a follow-up assessment six months post-intervention, where sustained positive effects were observed. However, this review does not extend to conclusively determine the long-term persistence of such intervention outcomes. In contrast, the meta-analysis by Durlak (2017) on school-based social and emotional learning programs indicates that these interventions yield enduring benefits, with the positive impacts being retained for up to four years post-participation. This comprehensive analysis revealed statistically significant mean effect sizes of academic performance, family cohesion, positive peer and family relationships, school attendance, responsible sexual behaviors, graduation rates, college enrollment, reduction in arrests, and improvements in mental health. The sustained nature of these positive outcomes not only points to continued developmental progress for the individuals involved but also implies the potential for long-term advantages and broader economic benefits at the societal level. This analysis provides promising data for researchers planning to incorporate empathy-developing interventions.

https://doi.org/10.33225/jbse/24.23.914

ISSN 1648–3898 /Print/
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Limitation and Challenges

This research highlights overarching patterns concerning the integration of empathy-enhancing interventions in K-12 science education, unveiling common themes and strategies. However, the implementation of such interventions faces a myriad of challenges and constraints that warrant careful attention. A significant hurdle is the integration of empathy into already content-heavy science curricula, which may not align well with the objectives of standardized testing. Teachers are central to the success of these interventions, but they require specific competencies that might only be achieved through additional professional development (Adams et al., 2015) Additionally, disparities in resource distribution could impact the practicality of adopting empathy-based programs across various educational settings.

Moreover, the complexity of assessing the effects of empathy on students' learning – encompassing both cognitive and affective realms – calls for multifaceted evaluation approaches, which go beyond the scope of conventional testing methods (Wei et al., 2021). Tracking the long-term influence of empathy training on students poses another issue, as does the extension of successful practices to accommodate a broader spectrum of students without diluting their efficacy. These challenges underscore the need for deliberate planning and resource allocation to effectively foster empathy within science education.

Successfully integrating empathy education requires careful navigation of cultural complexities. Empathy is interpreted and expressed differently across various cultural backgrounds due to distinct norms and values which can affect individual behaviors and emotional responses. Such cultural diversity necessitates tailored approaches to empathy interventions to ensure relevance and effectiveness (Nucci & Narvaez, 2008). Furthermore, empathy is not developed in isolation but is influenced by familial and community influences. Recognizing the role of family dynamics, community values, and social norms is essential, as these elements shape students' attitudes toward empathy. By engaging families and communities in the development of empathy-building activities, the effectiveness of educational interventions can be reinforced (Andrikopoulou & Koutrouba, 2019). Additionally, the broader sociopolitical environment, including historical events and prevailing societal issues, can impact how students perceive and understand empathy. Educational interventions must therefore be conscious of the historical and political contexts they operate within to foster a learning atmosphere that supports inclusive and effective empathy development (Zeidler et al., 2005).

Integration Suggestions

Integrating empathy into the fabric of science education requires a thoughtful approach that begins with an assessment of the current curriculum. Educators should look for natural junctures where empathetic practices align with the objectives of environmental education and the study of living organisms. These topics already lend themselves to discussions about human impact and lifestyle choices, making them ideal starting points for integration, as outlined in Table 8. Initiating the process with manageable activities, such as group discussions and reflective exercises, can help measure student engagement and the influence of these practices. These activities not only provide insights into students' understanding and attitudes but also allow them to encounter diverse viewpoints and acknowledge the input of their peers. Creating a culture of collaborative learning, underpinned by reflection, paves the way for enhanced empathic skills among students. This collaboration necessitates clear communication and fosters a sense of community where understanding others' perspectives becomes a natural extension of educational interactions. Educators can enrich the experience by bringing real-world scenarios into the classroom. Case studies, for instance, bridge the gap between scientific principles and empathy, grounding theoretical knowledge in tangible social contexts. Varied pedagogical methods, including role-play and the use of multimedia resources, serve to deepen students' immersion in empathy-building experiences. Objective measurement of empathy levels using established assessment tools, coupled with soliciting feedback, forms the basis for continuous curricular improvements. Moreover, incorporating the contributions of parents, community members, and professionals (such as veterinarians) into these initiatives can create a well-rounded, community-supported strategy for fostering empathy within science education.

Conclusions and Implications

This thematic review provides a comprehensive overview of the distribution and characteristics of studies focused on empathy development in K-12 science education. The analysis of 28 publications reveals a notable

https://doi.org/10.33225/jbse/24.23.914

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

concentration of research conducted between 2020 and 2023, indicating a growing recognition of the importance of empathy in educational contexts. Geographically, the majority of studies originated from the United States and Turkey, with contributions from several other countries, reflecting a diverse international interest in this area. In terms of publication type, journal articles predominated, suggesting a strong academic engagement with the topic.

Common trends among effective interventions highlight the use of collaborative learning environments, which typically span 3 to 10 weeks, and emphasize strategies that encourage perspective-taking and reflective exercises. These approaches not only enhance students' empathy levels but also integrate seamlessly into existing science curricula, making them practical for educators to implement within a semester.

Understanding the distribution and trends in this research is crucial for several reasons. First, it identifies gaps in the literature, particularly in underrepresented geographic regions and publication types, which can guide future research efforts. Second, recognizing effective intervention strategies allows educators to adopt evidence-based practices that foster empathy, ultimately contributing to the development of morally responsible citizens equipped to tackle complex global challenges. Prioritizing empathy in science education not only enriches students' learning experiences but also cultivates a generation capable of making informed, compassionate decisions in an increasingly interconnected world.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Competing Interests

The authors declare that there is no conflict of interest.

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ISSN 2538–7138 /Online/

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Received: *April 25, 2024* Revised: *August 30, 2024* Accepted: *September 22, 2024*

Cite as: Makal, N., & Çepni, S. (2024). Increasing students` empathy levels in science education: A thematic review. *Journal of Baltic Science Education*, *23*(5), 914–930. https://doi.org/10.33225/jbse/24.23.914

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