Science Education International
35(4),293-310
https://doi.org/10.33828/sei.v35.i4.1

RESEARCH ARTICLE

Navigating Wicked Problems through Science Education and Culture: Insights from Bangladesh, Estonia, Turkey, Ukraine

Tapashi Binte Mahmud Chowdhury[1]*, Miia Rannikmäe[1], Jack Holbrook[1], Maryna Zaluzhna[2], Bulent Cavas[3,4]

[1]Centre for Science Education, University of Tartu, Tartu, Estonia, [2]Department of English Philology and Linguodidactics, Zaporizhzhia National University, Zaporizhzhia, Ukraine, [3]Department of Science Education, Faculty of Education, Uşak University, Uşak, Turkey, [4]Department of Science Education, Faculty of Education, Dokuz Eylul University, Izmir, Turkey

***Corresponding Author:** tapashib@ut.ee

ABSTRACT

In dealing with wicked problems, such as pandemics, war, economic inflation, refugee influx, plus natural disasters such as earthquakes or floods, culture is seen as playing a strong role in determining peoples' responses. While school science education seeks to promote an awareness of, and even a preparedness toward, dealing with wicked problems, the isolation of school science from culture can result in promoting an image of science, within students, as unaccounted for and unaffected by cultural experiences. In reducing the gap between science education and culture, this study seeks to identify teacher perceptions toward a combined role to be played by both science education and culture in co-addressing wicked problems. In so doing, this study takes into consideration teacher views on four wicked problems – the current war in Ukraine, the recent earthquake in Turkey, a refugee influx into Estonia, and the reoccurring floods in Bangladesh. Through semi-structured interviews with 5 volunteer teachers from each country, the study explores teacher perceptions toward the roles played by culture and science education separately and possible ways to combine these so as to promote a culturally relevant, responsive, and adaptive science education orientation. The significance of this study lies in the multicultural nature of the research, seen as allowing the researchers to gain multicultural perspectives from science teachers with first-hand experience related to wicked problems.

KEY WORDS: Culturally responsive science teaching; emotion; multicultural study; science and culture; wicked problem in science

INTRODUCTION

The societal concerns that we face today are becoming increasingly more complex (United Nations, 2023). It is thus not surprising that addressing such concerns requires multiple and even conflicting dimensions to be considered (Takeuchi et al., 2020). And, as there are no straightforward solutions to these concerns, they are often referred to as wicked problems (Lönngren and van Poeck, 2020; Termeer et al., 2019). In facilitating student awareness of the complexity of such wicked problems, science educators generally agree that ideally, school science education should play a stronger role (Fernández et al., 2022; Pietrocola et al., 2021). In line with this, science educators also acknowledge a need for school science to change from a simplistic and fragmented representation to one, more complex and holistic, concerning the multiple contributing dimensions associated with wicked problems, one of which is seen as culture (Erduran and Dagher, 2014; Venville et al., 2012).

Cultural contributions promoting preparedness toward tackling wicked problems are documented by many social scientists (Appleby-Arnold et al., 2021; Castañeda et al., 2020). Particularly, the cultural experience (or lack thereof) with different disasters, as well as culturally promoted values and attitudes, have been associated with how people respond to wicked problems (Castano, 2012; Mercer et al., 2012; Thomas et al., 2019). Nevertheless, noting the changing nature of wicked problems, cultures are also subject to change, thereby enhancing adaptive behaviors which are more effective in responding to wicked problems (Carcasson, 2016), for example scientifically informed behavior (Song et al., 2021).

In suggesting that science education and culture can both play a role in promoting awareness and preparedness toward potential approaches to addressing wicked problems, both may require adaptation. Furthermore, both culture and science education may influence each other, for example, in the manner in which wicked problems are addressed. Thus, while Upadhyay et al. (2017) suggest that students' cultural experiences of wicked problems impact their science learning, on the other hand, Chowdhury et al. (2024) point out that students' science learning associated with wicked problems impacts on their culture.

In seeking ways to formulate mechanisms through which to address wicked problems by interrelating science education with cultural experiences, this study aims to identify science teacher perceptions with respect to the following questions:

1. Which dimensions of wicked problems are identified by science teachers?

2. Which cultural attributes influence the awareness and preparedness toward wicked problems, as identified by science teachers?
3. Which attributes promoted by science education are identified by the science teachers as influencing the awareness and preparedness toward addressing wicked problems?
4. How can culture and science education play a combined role in co-addressing wicked problems?

LITERATURE REVIEW

Wicked Problems: What Makes them Wicked?

While researchers generally agree that there is no one single way to define a wicked problem (or problems), as a theoretical construct, wicked problems have some fundamental characteristics. For example:

Complexity

Peters (2017) suggests that the "wickedness of the wicked problems" is mostly its complexity. He takes into consideration that wicked problems cannot be conceptualized in a linear, cause-and-effect approach, but rather through an inter-connected web of different contributing dimensions, which to different extents, cause the problem, and/or are affected by the problem. Considering the multiple interconnected contributing dimensions, and multiple or even conflicting perspectives, wicked problems lack clear-cut solutions. In this respect, Carcasson (2016) suggests that resolutions put forward for addressing wicked problems, through consolidating multiple dimensions, may induce value-laden dilemmas for the enactors.

Subjectivity

In a foundation article, Rittel and Webber (1973) point out that wicked problems generally lack objectivity i.e., there can be multiple explanations of the same wicked problem depending on the specific perspective utilized for conceptualization. Hence, the authors perceive that the resolution of problems is less evaluated by its rightness (or wrongness), but more by its quality of being optimum (with minimal damage).

Universal significance

In general, all wicked problems are seen as having an impact, which concerns not only one person, community, or country, but humanity in general (Carcasson, 2016; Peters, 2017; Rittel and Webber, 1973; Termeer et al., 2019). In line with this, Peters (2017) also identified a paradoxical nature of a wicked problem, i.e., – on the one hand, the problem needs immediate addressing, but, on the other hand, the effect of any attempts toward resolving a wicked problem may not be immediately visible. Hence, Peters (2017) and Termeer et al. (2019) both suggest that there is a need to shift from overemphasizing the conceptualization of wicked problems, toward a greater emphasis on the operationalizing of potential resolutions, i.e., ways of addressing the wicked problems.

Examples of wicked problems of universal significance (in some cases, also reported as super wicked problems) include both nature-influenced and human-influenced concerns, such as war, migration, flood, and earthquakes (Brinkmann, 2020; Termeer et al., 2019; Zellner and Campbell, 2015).

Science, Science Education and Culture: Fixed and Separate or Mutable and Overlapping?

There is a general consensus among scientists and science educators that science as a process, a human endeavor, or an enterprise, is certainly embedded in, and influenced by, culture (Aikenhead, 2007; Lederman et al., 2002; Wong and Hodson, 2009). Such a view, focussing on the nature of science, rejects the universalism of science (i.e., science is fixed in all respects around the world), and suggests that the motive, construction, or even dissemination of scientific knowledge is strongly influenced by cultural experiences, values, and attitudes. Moreover, since cultural experiences, values, and attitudes are constantly evolving, the purpose, process, and product of science are also subject to change (Akgun and Kaya, 2020; Lederman, 2019).

Nevertheless, with respect to school science education, divergence is noted among science education practitioners as to whether it is appropriate to promote a simplistic and unproblematic account of science, isolated from culture, or to promote a complex and holistic account of science embedded within the culture (Erduran and Dagher, 2014; Venville et al., 2012). The dilemma is not easily resolved. For example, science educators have pointed out the dangers of promoting science as separate from culture, because:

1. It encourages a student's perception of science as an abstract set of concepts, which may not be relevant when addressing wider societal concerns (Lederman, 2019);
2. It ignores the cultural experiences students bring to the classroom, further promoting student perceptions that their cultural experiences may not be relevant in addressing wider societal concerns (Brown and Crippen, 2016a).

In mitigating against these limitations, it can be suggested that there is a need for school science to promote a student image of science as:

1. Culturally influenced, and hence deriving a counter-narrative that challenges the traditional image of science, plus the work of scientists as fixed and free from all cultural influences (Wong and Hodson, 2009);
2. Culturally embedded, and hence paying careful consideration to building on students' cultural background, while enhancing their science learning experience (Bransford et al., 2004).

Culturally Responsive Science Education: A Potential Way Forward to Address Wicked Problems

A culturally responsive approach to teaching and learning is seen as addressing both the above-mentioned needs (Hernandez et al., 2013; Powell et al., 2016). For example, the approach is seen as useful in ensuring the teaching of science as a contextually appropriate and culturally informed practice; and at the same time, acknowledging and building

on students' cultural experiences, needs, and diversity in facilitating their science learning (Brown et al., 2018; Brown and Crippen, 2016b).

Within a culturally responsive science learning approach, some important considerations can be perceived as:

Students' identity

According to Banks (2009), Nieto (2010), and Yoon and Martin (2019), culturally responsive teaching-learning aims to facilitate students' sense of identity, which further enables them to function in cultural, national, and global communities. In so doing, the teaching-learning of science within a culturally responsive approach

"Recognizes, respects, and uses students' cultural identities and backgrounds as meaningful sources." (Yoon and Martin, 2019)

Exposure to complexities

Codrington (2014) and Powell et al. (2016) strongly emphasize that one of the critical goals of culturally responsive science education is to expose the students to the complexity of societal issues. In so doing, they suggest that teachers need to contextualize the science teaching-learning within a complex, real-world problems, in a culturally sensitive manner.

Agency of change

One common feature in Brown and Crippen's (2016a) and Hernandez et al.'s (2013) models of culturally responsive science teaching is that, in both models, students and teachers are seen as the agents of change, with respect to both culture and science education. In so doing, they suggest students need to challenge the cultural inequalities, or abnormalities, and teachers need to challenge the current approach of science teaching-learning where this is seen as isolated from the culture.

METHODOLOGY

Contexts of the Study

This study selected four recognized wicked problems: two seen as related to nature and climate (earthquake and flood), and two considered as related to peace and equality (war and refugee influx) (United Nations, 2023). Based on this purposeful selection of four global crisis scenarios, four potentially culturally different countries were identified for this study[1]:

1. Turkey with respect to the recent earthquake[2]
2. Ukraine with respect to the ongoing war[3]
3. Bangladesh with respect to the recurring floods[4]
4. Estonia with respect to the war refugee influx.[5]

1. This study considers Eldering's (2002) definition of culture as 'intergenerationally transmitted sociohistorical forms of economy, social organization, family life, religion, language, tools, and other products of human agency and creativity.'
2. https://en.wikipedia.org/wiki/2023_Turkey%E2%80%93Syria_earthquake
3. https://en.wikipedia.org/wiki/Russian_invasion_of_Ukraine
4. https://en.wikipedia.org/wiki/Floods_in_Bangladesh
5. https://en.wikipedia.org/wiki/Ukrainian_refugee_crisis_(2022%E2%80%93present)

The selected four countries, i.e., Bangladesh, Estonia, Turkey, and Ukraine are geographically distant (as indicated in the following map). However, all these countries have each undergone historical and political experiences that have shaped their distinct cultural identities and their unique approaches to address wicked problems.

Geographic location

Bangladesh is a country in South Asia. Estonia is located in Northern Europe. The major part of Turkey is located in West Asia, and a smaller part is in Southeast Europe. Ukraine is located in Eastern Europe (Figure 1).

Language

The official languages of communication for Bangladesh, Estonia, Turkey, and Ukraine are respectively, Bangla, Estonian, Turkish, and Ukrainian Other than the official language, Russian language is the second predominant language of communication in both Estonia and Ukraine.

Socio-historical background

Bangladesh has been part of British Indian colony until 1947 and Pakistan until 1971. Turkey, though never formally colonized, has been influenced by the Ottoman Empire's expansionist policies. Estonia and Ukraine have been part of the Soviet Union until 1991. Cultural beliefs and practices in Bangladesh and Turkey are strongly influenced by the same religion. Although Estonia and Ukraine have different perceptions toward religion, cultural beliefs in these two contexts are strongly influenced by their similar historical background.

Population and economy

According to World Population Review Report 2023, the population density (person per square kilometer) of Bangladesh is 1333, Estonia is 32, Turkey is 112, and Ukraine is 65[6]. Evidently, population density plays a strong role on the economy of these countries. Based on the World Bank Report 2024, Bangladesh is ranked as lower middle-income, Estonia as high-income, and Turkey and Ukraine as upper middle-income countries[7].

School science education

In Bangladesh, the curriculum includes science as a compulsory subject from grades 1 to 10. At a primary level (grade 1–5), and at a lower secondary level (grade 6–8), science is taught as an integrated subject with topics from biology, physics, and chemistry. At secondary level (grades 9–10), physics, chemistry, and biology are taught as separate subjects to students who choose science as their major (Chowdhury et al., 2021). For students who choose humanities or business as a major, science is taught as one subject with topics from physics, chemistry, and biology. Geography is taught as a humanities subject[8].

6. Total Population by Country 2024 (worldpopulationreview.com)
7. World Bank Country and Lending Groups – World Bank Data Help Desk
8. Ministry of Education- (moedu.gov.bd)

Figure 1: Geographic locations of the selected countries

In Estonia, the Estonian national curriculum for compulsory education, covering grades 1–9, follows a competence-based approach and emphasizes the development of scientific literacy as one of its key objectives (Chowdhury et al., 2019). At stage I (grades 1–3), and stage II (grades 4–6), science is taught as an integrated subject. For students in grades 7–9, science is divided into five specific subjects: biology, chemistry, earth science, physics, and interdisciplinary science[9].

In Turkey, according to the revised curriculum (2018), science is mandatory for primary (grades 1–4), and secondary (grades 5–8) levels. At grades I and II, science is taught as an integrated subject named Knowledge of Life, which includes topics from social studies. Science taught at grades 3–8 have four key learning areas: earth and the universe, living things and life, physical processes, and matter and its properties. In addition to that, the curriculum also integrates science-engineering-entrepreneurship[10].

In Ukraine, the primary level (grade 1–4) is divided between two stages – adaptive play (grade 1–2), and basic (grade 3–4). At the adaptive play, subjects include - Exploring the World, where science is taught on an integrated basis, with a predominance of game-like methods. At the basic level, the same subject is taught for conceptual learning. Middle school is also divided into two stages - adaptive (grades 5–6), and basic (grades 7–9). Health and safety and environmental studies are taught at middle school, both adaptive and basic levels. Biology and geography are taught at grades 6–9, while physics and chemistry are taught at grades 7–9. Computer science is taught as a separate subject at both primary and middle school levels[11].

Samples

To seek views from science educators, five science teachers were chosen from each country, based on a convenient sampling technique. These teachers were approached by the corresponding author from their country. A brief description about the participants is listed in the following Table 1:

Instrument

In this study, semi-structured open-ended interviews were used as the instrument. The interviews were based on five constructs:

1. Establishing familiarity with the selected wicked problem.
2. Identifying the dimensions of wicked problems (with respect to RQ1).
3. Identifying the influence of culture in the addressing of wicked problems (with respect to RQ2).
4. Identifying the influence of science education in the addressing of the wicked problems (with respect to RQ3).
5. Identifying the combined role of culture and science education in the co-addressing of the wicked problems (with respect to RQ4).

To facilitate participants' familiarity with respect to the selected crisis (construct 1), relevant images were used as visual aids during the interview. In so doing,

a) Five images for each crisis were initially chosen by the first author using internet resources.

b) One image for each crisis was finalized after expert

9. Pre-school, basic and secondary education | Haridus- ja Teadusministeerium (hm.ee)
10. Öğretim Programları || Millî Eğitim Bakanlığı (meb.gov.tr)
11. Middle school - Ukrainian education in emergency (mon.gov.ua)

consultation.

c) The relevance of the images was confirmed by corresponding authors from the respective countries.

In the following, the final images are demonstrated in Figure 2:

The constructs for the interview instrument were further elaborated in the following Table 2.

Data Collection

Considering the multi-national nature of the study, the corresponding authors from each involved country collected data in their own country. This allowed the researchers to facilitate effective communication with the participants. Data were collected through both face-to-face and online interviews through zoom. Each interview typically lasted around 30–45 min. Upon receiving permission from the participants, interviews were recorded. The language of communication between the interviewers and interviewees was English in all interviews.

Data Analysis

For the analysis of data, the following steps were undertaken:

Table 1: Teachers involved in the study

Teacher	Teaching grade	Teaching subject (s)	Educational background
Turkey			
T1	6–8	General science (incl. physics, chemistry, biology, astronomy, geology)	Science education
T2	6–8	General science	Science education
T3	6–8	General science	Science education
T4	6–8	General science	Science education
T5	6–8	General science	Science education
Estonia			
E1	7–12	Physics and computer science	Robotics
E2	7–9	Geography	Geography, biology
E3	7–8	Geography	Geography, biology
E4	8–9	Physics	Physics, chemistry
E5	7–9	Chemistry, Biology	Biochemistry
Ukraine			
U1	8–10	Biology, Chemistry	Biology
U2	9–10	Physics, Physics and Astronomy	Electric engineering
U3	9–10	Geography, History	History
U4	5–9	Exploring the world (incl. Physics, Chemistry, Biology, Ecology, Geography), Biology, Ecology, Health and Safety	Biology, chemistry
U5	5–8	Exploring the world	Biology, chemistry
Bangladesh			
B1	6–8	General science (incl. physics, chemistry, biology, health)	Physics
B2	6–8	General science	Physics
B3	6–8	General science	Biology
B4	6–8	General science	Chemistry
B5	6–8	General science	Chemistry

Figure 2: Visual aids used as part of the instrument

Table 2: Construction of the interviews

Purpose: to identify	Sample questions	Possible outcomes	Improvisation
1. Whether the participants are aware about worldwide wicked problems	1. Are you familiar with: a. the current war in Ukraine, b. the recent earthquake in Turkey, c. migration into Estonia, and d. reoccurring floods in Bangladesh? 2. Can you share with us your experiences (in case of their own country event) or knowledge (in case of another country event) about it?	a. Participant may be informed about the event in their own country. b. There is a possibility that participants from one country are not fully aware about the events in another country.	If they are familiar with the given four events, then the interviewer moves on to the next construct. If they are not familiar with some events, the interviewer gives brief information and moves to the next construct.
2. Whether participants from different cultures see the wicked problems from different dimensions	1. Do you think these events are important to know about? Subsidiary questions: I. Why do you think so? II. Can you please explain your answer?	a. The participants may not use the exact terminologies, such as social, economic, value-laden, emotional, cultural, or worldview. b. The participants may have either clear or unconstructed ideas about the complexity of wicked problems.	If the participants do not use the terminologies that can be categorized, then the interviewers will ask probing questions, such as – can you please elaborate your answer?
3. Whether participants perceive the influence of culture in addressing wicked problems	1. Do you think people from your culture would address (event from another culture) differently? Subsidiary questions: I. (If they say yes) can you please tell us how would it be different? II. (If they say no) do you think all cultures respond to these kinds of events similarly?	a. The participants may identify that their own culture may tackle the events from other cultures differently. b. The participants can identify the cultural strengths and weaknesses, in addressing the global events. c. The participants also may identify that all the cultures address global events very similarly.	If the participants identify that their own cultures would tackle global events differently, the interviewer asks probing questions about the strengths and weaknesses of the participants' culture.
4. Whether participants perceive the importance of science learning in addressing wicked problems	1. Have you ever used these events as examples, when introducing a science concept? Subsidiary questions: I. (If they say yes) can you share more details about how you did it? II. (If they say no) do you think we can use science learning in addressing wicked problems? How?	a. Participants may recognize the relevance of natural events, such as earthquakes and floods with science education. b. Participants may not recognize the relevance of human-caused events, such as war or migration with science education.	If the participants recognize the relevance of science education with the selected events, then the interviewer asks the participants to give examples. If not, the interviewee moves on to the next construct.
5. Whether participants think we can address wicked problems through culturally embedded science education.	1. If we relate science teaching-learning with students' cultural experiences, do you think, it will help the students to tackle global problems? Subsidiary questions: I. (If they say yes) how can we utilize our science teaching-learning and cultural experiences together to tackle global problems? II. (If they say no) can you suggest, how can we tackle the global concerns?	a. Participants may recognise that the cultural experiences, combined with the present advancements of science education would prepare the future generation to tackle global concerns. b. Participants may perceive that the government may have a more dominating role in tackling global concerns.	1. If the participants recognise the impact of science education and cultural experience on the resolving of global concerns, the interviewer will ask the participant to clarify their point of view with examples.

Step I: Initial analysis

1. Corresponding authors of the countries involved in the study transcribed the interviews from their own countries.
2. While transcribing, further explanations were sought from the participants when needed.
3. Corresponding authors of the countries involved in the study made an initial classification of data based on the constructs of the interview.

Step II: Coding

1. With respect to RQs 1, 2, and 3, the first author conducted an inductive analysis of data to manually generate level I, level II, and level III codes for each participant response to construct 2, 3, and 4 (Tables A1-A3 in appendices illustrated the coding process).
2. The initial coding of data was sent to the authors. Authors with expertise related to science, science education,

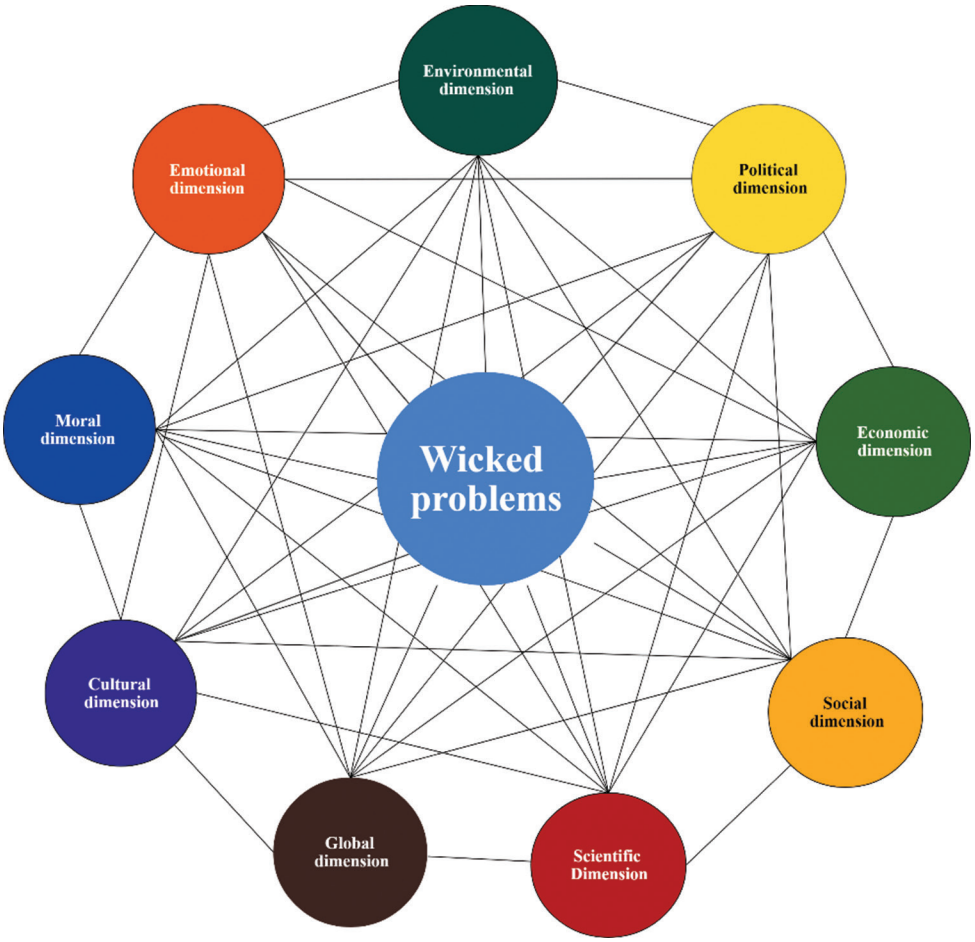

Figure 3: Dimensions of wicked problems

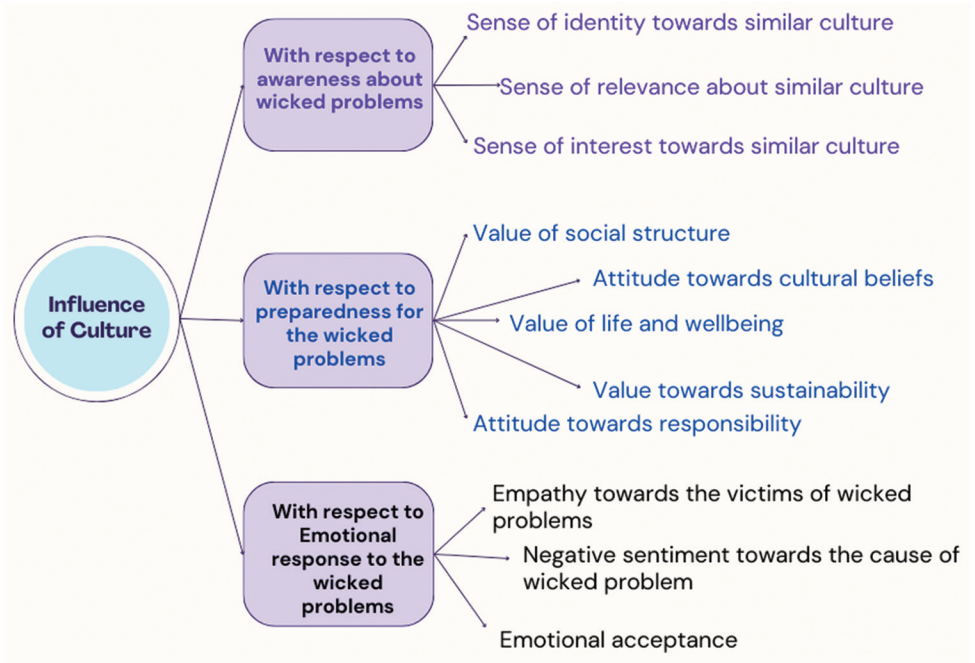

Figure 4: Influence of culture in addressing wicked problems

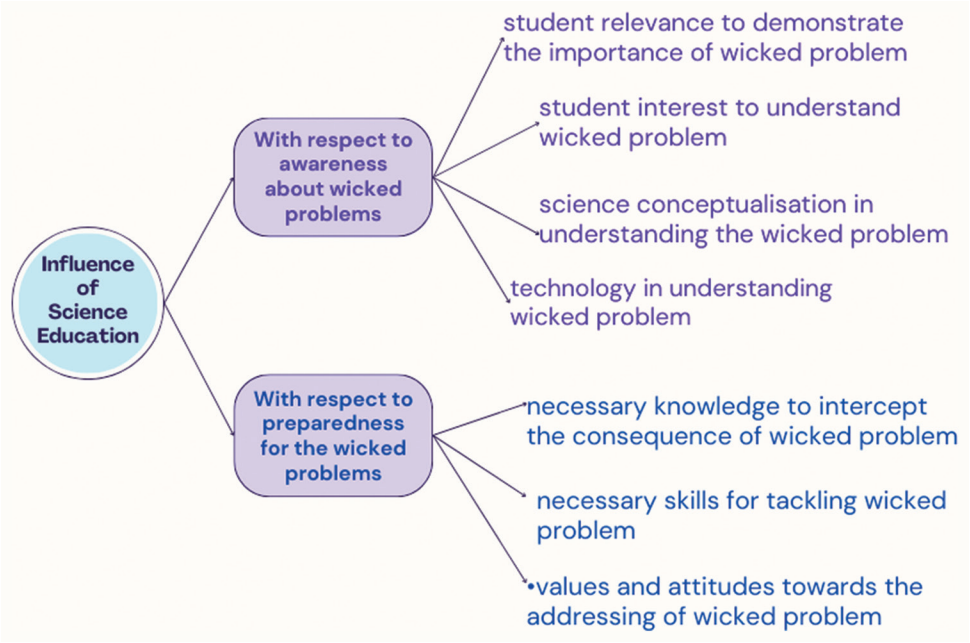

Figure 5: Influence of science education in addressing wicked problems

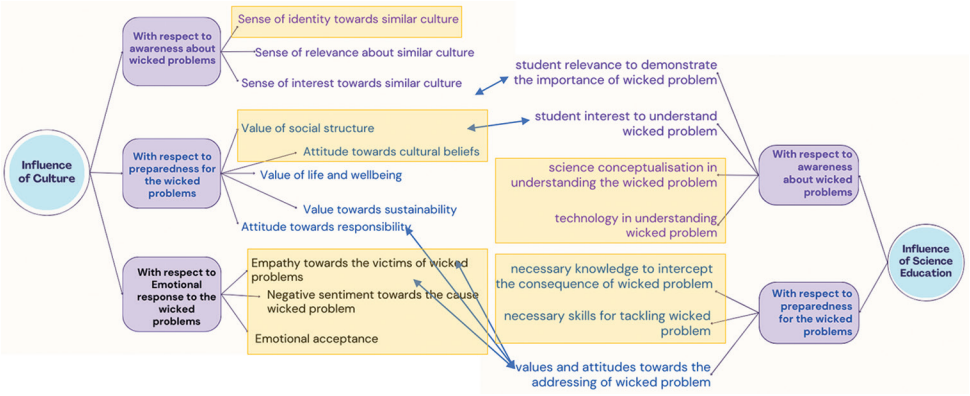

Figure 6: The combined role of culture and science education in co-addressing wicked problems

and philology examined the coding from a scientific, educational, and linguistic point of view.

3. After the consolidation of all authors' agreements, the codes were finalized.

Step III: Final analysis

1. With respect to RQ 1, 2, and 3, the first author generated data representation from the coding, for construct 2, 3, and 4 (Figures 3-5, respectively). With respect to RQ 5, the representations for constructs 3 and 4 were contrasted to identify the communalities and differences between the aspects promoted by culture and science education in addressing wicked problems (Figure 6).
2. Participant responses to construct 5 were utilized to validate the finding to RQ5.
3. All authors were consulted and agreement was consolidated in finalizing the analysis.

Utility, Validity and Reliability

The utility, validity, and reliability of the instrument were established though the following steps:

Utility of the visual aids

Initially, the images were primarily agreed by the authors from the corresponding countries. Expert consultations were then sought from science educators to establish the relevance of the images. Participants' referrals to the images during interviews were also observed to justify the utility of the image. For example, U5 consistently related to the images while discussing the wicked problems:

> *"Here I can see devastation and ruins after the earthquake* (referring to the image demonstrated by the interviewer)*, and we also have a lot of very similar photos taken in our cities and towns during the war*",

> "*Speaking about a flood in Bangladesh, on the one hand, it is quite far from us, on the other hand, when I see the picture, something reminds me what we have recently had in Ukraine* (referring to the disastrous destruction of the Kakhovka dam in June 2023 that caused extensive flooding in the south of Ukraine)." (U5)

Such resemblance allowed her to draw parallels between the events for which she was familiar, and those depicted in the photos for which she had only heard about, before or during the interview. The images also made it easy for the participants to associate with the events from cultures besides their own.

Validity of the instrument

The instrument was primarily validated by experts with a science education and philology background. Upon consultation with the experts, some modifications were made; for example, terminologies were simplified, and sample questions were modified. Pilot interviews were conducted, and based on the participants' responses taken as being in line with the research question – the instrument was considered valid.

Reliability of data analysis

The coding approach and data interpretation were primarily generated by the first author and reviewed independently by all contributing authors. Based on the constructive feedback from all authors, both with expertise in science education, and linguistics, minor modifications were made to the data coding (for example, revising and using simple terminology). In case of disagreement with respect to the data representation, authors reached consensus through discussion and consolidation of opinion. Based on the final codes and representation being replicable, the data analysis was considered reliable.

FINDINGS

Awareness about Wicked Problems

Based on the responses of participants to construct 1 in the interview instrument, participants' awareness about wicked problems with respect to their own context, and other contexts were identified. An overview of the findings is given in the following Table 3.

Dimensions of Wicked Problems

From the responses of the participants to construct 2 in the interview instrument, nine interconnected dimensions of wicked problems were identified. While the following Figure 3 was a representation of the dimensions identified by different participants, Table A4 in the appendix demonstrated exemplary participant responses related to the dimensions.

Influence of Culture on Addressing Wicked Problems

From the responses of the participants to construct 3 in the interview instrument, 11 attributes were identified as promoted by culture, which influence the addressing of wicked problems. These attributes were further classified under three wider themes: awareness, preparedness, and emotional response. While the following Figure 4 was a representation of the final data analysis, Table A5 in the appendix demonstrated exemplary participant responses related to the attributes[12].

12. The authors agreed to use the terminology cultural beliefs as opposed to religion (as in figure 4). Religion is seen as including 'a set of beliefs about the nature of the universe, ritual practice, and is embedded in doctrine and tradition' (Abdulla, 2018), Cultural beliefs, are seen as, 'the ideas and thoughts common to several individuals that govern interaction-between these people, and between them, their gods, and other groups-and differ from knowledge in that they are not empirically discovered or analytically proved. In general, cultural beliefs become identical and commonly known through the socialization process by which culture is unified, maintained, and communicated' (Greif, 1994).

Table 3: Participant awareness about the wicked problems (√ = aware, X=unaware)

Country	Participant	Earthquake in Turkey	Migration in Estonia	War in Ukraine	Floods in Bangladesh
Turkey	T1	√	√	√	√
	T2	√	X	√	√
	T3	√	X	√	√
	T4	√	X	√	√
	T5	√	X	√	√
Estonia	E1	√	√	√	X
	E2	√	√	√	X
	E3	√	√	√	X
	E4	√	√	√	X
	E5	√	√	√	√
Ukraine	U1	√	√	√	√
	U2	√	√	√	√
	U3	√	√	√	√
	U4	√	X	√	X
	U5	√	√	√	X
Bangladesh	B1	√	√	√	√
	B2	√	X	√	√
	B3	√	X	√	√
	B4	√	√	√	√
	B5	√	X	√	√

Influence of Science Education on Addressing Wicked Problems

From the responses of the participants to construct 4 in the interview instrument, 7 attributes were identified as promoted by science education, which influenced the addressing of wicked problems. The attributes were further classified under two wide themes: awareness and preparedness. While the following Figure 5 was a representation of the final data analysis, Table A6 in appendices demonstrated exemplary participant responses related to the attributes.

The Combined Role of Culture and Science Education in Co-addressing Wicked Problems

Based on contrast of data representation of constructs 3 and 4 in the interview instrument, the following representation (Figure 6) was generated, so as to identify how culture and science education could together play a stronger role in the co-addressing of wicked problems. The representation was further supported by participant responses related to construct 5 of the interview instrument.

Further justification of the data representation in Figure 6:

1. Participant science teachers identified the role of culture in developing a sense of relevance with, and interest about, a similar culture, which in their perception, promoted awareness about wicked problems within similar cultures. Participants also identified a role within science education as utilizing student relevance and interest about similar cultures to promote awareness about wicked problems. For example, *"We have a topic, "natural disaster" in general science in which we teach about earthquakes, floods, and droughts. When I am realising that my students feel some sort of cultural similarity with Turkish people, I start using the Turkish earthquake as an example in the topic of natural disasters. The students have already seen the videos of the building collapsing. In a way, you can say I am capitalizing on (benefiting from) their interest about a similar culture, to teach science."* (B1)
2. Participant teachers recognized the role of culture in promoting a sense of identity as influential in promoting awareness about wicked problems. They also pointed out that through contextualizing science teaching-learning within relevant wicked problems, such identities could extend to a global scale and promote awareness about wicked problems on a global scale. For example, *"At least, if it is discussed in class, then perhaps it can lead them to some thoughts and reflections about the future of humanity, and about their participation, because many children consider that a global problem - they are out there somewhere, they are global, what can I do?... We don't live in some kind of closed space; we are not disconnected from the rest of the world. We need to know. Thus - When we are facing such an event in our country, so many countries respond to our problem, to the problem of our war, and help us."* (U5)
3. Participants recognized the role of science education in promoting science conceptualization, the necessary skills, values, and attitudes as preparedness for addressing wicked problems. However, the role of culture in promoting preparedness for addressing wicked problems was seen as limited to promoting values and attitudes. Participants also pointed out that cultures needed to adapt based on science conceptualization of wicked problems. For example, *"At this point, new and scientific solutions can be put forward by taking the social culture and scientificity* (the application of scientific methods and principles) *of the earthquake in those countries and adapting them to the norms of their own country."* (T1)
4. Participants identified the role of culture in developing attitudes toward cultural beliefs and social structure which influenced the preparedness for addressing wicked problems. With respect to science education, they expressed the need for sensitivity within a science education approach related to students' social and cultural backgrounds. For example, *". (As a teacher) you can't ignore that the teaching is taking place in a society and society inherently has some common attitude toward cultural beliefs. (Such attitude can be) either in support of beliefs like in Muslim cultures, or against it like in atheist cultures... And of course, students bring their (attitude toward) cultural beliefs when they come to the class. You don't have to agree with their attitude, you just have to respect the fact that they have their own beliefs. If we (as science teachers) don't show tolerance, respect to their (students') beliefs, how can you expect them (students) to grow up as tolerant and respectful to others?"* (B5)
5. Based on the participant responses, a third important component, in addition to promoting awareness and preparedness was identified as facilitated by culture – emotional responses to wicked problems. Such emotional responses were related to empathy toward the victim or negative feeling toward the cause of the wicked problem, or even emotional acceptance when wicked problems occur. With respect to science teaching-learning, participants from Bangladesh and Turkey did not identify with the need for facilitating emotional responses through science education. Furthermore, all Estonian participants perceived the facilitating of emotional responses through science education as contradictory to the purpose of school science. However, all Ukrainian science teachers strongly emphasized the need for science education to enable a positive integration of emotional attributes with respect to wicked problems. Based on linguistic analysis, the participant's agreement to facilitate empathy toward the victims of wicked problems was identified by terminologies such as "help" (23 mentions), "aid" (7), "sympathy" (6), and "empathy" (3). The negative emotional connotations toward the cause of wicked problems were identified by terminologies such as "disaster" (17 mentions, although the interview questions neutrally named the discussed global problems

as "events"), "suffer" (10), "pain" (4), "devastation" (3), "grief" (2).

"In some way, we also teach our pupils to be kinder, to be more sympathetic (through science education). We give knowledge, to overcome such problems. And we give them knowledge, they absorb it, and accept that it is definitely necessary for them sometime in the future. Moreover, we educate them and familiarize them with important concepts. Moreover, it is important that they rely not only on their experience and the knowledge of their country, their culture, but also on what is happening in other countries." (U2)

DISCUSSION

This study sought to identify how science education at the school level and students' cultural experiences could be brought together so as to facilitate student awareness and preparedness toward addressing wicked problems prevailing in society. In so doing, this study explored the conceptualization of wicked problems, the role of culture, together with science education, in co-addressing wicked problems by science teachers, who had first-hand experience in interrelating these with at least one wicked problem.

Enabling Exposure to the Complexity of Wicked Problems

The identification of the suggested wicked problems as complex, subjective, and universally significant by the participant science teachers, was in line with the literature (Carcasson, 2016; Peters, 2017; Rittel and Webber, 1973; Termeer et al., 2019) as were the identified nine dimensions represented in Figure 3 (Colucci-Gray et al., 2013; Costantino, 2018; Strong et al., 2016). However, although all participant science teachers agreed to the multi and interconnected dimensional characteristic of wicked problems, individual teachers did not identify with all dimensions. For example, T1 only pointed out the emotional dimension, T2 only the social dimension, T3 only the global well-being dimension, T4 only the environmental dimension, and T5 only the economic dimension. Furthermore, some individual participant science teachers were not well-informed about all the mentioned wicked problems (Table 3). This implied a lack of holistic awareness and conceptualization of wicked problems by the participant science teachers themselves, and hence a danger of promoting an unproblematic and simplistic account of science learning (Erduran and Dagher, 2014; Lederman, 2019; Venville et al., 2012). In addressing the concern, this research could be seen as recommending that science teachers were provided with appropriate in-service training, so as to facilitate a wider conceptualisation of wicked problems and its contextualization within science teaching-learning.

Depolarizing Science Education and Culture in Co-addressing Wicked Problems, through Culturally Responsive Science Education

Participant science teachers, to some extent, polarized science education and also culture, in their response to constructs 3 and 4 (Figure 6). For example, in construct 3, they did not identify a role of promoting conceptual understanding of wicked problems through culture, neither did they identify a role of developing a sense of identity among students through science education in construct 4. This result was particularly of concern, considering such polarization potentially promoted an image of science to students that was uninfluenced by, and unaccounted for, by culture (Aikenhead, 2007; Akgun and Kaya, 2020; Lederman et al., 2002; Wong and Hodson, 2009). However, with respect to construct 5, (how can science education and culture seek to co-address wicked problems), participants did come to an agreement that possible ways existed for science education to develop a global identity, and culture to promote a conceptual understanding about wicked problems. In this respect, an important consideration of culturally responsible science education was students' sense of identity (Banks, 2009; Nieto, 2010; Yoon and Martin, 2019), and another was to enable the learners to act as agents of change in their cultural setting through an enhanced science conceptualization (Brown and Crippen, 2016b; Hernandez et al., 2013).

Another example of polarization of science education and culture was identified with respect to attitudes toward cultural beliefs and social structure (Figure 6), for which participants later pointed out that science teachers needed to acknowledge students' attitudes toward cultural beliefs and social structure and promote the science learning through a sensitive approach. A particular example brought by a Bangladeshi science teacher was of interest in this regard,

"Recently there was an incident (in one of the Bangladeshi schools)*, where a new science teacher went to a class and told students that belief is an obstacle to science learning. Students, who were coming from very religious families, were very unhappy, and it was all over the media. They even posted* (on social media) *that "science is an atheist propaganda." If these students were to grow up hating science, who would you blame?"* (B5)

The authors of this article agreed and recognized the danger of ignoring students' attitudes toward cultural beliefs in the teaching and learning of science. Hence, this study strongly recommended a culturally appropriate and responsive science education approach, so as to recognize, respect, and utilize students' cultural backgrounds in facilitating their science learning (Banks, 2009; Bransford et al., 2004; Nieto, 2010; Yoon and Martin, 2019).

Facilitating Appropriate Emotional Response through Culturally Responsive Science Education toward Addressing Wicked Problems: A Lesson from Ukraine

A third attribute of culture, influencing the addressing of wicked problems, in addition to awareness and preparedness, was in the facilitating of emotional responses (Figure 6). Participants from all countries reported the development of emotional responses as strongly related to culture, while the facilitation of students' emotional responses through science education was primarily

recognized by the Ukrainian participants. First, the Bangladeshi, Turkish, or Estonian participants' perception of science teaching-learning as *"necessarily uninfluenced"* (E1) by emotions could be explained by the traditional image of science as isolated from human emotions such as empathy, passion, or love (Venville et al., 2012). Second, in explaining the particular viewpoint by Ukrainian participants, there was a need to consider that the war was still ongoing at the time of the interviews (summer 2023). It was perceived that a majority of civilians within a war situation experienced a strong sense of responses being emotional (ICRC, 2016). They commonly applied major emotional attributes in all aspects of life when forming their attitude to the crisis situation:

> *"War today is a social, economic, and cultural disaster for hundreds of millions of people who never see or hear a battle. However, people are also remarkable in war. They mostly do what human beings always do by surviving, acting and adapting, as people's energy and agency are redirected to coping, caring and resisting the inhumanity of war."* (Civilian experience of war)

In the existential situation of war victims' views tended to radicalize, dividing the whole world around them into categories of good/evil, victory/defeat, allies/enemies, and mercy/violence. For them, it was natural that if you were on the good side, you sympathized and helped those suffering from the impact of a wicked problem, as stated by the participant from Ukraine,

> *"I think something has changed in the past two years. When we ourselves face a certain amount of problems, we probably start to treat other people's problems a little differently; we probably become less distant from them*." (U4)

In line with this response, literature suggested that:

> *"Mental and emotional pain has recently been unanimously recognized as a core part of people's experience of war, alongside the thirst, hunger, injury, and displacement of their bodies*." (Slim, 2022)

This research agrees with recognizing the importance of facilitating positive emotional attributes through science education, particularly empathy, so as to contribute to awareness and preparedness through science learning and cultural experience, in addressing wicked problems.

CONCLUSION

In exploring ways through which to address the wicked problems through depolarising science education and culture, this research sought opinions from science teachers who had first-hand experience in tackling at least one wicked problem. The science teachers responded to the four research questions as follows:

The participant science teachers identified the dimensions of wicked problems as multiple and inter-connected but also potentially polarizing. These dimensions were classified as science, culture, economics, politics, environment, global well-being, moral, societal, and emotional.

Participants identified 11 attributes of culture through which to address wicked problems. Among these attributes, promoting a sense of identity with, relevance toward, and interest about similar cultures, were seen as contributing to promoting awareness about wicked problems in a similar culture. Participants also recognized the role of culture in promoting a value of well-being, sustainability, social structure, attitude toward responsibility, and cultural beliefs as influencing preparedness for handling wicked problems. A third component – emotional response, was identified by the participants and was seen as promoted by the culture and hence influential in addressing the wicked problems.

Participants identified 7 attributes promoted by science education, which influence the addressing of wicked problems. In promoting awareness of wicked problems, science education was seen as playing a role in promoting student relating to the relevance and demonstrating the importance of wicked problems, addressing student interest to appreciate and understand the wicked problems, facilitating science conceptualization and use of technology in conceptualizing the wickedness of such problems. In promoting preparedness, science education was seen as playing a role in promoting the necessary knowledge to interpret the consequences of wicked problems, promoting the necessary skills for putting forward potential ways of tackling wicked problems and promoting the holding of values and attitudes in seeking ways toward addressing of wicked problems.

Of particular importance, participants agreed to the need for science education and culture to co-address situations involving wicked problems. In so doing, participants suggested the need to bring students' cultural experiences and science learning closer, to promote science education through a culturally responsive approach, to benefit from students' cultural experiences, and seeking to contribute to the cultural development at the same time.

IMPLICATION, LIMITATION, AND FUTURE RESEARCH

The findings from this study implied that school science education and culture both needed to adapt and enhance, and particularly collaborate, so as to enable the future generation to be willing to meaningfully address wicked problems. The identified dimensions, and dominance of teacher emphasis to certain dimensions, pointed out that there was a need for adequate in-service or pre-service training for teachers so as to enhance their perception of the overwhelming complexity of wicked problems. Although the sample size for this study was limited, this research gave an insight into science teachers' perceptions who had direct exposure to, and first-hand experience in tackling at least one wicked problem. Building on this study, a future undertaking could be a large-scale study so as to potentially identify insights from other contexts. Furthermore, building on the participant teachers' experience, the science education community could design culturally relevant, responsive, and adaptive science teaching learning approaches providing further

insights into the complexities of dealing with wicked problems. The significance of this study was embedded in a multi-cultural nature of research, which allowed the researchers to move past a narrow conceptualization, and gain an international perspective for science education.

Funding

This work was supported by the European Commission Horizon 2020 under Grant [number 952470 (SciCar)].

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APPENDICES

Table A1: Example of level I coding

Participant	Does culture have a role in addressing the wicked problems?	Participant response	Level I code
B1	√	*I think we feel that the Turkish culture is very close to us because of the region and cultural beliefs. Hence, when the earthquake happened, I was checking the updates even though it was not so much on the news anymore. I wanted to know what happened to them.*	Participants recognized the role of culture in developing interest about wicked problems in a similar culture
B2	√	*In our culture, we push our kids to be tolerant and obedient. It's like they have to believe whatever the elders say, do whatever they are told and never question the authority. This impacts on how the young generation reacts to the flood. The floods cause so much damage every year, and yet they don't see what they can do about it. They think it's the government's responsibility.* (B2)	Participants recognized the role of culture in developing an attitude with respect to responsibility to address the wicked problems
B3	√	*We have many disasters happening, not only just flood. There are fire incidents in readymade garments storage. Or some underground chemical storage blowing up the building. Then we have this kind of building collapse for poor infrastructure, if you remember the Rana Plaza incident. You would assume that so many disasters would normalize it, and people will stop acting on it. However, every time after an incident takes place, you will see people from all around the country comes forward to help. This kind of empathy, or urge to help comes from cultural upbringing. I don't think it is an individual thing.* (B3)	Participants recognized the role of culture in facilitating and promoting empathy for those who were affected by the wicked problems
B4	√	*I think our beliefs play a stronger role than we think. I grew up in a Muslim culture, I think many of us are Muslims in Bangladesh. And we have this kind of state of mind that death is inevitable, suffering is a blessing, tolerance is a virtue, life after death is real-life - something like that. Maybe that's why we don't complain much. We see problems, and we are like – let's pray and god will handle it.* (B4)	Participants recognized the role of culture in promoting cultural beliefs which influenced the addressing of wicked problems
B5	X	*I feel that it is very individual how people tackle wicked problems. Culture may have some role in developing individual characteristics, but it does not necessarily influence everyone… Let's say, one family has four kids, and four of them behave differently in a moment of crisis. This is what I mean by individually different.* (B5)	Participant did not recognize the role of culture in addressing of wicked problems

Table A2: Example of Level II coding

Participant	Level I code	Level II code
B1	Participants recognized the role of culture in developing interest in wicked problems in a similar culture	Sense of interest about similar culture
B2	Participants recognized the role of culture in developing an attitude with respect to responsibility to address the wicked problems	Attitude toward responsibilities
B3	Participants recognized the role of culture in facilitating and promoting empathy for those who are affected by wicked problems	Empathy toward the victims of wicked problems
B4	Participants recognized the role of culture in promoting cultural beliefs which influence the addressing of wicked problems	Attitude toward cultural belief
B5	Participants did not recognize the role of culture in addressing of wicked problems	--
T1	Participants recognized the role of culture in promoting views on social structure in the addressing of wicked problems	Value of social structure
T2	Participants recognized the role of culture in promoting the value of sustainability in the addressing of wicked problems	Value of sustainability
T3	Participants recognized the role of culture in promoting perspectives on life and well-being in the addressing of wicked problems	Value of life and well-being
T4	Participants recognized the role of culture in determining the emotional response when a wicked problem takes place	Emotional acceptance
T5	Participants recognized the role of culture in promoting a view on life and well-being in the addressing of wicked problems	Value of life and well-being

Table A3: Example of Level III coding

Level II coding	Level III coding
Sense of identity toward similar culture	Develops awareness about wicked problems in a similar culture
Sense of interest about similar culture	
Sense of relevance toward similar culture	
Value of life and wellbeing	Promotes preparedness for wicked problems
Value of sustainability	
Value of social structure	
Attitude toward cultural beliefs	
Attitude toward responsibility	
Empathy toward the victims of wicked problems	Facilitates emotional responses
Negative sentiment toward the cause of the wicked problem	
Emotional acceptance	

Table A4: Dimension of wicked problems

Dimensions	Examples of participant responses
Cultural dimension	*"The cultural norms of the country affect the profession, future plans, and lifestyle that individuals will choose, that is, they form the basis of their point of view. They are likely to have a different perspective, as different cultural structures will provide diversity. Knowing this teaches us to look at things differently. It enables us to think multidimensionally by gaining a new perspective"* (T1).
Scientific dimension	*"I think, these wicked problems are very linked with advancements in science and technology. The more technology you have, the less consequence you face. For example, the Netherlands also has floods but they use science and technology to reduce the aftermath. Or think about the war. If you have used science and technology, you have more advanced ways to make yourself less vulnerable"* (E1).
Economic dimension	*"These things, like war, or earthquake, or flood, no matter where it happens, it brings an impact on the economy. Let's take the example of the war in Ukraine. It is happening so far from us, yet our economy took a hit. I think every country has the same problem. Price of electricity, gas, everything was up"* (B4).
Social dimension	*"It also creates problems for Estonian society (referring to the refugee influx), because so many people came there. They shared everything they had. This student and his mother say that they received them well. They shared, took something from themselves, and brought everything the migrants needed. Besides, the migrants had to live somewhere there. I think this is also a problem for Estonians themselves, I mean providing these people with regular accommodation, and employment, and the essentials"* (U2).
Environmental dimension	*"The massacre after any of these events (referring to wicked problems), always leaves an impact on the environment. Maybe some of them are directly linked with the environment, like when the flood happens, or an earthquake happens. However, even the war also leaves an impact on the environment, with all the explosions, massive destructions, bombs – it can't be good for a sustainable environment"* (B5).
Emotional dimension	*"We also have recently had flooding in the Kherson region, and we did not have experience of tackling such a large-scale flooding before. Hence, we began, perhaps, to monitor more closely and react more emotionally and thoughtfully to the events taking place on the world stage. That is, it depends on people's own experience, if they have something similar, they draw parallels. Maybe the person from some other country that has never faced such disasters would react less emotionally and not take it so close to heart. Perhaps, these events are not be so carefully considered by them. However, when you have a similar experience, you start taking them closer to your heart and reacting more emotionally and more thoughtfully to similar situations that happen somewhere in another country."* (U4).
Political dimension	*"I saw that a lot of young people, don't really connect how a lot of world events (referring to wicked problems) and or the reaction to world events are actually political. Let's say in general, the political situation of the country determines how the wicked problems are tackled. You can see the refugees of Syria were tackled differently than the refugees of Ukraine. And this is all political"* (E1).
Worldview	*"We are undeniably linked geographically (never before it was this easy to travel and migrate) and also environmental problems are obviously only solvable with all countries having the same agenda and acting mutually in ways that benefit the common goal the most. We are linked economically, also in terms of natural resources, so on and so forth"* (T3).
Moral dimension	*"There is always this moral conflict when it comes to the wicked problem. Let's say the war – on one hand, Russia has shown their support in our liberation war in 1971. There is somewhat a diplomatic relationship between Russia and Bangladesh, they are also investing in Bangladesh. On the other hand, Ukraine is suffering from an unjust war. There is our moral conflict. It's the same when we talk about refugees or prioritizing help toward flood-affected or earthquake-affected countries"* (B5).

Table A5: Influence of culture in addressing wicked problems

Attributes promoted by culture	*Example of participant responses*	Further elaboration	*Example of participant responses*
Awareness about wicked problems in a similar culture	*I was constantly looking for updates about the war in Ukraine. Not just what came to the news on TV, I was also listening to podcasts, watching vlogs. I was very curious about it. However, the fact that I didn't have knowledge about the floods happening in Bangladesh, it can also be a cultural thing. I was assuming it's a Muslim country and I knew that it was very densely populated. The weather was very different, and that of course made many cultural habits different. Hence, it could be so that I wasn't curious because we didn't have any similarity in terms of culture.* (E2)	Sense of identity with similar cultures	*I think culture determines how we respond to problems in other countries. For example, religion, language, or something like that. I am not really sure what is the religion is in Ukraine. And I am assuming Estonia is one of the most atheist countries in the world. But when I compare it with Turkey or Bangladesh, I think our attitude toward religion is more similar to Ukraine than the other two countries. Then there is language. In both cultures, we have some people knowing the Russian language. Our lifestyle and food habits are maybe also close to Ukrainian. This is a big reason Estonians reacted to the Ukrainian war, and not about the war somewhere in Asia let's say. (*E4)
		Sense of interest about similar culture	*I think we feel that the Turkish culture is very close to us because of the region and cultural beliefs . Hence, when the earthquake happened, I was checking the updates even though it was not so much on the news anymore. I wanted to know what happened to them*. (B1)
		Sense of relevance toward events in a similar culture	*That is, it depends on people's own experience, if they have something similar, they draw parallels. Maybe the person from some other culture that has never faced such disasters would react less emotionally and not take it so close to heart. Perhaps, these events are likely not to be so carefully considered by them. However, when you have a similar experience, you start taking them closer to your heart and reacting more emotionally and more thoughtfully to similar situations that happen somewhere in another culture.* (U3)
Preparedness for wicked problems	*I think that different cultures approach the same events differently. Our approach to events is different because people's lifestyles are different and their expectations from life are not the same.* (T5)	Value of well-being	*Nonetheless, our well-being is connected. There can never be a total harmony on Earth when one part of the planet is suffering from natural disasters, another part suffering from wars, when there is a growing threat of global warming and there are still places where basic human needs cannot be met.* (T3)
		Value of sustainability	*I think that different cultures have an influence on people's perspectives and reactions to events. For example, a climate crisis and a series of global problems await the world in the near future. Here, some cultures prefer products with clean content and blend with nature because they look at the event with environmental sustainability, but some cultures do not care about this because they do not have these perspectives.* (T2)

(*Contd*...)

Table A5: (*Continued*)

Attributes promoted by culture	*Example of participant responses*	Further elaboration	*Example of participant responses*
		Value of social structure	*People from different cultures may approach an event from another culture in different ways, considering the surrounding conditions. For example, while women are not supported to enter business life in some cultures, in other cultures, women are supported in business life, and gender equality is prioritized. Every culture has its role distribution. This impacts heavily how they react to a global disaster.* (T1)
		Attitude toward cultural beliefs	*I think our beliefs play a stronger role than we think. I am raised in a Muslim culture, I think many of us are Muslims in Bangladesh. And we have this kind of state of mind that death is inevitable, suffering is a blessing, tolerance is a virtue, life after death is real-life - something like that. Maybe that's why we don't complain much. We see problems, and we are like – let's pray and god will handle it.* (B4)
		Attitude toward responsibilities	*In our culture, we push our kids to be tolerant and obedient. It's like they have to believe whatever the elders say, do whatever they are told and never question the authority. This impacts on how the young generation reacts to the flood. The floods cause so much damage every year, and yet they don't see what they can do about it. They think it's the government's responsibility. (*B2)
Emotional response	*I think how we emotionally accept or deal with the wicked problems, would be very similar in similar culture, such as Estonia and Ukraine. I have always thought that our emotions, like how we learn to feel about different things are taught by our culture, or at least the initial process begins with the help of culture. Maybe people change over time. However, let's say how I would feel when I see an innocent man suffering – comes very much from culture.* (E1)	Empathy toward the victims of wicked problems	*We have many disasters happening, not only just floods. There are fire incidents in readymade garments storage, or some underground chemical storage blowing up the building. Then we have this kind of building collapse for poor infrastructure, if you remember the Rana Plaza incident. You may assume that so many disasters may normalize it, and people stop acting on it. However, every time after an incident takes place, you see people from all around the country coming forward to help. This kind of empathy, or urge to help comes from the cultural upbringing. I don't think it is an individual thing.* (B3)
		Negative sentiment toward the cause of the wicked problem	*Civilians, their first reaction is based on cultural background for sure. Estonians are always anti-war. In some cultures, war or violence is more normalized, like they may even be proud if they initiate a war. But it's a very cultural thing that we don't like when someone initiates a war. Hence, I saw a lot of negative sentiment when the war started.* (E3)
		Emotional acceptance	*There may be a few events where people's emotional reactions may differ according to some traditional characteristics of the culture. For example; While a Turkish person may approach the event more dramatically, a German may be much more cold-blooded.* (T4)

Table A6: Influence of science education in addressing wicked problems

Attributes promoted by science education	*Example of participant responses*	Further elaboration	*Example of participant responses*
Promoting awareness about wicked problems	*To make the matter more approachable and relatable, I (as a science educator) always give examples of what happens in our country geographically and in terms of physics. While explaining the phenomenon, I supply examples not only from my country but from countries all around the world.* (T2)	Promoting student relevance to demonstrate the importance of wicked problems	*In my class, students do not face floods as much as they do in Sylhet (flood-affected area). I can say, they probably face some small earthquakes but not as big as Turkey. I do have Rohingya people in my class (refugees), but none of my students have faced any war. Does that mean they don't need to know about these? No. They do. Because no matter what kind of wicked problem it is, the aftermath is quite the same – shortage of food and pure water, affected mental and physical health. And these are linked with science. Hence, students know, this is also related to them.* (B4)
		Promoting student interest to understand the wicked problem	*Moreover, here is an example of an event that happened quite recently, students can watch reports and videos about it on the Internet, on YouTube, and on TikTok, which brings them closer to the events and the whole topic. It really illustrates what we talk about in the lessons, and really boosts up the students' interest.* (U3)
		Promoting of science conceptualization in understanding the wicked problem	*I (as a science educator) told my pupils about the earthquake in Turkey as an example of gigantic waves, when we discussed the topic "Waves", and also in the topic "Energy", because an earthquake is an enormous release of geophysical energy. And I tell about the connections, and the way sciences study these events, we definitely discuss various aspects of current global problems in our lessons. (U2)*
		Promoting of technology in understanding the wicked problem	*One of the latest events, such a catastrophe, is the blowing up of the Kakhovska HPP, our power plant, by the Russian invaders. The Kakhov Reservoir is already drying up. I (as a science educator) suggested that the children use Google Maps to monitor how the basin of our river Dnieper is changing in general, how this spot is changing its shape, I mean the flooding of our territories.* (U1)
Facilitating Preparedness for Addressing Wicked Problems (I)	*Especially about earthquakes; we (science educators) enable them to internalize what to do before, during, and after the earthquake with practices and exercises. We also try to minimize its psychological effects with stories and case studies (with help from the guidance service). (T3)*	Promoting necessary knowledge to intercept the consequence of wicked problems	*The Turkish earthquake example is a good example of providing first aid for injuries, such as limbs, when we speak about the musculoskeletal system. We also discuss what we can do to stop critical bleeding until professional help comes. I explain why they need to be able to apply a tourniquet in case of injury and how to do it.* *In Biology classes, when we spoke about bacteria, I explained how to purify water, and how to preserve products to avoid intoxication on the example of our war conditions. All these examples, to a greater or smaller extent, related to the preservation of health, the provision of medical aid, until the rescuers, doctors, and other services arrive, to be able to help the closest person or oneself.* (U4)
		Promoting necessary skills for tackling wicked problems	*There is problem-solving, which we teach in science class, so students become like problem-solvers. They use math, logic, machines, and everything they learned in the science class to solve the problems. And then there is critical thinking - they learn to get all the facts, then analyze. This is very necessary to come up with strategic plans when a disaster happens.* (U4)
		Promoting values and attitudes toward the addressing of wicked problems	In the Basics of Health, I tell the children about air raids, mines, and how to behave in the street during an explosion, and about emergency situations such as chemical releases, nuclear releases, and so on. We want to prepare students in a way so that the psychological effect is minimal. (U5)