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LIST OF ABBREVIATIONS

AIC: Active Informed Citizenry

CBL: Context-based learning

SSI: Socio-scientific Issues

CLARIFICATION OF KEY TERMS

The following terms sometimes appear as synonymous in science education literature. In extending the role of science education, shifting from a traditional individual development vision towards a comprehensive societal development vision, the author of this thesis recognises the need to distinguish these terms separately. The following clarifies the terminologies.

a) citizen, citizenship, and citizenry

Citizen refers, in this thesis, to member of a particular society, while *citizenship* is identified as the status, or membership of any citizen within a specified group.

C*itizenry* is used, in this thesis, to indicate a collective group of citizens, who are seen as acting or needing to act as a unified body.

b) social, and societal

Terminologies like social and societal overlap in the literature, often used interchangeably as synonyms when referring to a society.

Both social concerns or societal concerns refer to concerns related to the society. For example, they both relate to, but are not limited to, the recent COVID-19 pandemic, or climate change, or sustainability related concerns.

The author differentiates between social and societal, when related to the need to refer to ‘development’ via science education in addressing concerns within the society.

The author interprets social development as development of members of the society as individuals (i.e., development of the citizens). Societal development is used to reflect on the development of the society as a collective whole (i.e., development of a citizenry).

These are further elaborated in sections 4.3 and 5.2.

LIST OF ORIGINAL PUBLICATIONS

This thesis reflects on five original publications, conducted as part of the doctoral research. In the following, the publications are listed as they appear in the text:

Paper 1: **Chowdhury, T. B. M.**, Holbrook, J., & Rannikmäe, M. (2020). Socioscientific Issues within Science Education and their Role in Promoting the Desired Citizenry. *Science Education International*, *31*(2), 203–208. https://doi.org/https://doi.org/10.33828/sei.v31.i2.10

Paper 2: **Chowdhury, T. B. M.**, Holbrook, J., & Rannikmäe, M. (2019). Teachers' Ownership Towards Using Socio-Scientific Issues for an Active Informed Citizenry. *EDULEARN19 Proceedings*, *1*, 3834–3840. https://doi.org/10.21125/edulearn.2019.0989

Paper 3: **Chowdhury, T. B. M.**, Holbrook, J., & Rannikmäe, M. (2020). Addressing sustainable development: Promoting active informed citizenry through trans-contextual science education. *Sustainability (Switzerland)*, *12*(8), 3259. https://doi.org/10.3390/SU12083259

Paper 4: **Chowdhury, T. B. M.**, Holbrook, J., Reis, P., & Rannikmäe, M. (2021). Bangladeshi Science Teachers' Perceived Importance and Perceived Current Practices in Promoting Science Education Through a Context-Based, Socio-scientific Framework. *Science & Education*. https://doi.org/10.1007/s11191-021-00236-9

Paper 5: Holbrook, J., **Chowdhury, T. B. M.**, & Rannikmäe, M. (2022). A Future Trend for Science Education: A Constructivism-Humanism Approach to Trans-Contextualisation. *Education Sciences*, *12*(6). https://doi.org/10.3390/educsci12060413

The author responsibilities for the papers 1–5 were:

a) Overall conceptualisation of the research problem and approach;
b) Writing – original draft preparation;
c) Undertaking methodological approach to sample selection, instrument construction, data collection, data analysis, and establishment of validity and reliability;
d) Constructing meaningful discussion based on data, and literature;
e) Writing, revising manuscript based on supervisors', reviewers', editor's comments, suggestions, and requirements.

1. INTRODUCTION

In today's world, society is constantly facing new challenges, particularly within the scope of social, economic and environmental sustainability (United Nations, 2015). In mitigating against these concerns, education policies identify the role of education as preparing learners towards meeting the needs of a constantly-changing and sustainable-oriented society (Estonian Government, 2011; Constitution of Bangladesh, 1997; OECD, 2018) and undertake responsible, scientifically informed and collective actions for the future (OECD, 2018). Particularly with respect to enhancing scientific literacy, an envisaged goal of school science education (Holbrook & Rannikmäe, 2009), learners are prepared to develop an awareness of the role of science in the society (Hodson, 2003; OECD, 2008; Osborne, 2000; Pella et al., 1966). Nevertheless, school science teaching-learning has been seen as inadequate with respect to both promoting such core values and practices of science (Tanenbaum, 2016), as well as promoting scientific literacy for enabling learners in undertaking an active role in the learning process (Owens et al., 2020).

In promoting scientific literacy, within school science curricula, learning activities are proposed via a school teaching-learning framework, so as to develop scientific knowledge, skills, values and attitude (Blanco-López et al., 2015; Kori, 2022; Yao & Guo, 2018). In some science curricula, a particular emphasis is given, to promote social and citizenship competence, enabling students to acknowledge 'local and global environmental issues as well as seeking solutions' (Estonian Government, 2014, p.3), and prepare learners to 'contribute to societal development' (Ministry of Education of Bangladesh, 2022, p. 46). However, regardless of the policy, or curricula envisaged, school science practices are, in general, revealed to be irrelevant with respect to both students' interest in learning conceptual science and in its applicability to enhance societal development (Evagorou & Dillon, 2020; Mudaly, 2020; OECD, 2019a). Furthermore, it has been claimed that an over-emphasis on conceptual science is detaching science learning from a societal focus and hence is perceived to poorly prepare learners to identify the relevance of science in addressing societal concerns (Chmielewski, 2021; Levrini et al., 2021; Pietrocola et al., 2021).

In addressing the relevance of school science for society, researchers frequently advocate the need to incorporate socio-scientific issues (SSI) in science teaching-learning (Hancock et al., 2019; Holbrook & Rannikmäe, 2014; Parchmann et al., 2017; Pelch & McConnell, 2017). Such an inclusion has been seen as beneficial in promoting learners as responsible and competent citizens within the society (Garrido Espeja & Couso, 2020; Rundgren & Chang Rundgren, 2018). Yet, multiple studies report that science teachers exhibit resistance towards incorporating such society relevant issues in their teaching practice, because of a perceived content-overload in the curriculum, leading to teachers omitting SSI-based instructions (Herman et al., 2017; Levinson, 2006; Tidemand & Nielsen, 2017).

Although the inclusion of socio-scientific issues was reported beneficial in promoting learners' awareness of societal concerns (Klaver & Molen, 2021; Macalalag et al., 2020), a question can be raised as to whether simply promoting awareness is sufficient, or whether science education needs to play a role in addressing societal development (Bencze et al., 2012; Carroll & Conboy, 2020; Klaver & Walma van der Molen, 2021).

This research is based on two aims.

Initially, this research aims to identify the contribution of SSI in promoting citizenry in addressing societal concerns. In line with this, the following research questions are put forward:

1a) In what ways does the *literature* identify the contribution of SSI towards promoting citizenry?
1b) In what ways do *teachers*, familiar with an SSI-based teaching approach, perceive the contribution of SSI towards promoting citizenry?

This research also aims to establish and justify a theoretically sound and practically applicable model, through addressing the need for school science education to play a stronger role in scientifically enhanced societal development, beyond SSI-based classroom decision-making. In line with this, the following research questions are put forward:

2a) In what way can a science teaching-learning model be synthesised, based on the *literature,* to address societal development by promoting citizenry?
2b) To what extent do *teachers* perceive the importance of, and perceive their practice towards incorporating, a science teaching learning model addressing societal development?
2c) To what extent do *science education researchers, curriculum developers and teacher educators* perceive the value, feasibility and challenges towards incorporating a science teaching learning model for societal development?

1.1 Overview of the research

In paper 1, a purposeful narrative review of the literature was conducted, to identify the multidisciplinary roles of SSI in meeting the societal goals within science education for promoting citizenry.

In paper 2, teachers' perception towards incorporating socio-scientific issues towards promoting learners as citizens of the society, was reported via a qualitative approach, by undertaking interviews with science teachers familiar with dimensions involved within socio-scientific issues.

In paper 3, a 4-phase science teaching-learning model was put forward, building on a literature based 3-stage model, addressing the promotion of a collective body of citizenry who are scientifically informed, willing to and able to collectively engage in addressing societal development (Active Informed Citizenry AIC).

In paper 4, teacher perception of the importance and perception of practice towards incorporating different attributes of the 4-phase model were reported, based on a quantitative instrument developed by the author, evaluated by experts, and validated through a pilot study.

In paper 5, opinions from science education researchers, curriculum developers and a science teacher trainer, were reported with respect to the need to extend a literature defined 3-stage model, to value a 4th phase, and to identify the potential challenges with respect to implementing the 4th phase.

In addition to the papers, a classroom teaching module was devised in this research (appendix A4), based on the 4 stages, evaluated and validated by science education experts, curriculum experts, and science teachers.

2. LITERATURE REVIEW

2.1 Theories of learning

This research is based on two learning theories established in the literature: constructivism and humanism.

Constructivism

Although there is a lack of consistency in defining constructivism (Harlow et al., 2007), based on the literature, constructivism is perceived in this research as – a theory of constructing knowledge from experience (Piaget, 1976), focusing on the learners' active interaction (Bruner, 2009), especially within socio-cultural factors (Vygotsky, 1978). A constructivist teaching approach is based on the philosophically and psychologically rooted constructivism theory of learning (Perkins, 1991; Fensham et al., 1994).

In contrast to conditioning theories and information processing theories, which tend to define and operate *what* learners think (Schunk, 2012), the constructivism theory of learning emphasises the need for teachers to conceptualise *how* the learners think and how to enrich their thinking (Seifert & Sutton, 2019). In so doing, constructivism perceives that students play the active role in constructing knowledge (Bruner, 1966). However, constructivists differ in the orientation in which this active participation take place. Thus psychological constructivists perceive that students, individually, construct knowledge from experience by assimilating, accommodating, equalising and finally internalising new information or experience (Piaget, 1955), while the social constructivists emphasise the need for collaborative learning (Jerome Bruner, 1985), ensuring interaction between the learners and teacher (Oxford, 1997), or even the society (Vygotsky, 1978).

In science education, the incorporation of teaching and learning activities based on constructivism, in particular social constructivism theory of learning, has been advocated by many researchers (Bingle & Gaskell, 1994; Develaki, 2021; Lima & Nascimento, 2022; Sánchez Gómez, 2021). Such science teaching and learning activities, based on constructivism theory, focus on enabling students to construct their science conceptualisation from prior experience (Zeidler et al., 2005), meaningfully stemming from a social, or cultural context (Cobb & others, 1994; Cobern, 2012). The science education literature often reports such a constructivist approach as beneficial in addressing student motivation to learn science (Palmer, 2005), as well as facilitating the promoting of conceptual learning (Banet & Ayuso, 2003), socio-scientific decision-making (Chen & Xiao, 2021), and even encouraging students in pursuing science-related careers (Wild, 2015).

Humanism

While a constructivist approach to teaching and learning is intended to meaningfully promote students' active participation in achieving cognitive knowledge and skills (Cooper, 1993; Gray, 1997), educators have argued that constructivism lacks an emphasis on enabling students' empowerment (Tangney, 2014); holistic lifelong learning (Mezirow, 2018); self-development (Huitt, 2009), and the addressing of social concerns (Tobolowsky, 2014).

In addressing this gap, the humanism theory of learning emphasises the need to promote non-cognitive variables, such as the learners' self-efficacy (Bandura et al., 1999) and self-actualisation (Maslow, 1989), with an aim to stimulate responsible, justice-oriented and democratic behaviour among learners (Tangney, 2014). In this thesis, based on the literature, the humanism theory of learning is perceived as a 'holistic' approach (Graham & Weiner, 1996), enabling the learners' personal growth, with the added emphasis on instigating students' intrinsic motivation (Deci & Ryan, 2010) for societal reform (Veugelers, 2011) through achieving students' self-efficacy and self-actualisation (Schunk, 1991, 2012). Furthermore, the humanism theory of learning is seen as stressing:

a) the learners' acquisition of social and affective skills through cooperative and collaborative learning (Huitt, 2009);
b) promoting critical thinking, positive changes in attitude, plus logical and persuasive actions (Hale, 2020), and
c) inclusion of argumentation on value-laden, societal concerns (Alexander & Bushnell, 1997).

In science education, a humanism orientation for promoting learning is seen as enabling science education to have a meaningful role in reflecting on society sustainability issues (Li et al., 2022). Science teaching learning activities, based on humanism theory of learning, further support socio-scientific argumentation on value-laden, social concerns (Allgaier, 2010) and in addressing society development such as dialogue among citizens (Liu, 2013). Within science education, the humanism addition places an emphasis on promoting socio-scientific decisions, which lead to the active and collective participation within society. In particular, the humanism approach can be seen as a way of addressing social transformation via scientific literacy (Santos, 2009; Scantlebury & Milne, 2020; Sharma, 2012).

2.2 Aims of science teaching-learning

In general, education is perceived as promoting democracy and human rights, enhancing global citizenship and tolerance, initiating civic engagement, and addressing sustainable development (United Nations, 2015). Incorporating this United Nations education vision, the Organisation for Economic Co-operation and Development (OECD) advocates the role of education as addressing challenges within three domains, e.g. social, economic and environmental (OECD, 2018a). In line with that, the United Nations Educational, Scientific and Cultural Organization (UNESCO) emphasises the need to 'transforming the goals of education toward achieving peaceful, inclusive and sustainable futures of humanity and the planet' (UNESCO, 2022).

Within a science education framework, the aim of science education in the 1960s was more oriented to 'produce citizens who understood science and were sympathetic to the work of scientists' (DeBoer, 2000). A call for orienting school science towards 'science for all' could be particularly recognised since the 1980s (Fensham, 2003; Fensham & Harlen, 1999). This 'science for all' movement incorporated a new dimension of promoting 'scientific literacy', primarily introduced as 'science literacy' (Hurd, 1958), within school science teaching (Fensham & Harlen, 1999), the promotion of which was often associated with the aim of science education (Sadler & Zeidler, 2009).

Within the literature, promoting conceptual science learning can be seen as the predominant aim of science education (Bybee, 1993; Duschl, 2002; Duschl, 1990; Holbrook & Rannikmäe, 2009; Osborne, 2000; Pella et al., 1966), thereby perceived as cognitive learning by individual learners (Skinner, 1989). However, beyond the individual cognitive learning, towards a more social and societal development dimension, further aims of science education have been put forward as:

a) enabling learners to implement scientific knowledge and skills in explaining scientific phenomena (OECD, 2008), engaging in scientific activities, and resolving scientific problems (Duschl, 2002);
b) preparing learners as able to utilise science learning in making career-related decisions (Bybee, 1993; Holbrook & Rannikmäe, 2009);
c) developing an awareness of the role of science in the society (Hodson, 2003; OECD, 2008; Osborne, 2000; Pella et al., 1966), and everyday life (Duschl, 2002; Holbrook & Rannikmäe, 2009);
d) empowering learners to engage in scientifically embedded, societal concerns (Bybee, 1993; European Commission, 2015; Hodson, 2003; Holbrook & Rannikmäe, 2009; OECD, 2008; Osborne, 2000), and
e) preparing learners as future citizens (Auld & Morris, 2019; Bybee, 1993; Hazelkorn et al., 2015), for undertaking democratic, economic (Hodson, 2003; Osborne, 2000), socio-scientific decisions (Holbrook & Rannikmäe, 2009; Osborne, 2000).

Although a critical aim of science education is seen as promoting learners as citizens (Auld & Morris, 2019; Hodson, 2014; Jack et al., 2017; Osborne, 2000), a lack of consistency can be identified in the science education literature with respect to the kind of citizens to be promoted via science education. For example, science education can be claimed as having an intent promote cognitive outcomes leading to prepare citizens who are able to conceptualise the role of science in society, i.e. informed citizens (Duschl et al., 2013; Kahn & Zeidler, 2019). Other science educators recognise the need for promoting behavioural aspects, i.e., preparing learners through science education, to undertake engagement within the society, so as to be active citizens (Hadjichambis et al., 2019; Maass et al., 2021; Marques & Reis, 2017). Furthermore, other citizenship dimensions are suggested as promoting socio-emotional aspects, leading to promoting a collective body of global citizens (citizenry) who are responsible (European Commission, 2015; Evagorou & Dillon, 2020; Garrido Espeja & Couso, 2020; OECD, 2019b), democratic (Kolstø, 2008; Jenkins, 2006), justice oriented and politically concerned (Lozano-Díaz & Fernández-Prados, 2020; Maass et al., 2021).

2.3 Approaches to science teaching-learning

Context-based Learning

In enhancing students' active engagement in the science learning process and bridging the gap between students' science conceptual learning and the application of the learning to everyday life, 'Context-Based Learning' (CBL) has been put forward as a very pragmatic approach (Vocht et al., 2017; Kang et al., 2019; Podschuweit & Bernholt, 2018; Vos et al., 2016). The intention of such context-based learning is more than addressing a perceived shift in science education towards a more social interrelationship (Swirski et al., 2018). It also addresses perceived science-in-society key challenges, such as – interrelating science and society, thereby paying attention to an adequate emphasis on transferring science learning to everyday life (Gilbert, 2006; Gilbert et al., 2011; Podschuweit & Bernholt, 2018; Sevian et al., 2018).

Based on the literature, context-based learning is seen as a pedagogical methodology, applicable in science and technology education (Yu et al., 2015), so as to embed science content within a societal topic, or 'context' (Podschuweit & Bernholt, 2018). Such an approach is seen as beneficial to initiate students' conceptualisation of relevance of the science topic through societal concerns (Sadler, 2011), and thus intriguing student interest to enhance their engagement in science leaning (Pilot & Bulte, 2006).

Socio-Scientific Issues (SSI)

Socio-scientific issues (SSI) are controversial (Zeidler & Sadler, 2007) socially embedded issues within a scientific context (Linder et al., 2011). Such issues are ill-structured (Yahaya et al., 2016) and encompasses ethical (Zeidler et al., 2009), moral (Morris, 2014) and value laden views (Hong & Chang, 2004). As opposed to a scientific problem, a socio-scientific issue does not have a clear-cut solution. Hence, in order to resolve an SSI, science teaching-learning requires developing students' scientific evidence-based argumentation skills (Zeidler et al., 2009); moral reasoning (Sadler & Donnelly, 2006), and informed decision-making abilities (Yacoubian & Khishfe, 2018).

The contemporary vision of scientific literacy heavily emphasises the need for learners to transfer their science learning to 'real-life contexts' (Sadler & Zeidler, 2009), promoting learners' social values (Holbrook & Rannikmäe, 2007) through developing informed decision-making skills on 'contextually embedded science and social issues' (Zeidler & Sadler, 2010). Hence, over the last two decades (Ke et al., 2021), science educators have been advocating the importance of incorporating socio-scientific issues (SSI) as 'contexts for transforming science learning opportunities' (Ekborg et al., 2013; Espeja & Lagarón, 2015b; Reis & Galvão, 2004; Romine et al., 2017), towards achieving scientific literacy (Böttcher & Meisert, 2013; Constantinou et al., 2018; Galvão et al., 2011; OECD, 2004).

A 3-stage Teaching Approach based on CBL and SSI

Through incorporating SSI within a context-based learning framework, a 3-stage teaching approach, namely *contextualisation-de-contextualisation-re-contextualisation* (Holbrook & Rannikmäe, 2010), has been developed to address major concerns in science education following an 'education through science' philosophy (Holbrook, 2010; Holbrook & Rannikmäe, 2007, 2010). In demonstrating the constructs of the 3-stage model, figure 1 is adapted from Holbrook and Rannikmäe (2014).

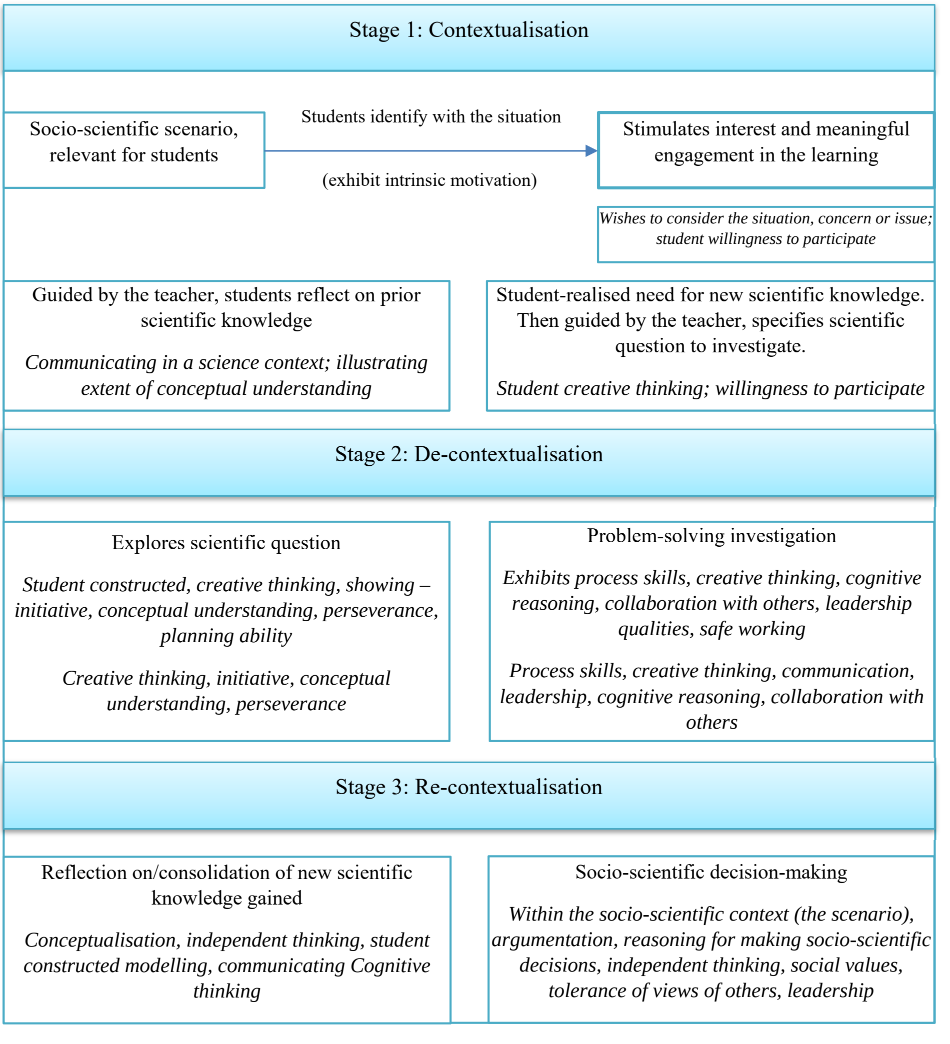


Figure 1: An SSI-based, 3-stage model

Within the 3-stage model in the above figure 1, three important attributes can be identified – student motivation, student scientific problem solving through an inquiry-based approach and student socio-scientific decision-making.

Student Motivation

Motivation theories of learning indicate that, while a lack of motivation leads students to undertake surface learning (Pintrich & Schunk, 2002), positively motivating students can lead to a willingness to engage in learning approaches (for example, questioning, participation in groups, self-learning) (Schunk et al., 2008). Student motivation is also emphasised in constructivism and humanism theories of education, seeing such motivation as initiating students to actively participate in learning activities (Cooper, 1993), or in a collaborative learning process (Huitt, 2009) It is thus not surprising that in recognising the role of motivation, context-based learning within a socio-scientific framework is seen as seeking to:

a) intrigue student motivation (Hewitt et al., 2019; Valdmann et al., 2017);
b) stimulate interest for science learning (Morris, 2014; Sevian et al., 2018), and
c) actualise relevance of science within everyday life (Hancock et al., 2019; Kara, 2012), or even future life (Lewis & Leach, 2006; Ottander & Ekborg, 2012; Zeidler et al., 2011b).

Incorporating SSI within a context-based learning framework is often seen as a way forward to overcome concerns related to promoting student motivation (Bennett & Lubben, 2006; Lee et al., 2006; Zeidler & Nichols, 2009) by addressing: a lack of student interest in science learning (Kang et al., 2019); a lack of relevance of science with respect to societal aspects (Brunner & Abd-El-Khalick, 2020; Davis & Krajcik, 2005; Parchmann et al., 2017), and students' perceptions of their competence (Sevian et al., 2018).

Student scientific problem-solving:

Overall, the literature suggests that context-based learning is designed with a view to embed student scientific problem-solving within a societal context (Kahn & Zeidler, 2016; Sadler et al., 2016) and seeing such problem-solving approaches, within a well-defined context, as being expected to activate students' transfer of learning to address the scientific problem (Bolte et al., 2012; Bolte et al., 2011; Holbrook & Rannikmäe, 2010). Incorporating SSI within a context-based learning framework thus intends to promote students' scientific problem-solving competence (Chen, 2020; Giri & Paily, 2020; He et al., 2020; Yu et al., 2015), which is seen as a major contributing factor in promoting scientific literacy (Böttcher & Meisert, 2013; Constantinou et al., 2018; Galvão et al., 2011; OECD, 2004). More specifically, students' scientific problem-solving, through an contextual inquiry-based learning approach, involves students in conceptualising scientific ideas (Choi et al., 2014), on a 'need-to-know' basis (Holbrook & Rannikmäe, 2014) and applying the gained science conceptual learning in resolving a posed scientific problem (Yu et al., 2015). Furthermore, students' active engagement within social constructivist learning facilitates the gaining of conceptual understanding of science, especially in a challenging problem-solving setting, involving self-learning, or group learning, activities (Schunk et al., 2008).

Student socio-scientific decision-making:

Socio-scientific decision-making, based on a constructivist learning approach, is considered as a situated and social metacognitive learning process (Wray & Lewis, 1997), enabling students to apply their science learning in undertaking scientific evidence-based argumentation (Chen, 2020; Giri & Paily, 2020; He et al., 2020). In so doing, incorporating SSI within a context-based learning framework aims to enhance students' moral reasoning skills (Kahn & Zeidler, 2019; Oh, 2019), ethics considerations (Barrett & Nieswandt, 2010; Berne, 2014; Tsai & Jack, 2019) and justification of values (Dorph et al., 2018; Koster & de Regt, 2020; Sutter et al., 2018). In fact, research in science education advocates that incorporating SSI within a context-based learning framework promotes citizenship aspects, identified by different researchers as: responsible citizenship (Espeja & Couso, 2020), competent citizenship (Rundgren & Chang Rundgren, 2018), global citizenship (Kim et al., 2020; Uzel, 2020), or even environmental citizenship (Iversen & Jónsdóttir, 2019), etc.

Extending the 3-stage model

The 3-stage teaching approach is based on a constructivism theory (Holbrook & Rannikmäe, 2014). However, Santos (2009), Scantlebury & Milne (2020) and Sharma (2012) point out that in addressing the need to enhance scientific literacy for societal transformation, science teaching learning requires a humanism orientation. In so doing, the literature further advocates the need to incorporate students' collective engagement within the society (Hodson, 2014), through science teaching and learning (Cohen et al., 2020; Felt, 2017; Furman et al., 2020; Jeong et al., 2021; Mudaly, 2020; Valladares, 2021).

Lima and Nascimento (2022) indicate that promoting a need for a creative approach to the teaching of science so as to stimulate scientifically influenced, collective actions related to a societal concern, requires a vision of science education going 'beyond' the classroom context. Furthermore, the integration of such a 'beyond classroom', societal context, is seen as enabling science education to encompass the involving of students in seeking creative ways of transferring their socio-scientific decisions to relevant real life situations (Morin et al., 2017).

From a developmental point of view, the 3-stage model addresses students' individual development via enhancement of their motivation (Valdmann et al., 2017) and promoting inquiry-based, science conceptual learning (Bolte et al., 2012). Such an approach further enhances students' social development via the third stage by seeking to promote student argumentation and decision-making involving socio-scientific issues (SSI) (Holbrook & Rannikmäe, 2014). However, Evagorou and Dillon (2020), Garrecht et al. (2018) and Mudaly (2020) recognise the need to incorporate a societal development focus within science education, to reflect on action to resolve societal concerns in a scientific, active and collective manner. This suggests the need to extend the 3 stages.

3. METHODOLOGY

The research followed a mixed method approach, defined as a research design incorporating both quantitative and qualitative data collection and analysis, with an aim to understand the research problems (Creswell, 2013; Swanson & Holton, 2005). The overall design of the research is illustrated in figure 2.

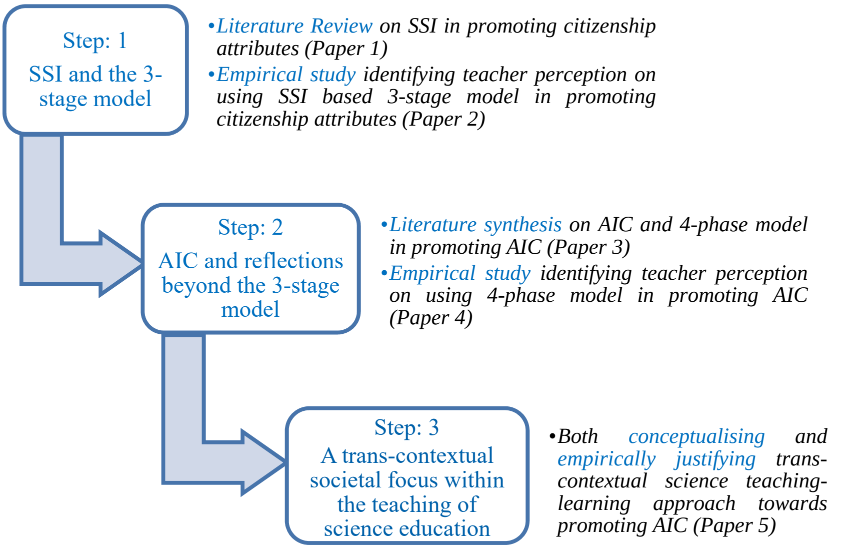


Figure 2: Design of the research

Participants involved in each of the steps

The 4 research samples were purposefully chosen to identify and select potentially 'information-rich cases, related to the phenomenon of interest' (Palinkas et al., 2015).

For step 1, in identifying teacher perceptions towards utilising an SSI-based 3-stage model to promote citizenship attributes, participants were chosen from an Estonian science education context, taking into consideration their expected familiarity with SSI-based teaching approaches (paper 2). The Estonian curriculum explicitly stated the need to promote scientific literacy, leading to learners' high performance in past PISA studies (OECD, 2016). The curriculum also encompassed the incorporation of socio-scientific issues within science teaching-learning as well as the promoting of social and citizenship competences (Estonian Government, 2014). The sample consisted of 10 Estonian teachers, who were familiar with the SSI-based, 3-stage model. The participants were identified as:

a) Highly experienced teachers having prior in-service course involvement (3 participants; Group A),
b) Experienced teachers without any involvements in projects or in-service courses (3 participants; Group B).

c) Teachers who recently completed a pre-service or in-service course (2 participants; Group C), and
d) Recently graduated teachers without any involvements in projects or in-service courses (2 participants; Group D).

For step 2, two separate teacher samples were utilised. To validate the devised questionnaire, participants were chosen from an international context (Portugal, Brazil, Colombia, Spain, Cabo Verde and Belgium), based on their familiarity with promoting student awareness and active engagement in the society. These participants were involved in a project, 'We Act' which aimed to promote students' socio-scientific issue-based activism (Baptista et al., 2018; Reis, 2014, 2020; Reis et al., 2020a). The 111 science teachers involved in the project were contacted via email from the project coordinator and all the email recipients participated in the study (paper 4).

To undertake the main study in step 2, seeking to identify teacher perceptions towards AIC and a potential 4th phase to the 3-stage model, a sample of teachers was chosen following a similar curriculum. This sample, based on the convenience of data collection, was from Bangladesh. Although the Bangladesh National Education Policy did not explicitly encompass the vision of scientific literacy, the aim of science education was seen as promoting a scientific mindset in learners, referring to the attainment of basic science disciplinary knowledge, application of the knowledge in their everyday life and an understanding of the interrelationship between science, technology and humanity (Ministry of Education of Bangladesh, 2010). The 126 Bangladeshi participant science teachers (paper 4), were practicing in secondary schools (grade 6–9) by following the national curriculum (NCTB, 2012).

For step 3, a 4th sample was utilised to seek further justification for the need for science learning to go beyond the 3-stages, identifying the value and challenges with respect to incorporating an additional 4th, trans-contextual stage (paper 5). For this, experts were chosen from an international context (Ireland, Estonia, Turkey, Finland and Israel), based on their prior familiarity with the 3-stage model. These expert participants were involved in a European Commission project, named 'Professional Reflection-Oriented Focus on Inquiry-based Learning and Education through Science (PROFILES)' (Bolte et al., 2012a; Bolte et al., 2011; Bolte & Rauch, 2014). The participants were selected based on their area of expertise, as followed:
a) 2 science education researchers;
b) 2 curriculum developers, and
c) 1 teacher educator

Table 1 further amplified figure 2, in line with the research questions, to present an overview of the research.

Table 1: A summarised overview of the research

Research questions	Steps	Rationale for literature review approach/ Rationale for purposeful selection of participants	Outcome
1. In what way, SSI contributes towards promoting citizenry,			
a) as identified by the literature?	Step 1: SSI and the 3-stage model	Narrative literature review to investigate all relevant publications on SSI, regardless of any inclusion or exclusion criteria	Paper 1: Literature identification of 1. Attributes of SSI 2. Contribution of SSI in promoting citizenry
b) as identified by teachers, familiar with an SSI-based 3-stage teaching approach?		Qualitatively investigate teacher perceptions <u>who were familiar with 3-stage model</u>	Paper 2: Identification of teacher perception and practice towards 1. 3-stage model 2. promoting citizenry via SSI-based approach
2. To what extent, science education is perceived to play a role towards societal development by promoting citizenry			
a) theoretically and in practice, identified from the literature?	Step 2: AIC and reflections beyond the 3-stage model	Integrative literature review to establish, from literature, the value of 1. Promoting a wholistic conceptualisation of citizenry to be promoted via science education 2. The need to extend the 3-stage model in promoting citizenry via science education	Paper 3: 1. Conceptualisation of AIC 2. establishment of 4-phase model
b) identified by teachers?		To validate the instrument by teachers <u>who were familiar with socio-scientific issue-based activism</u>	Paper 4: Validated instrument
		Quantitatively identify teacher perceptions towards 4-phase teaching approach	Paper 4: Identification of teacher perception and practice towards promoting AIC via 4-phase teaching approach
c) identified by science education researcher, curriculum developer, teacher educator?	Step 3: A trans-contextual societal focus within the teaching of science education	Qualitatively identify the value of promoting trans-contextualisation by those who is 1. training secondary school science teachers to appreciate the value of the 3-stage model. 2. developing science curriculum content (related to 3 stage model learning outcomes). 3. developing science curriculum framework (based on learning theories/policies associated with the 3-stage model). 4. researching teacher professional development associated with relevance, science competence and socio-scientific issue-based teaching. 5. researching transversal skills via science teaching, involving teacher designed SSI-based scenarios.	Paper 5: 1. Establishment of the need to extend the 3-stage model 2. Establishment of the value of incorporating a 4th trans-contextualisation phase in promoting AIC via science education. 3. Identification of possible challenges with respect to implementing the trans-contextualisation phase

3.1 Step 1: SSI and the 3-stage model

3.1.1 Literature review on SSI promoting citizenship attributes:

In identifying the attributes of SSI, as established by other researchers, and their contribution to promoting 'a desired citizenship' via science education, a narrative literature review was conducted (paper 1), following the 10 steps identified by Pautasso (2019). According to Ward et al. (2009), a narrative literature review was the most appropriate for identifying common attributes, theoretical perspectives and themes within a specific research topic. As opposed to a systematic literature review, this approach allowed the researcher to investigate all relevant publications regardless of any inclusion or exclusion criteria (Snyder, 2019).

3.1.2 Teacher perception on using SSI based 3-stage model in promoting citizenship attributes

In identifying teacher perceptions with respect to incorporating SSI-based 3-stage teaching approach in promoting citizenship attributes, this research undertook an interview-based qualitative study (paper 2).

Instrument:

An open ended, semi-structured interview was devised, following the four defined constructs based on the 3-stage model (amplified in chapter 2). In identifying teachers' perceived importance and perceived current practice of incorporating SSI, the interview instrument followed the following constructs:

a) motivation of students to learn science;
b) scientific problem-solving by students;
c) socio-scientific decision-making by students;
d) citizenship attributes of the students.

Data collection:

Participant responses from each teacher interview were obtained using semi-structured, open-ended questions. Such data was recorded and later transcribed for analysis. Each interview lasted approximately 45–60 minutes.

Data analysis:

Data for teacher interview was transcribed, inductively and analysed both manually and using NVivo (Qualitative Data Analysis Software).

Validity and reliability:

The interview instrument was initially reviewed by two science education researchers with expertise on qualitative research methods and semi-structured interviews. Based on their suggestions, the interview constructs were revised. In addition, two pilot interviews were undertaken. Considering the responses from the pilot interviews which confirmed that the instrument allowed the authors to obtain meaningful data, the instrument was considered valid.

The data analysis scheme was generated by the researcher and the coding reviewed independently by two other researchers. In case of disagreement with respect to the labelling of coding, consensus was obtained via discussions. By this process, the final version of the coding was considered to be reliable and possible to replicate.

3.2 Step 2: AIC and reflections beyond the 3-stage model

3.2.1 Literature synthesis on AIC and an extension to the 3-sage model in promoting AIC

An integrative literature review was undertaken to synthesise, based on the literature, a conceptual model of Active Informed Citizenry (AIC), to be promoted via science education. Such integrative literature review approach also enabled the researcher to extend the 3-stage model, and enabled the putting forward of a proposed, 4^{th} trans-contextual phase in promoting AIC (paper 3). Snyder (2019) suggested that the integrative literature review approach as the most appropriate

> 'when the purpose of the review is not to cover all articles ever published on the topic, but rather to combine perspectives to create new theoretical models.' (p. 334)

As opposed to a narrative or systematic literature review, an integrative literature review enabled the researcher to synthesise new knowledge on the topic e.g., integrating existing ideas with new ideas to create and justify a new model (Torraco, 2016).

3.2.2 Teacher perceptions on applying a 4-phase model to promote AIC

In seeking to identify teacher perceptions, with respect to incorporating a 4-phase teaching approach in promoting AIC, a quantitative approach was undertaken, both in a pilot study to developing the instrument, and in the main study (paper 4).

Instrument:

An initial pilot instrument was devised based on the 4-phase teaching approach, initially developed by the researcher, reviewed and modified by 13 science educators. The pilot questionnaire comprised 35 items, under 5 constructs. Table 2 demonstrated the pilot interview instrument- the constructs, key emphasis of each construct and sub-categories for items.

Table 2: The initial pilot instrument in 5 constructs

<table>
<tr><td>Constructs</td><td>Key emphasis given to</td><td>Sub-categories</td></tr>
<tr><td>Construct 1</td><td>Teacher perceived importance towards</td><td rowspan="3">1. Student motivation (items 1.1, 2.1 and 3.1)
2. Student science conceptual learning (items 1.2, 2.2 and 3.2)
3. Student socio-scientific decision-making (items 1.3, 2.3 and 3.3)
4. Student transference of science learning beyond classroom (items 1.4, 2.4 and 3.4)</td></tr>
<tr><td>Construct 2</td><td>Teacher perceived current practice of</td></tr>
<tr><td>Construct 3</td><td>Teacher perceived feasibility of</td></tr>
<tr><td>Construct 4</td><td>Teacher perceived importance towards</td><td>1. addressing student perceived awareness of conceptual science embedded in local, national or global issues (4 items);
2. developing student perception of values, morals, or ethics in complex socio-scientific issues (4 items), and
3. perceived aspects promoting student participation in addressing societal development issues through ill-structured, socio-scientific, cross-curricular contexts (4 items).</td></tr>
<tr><td>Construct 5</td><td>Teacher perceived importance towards</td><td>1. value transferring of science conceptual learning to students' everyday life situations (4 items);
2. promote an active democratic role as a citizen (4 items), and
3. address aspects of sustainable development of the society through science education (3 items).</td></tr>
</table>

Based on expert opinion and results from the pilot study, a final instrument was developed for the main study (paper 4, tables 2–5), comprised of 29 items using a justified, 3-point Likert scale.

Data collection:

Data on instrument development for the pilot study was collected via a questionnaire, modified slightly from an initially devised version (revised based on expert opinion), and presented to teachers, electronically, using Google Forms.

Data from the main study was obtained via a questionnaire, devised electronically using Google Forms and sent via email. Alternatively, where appropriate, printed questionnaires were sent to the teacher in some schools with the aid of the school principal.

Data analysis:

Data collected from both pilot teachers and teachers for the main study were analysed using SPSS and JASP (for case analysis, Cronbach Alpha and descriptive analysis). R was used for determining correlations between variables and plotting graphs.

The study further sought to identify the correlation between teacher perceived importance towards, and current practice of incorporating a context-based socio-scientific framework (paper 4). In so doing, a null hypothesis (H_0) and alternative hypothesis (H_1) of the significance test for correlation was expressed as:

> H_0: There is no correlation between teacher perceived importance and current practice.
>
> H_1: There is correlation between teacher perceived importance and current practice.

Spearman correlations were undertaken in this research, noting that a Pearson correlation was not seen as an adequate measure for two-item scales (Eisinga et al., 2013).

Validity and reliability:

The pilot questionnaire was scrutinised by 13 science educators from a range of countries, with expertise related to socio-scientific issue-based activities. Expert validation of the questionnaire was based on critical comments to four specific questions specifically posed to the science educators.

a) Do the constructs follow the rationales, philosophy and purpose of the instrument?
b) Do the items follow the constructs and intent so as to provide verified data?
c) Is the Likert scale appropriate in each case?
d) Is there any case where more specifications/explanations/examples will be helpful for better understanding the question?

Validity of the questionnaire constructs and its items were based on expert suggestions, and the undertaking of relevant modifications. The experts recommended:

a) justifying the constructs based on a greater number of literature sources, thus establishing greater credibility;
b) simplifying the wording of the items;
c) modifying explanations for better understanding by the participants;
d) adopting the use of a 3-point Likert scale to gain a specific range of teacher perceptions;
e) including the purpose of the items under each construct in the final instrument for teachers to better understand the purpose of the questionnaire.

Correlation calculated between the items, per construct, were as given in appendix A1.

The internal consistency of pilot questionnaire items, based on Cronbach Alpha for each construct was as given in appendix A2. The overall score pilot questionnaire was 0.952, and main study was 0.965.

3.3 Step 3: A trans-contextual societal focus within the teaching of science education

To conceptualise and justify a trans-contextual science teaching-learning approach towards promoting active informed citizenry, a final interview-based qualitative study was undertaken (paper 5).

Instrument:

A teaching module was prepared, based on the proposed 4-phase teaching approach (paper 3). The module consisted of an abstract, student activities, and suggested teaching strategies (appendix A4). An open ended, semi-structured interview was devised, particularly focusing on establishing the value of trans-contextualisation within science learning. The interview instrument followed these constructs:

a) establishing familiarity with the 3-stage model;
b) identifying whether there is a need to go beyond the 3-stages, i.e., extend the model;
c) recognising the value of trans-contextualisation in science learning, and
d) determining the feasibility and challenges with respect to incorporating trans-contextualisation within teaching-learning activities.

Data collection:

To establish the value of including trans-contextualisation with science learning, data was collected through semi-structured open-ended questions, conducted and recorded via ZOOM, and transcribed for analysis. Each interview lasted approximately 45–60 minutes.

Data analysis:

The recorded responses from each interviewee were transcribed for analysis and collected data was *inductively* analysed so as to identify:

a) the subjective perceptions of the participants with respect to their perceived value and challenges of incorporating trans-contextualisation, considering the inductive approach allows the researcher to 'focus on individual's meaning' (Creswell & Creswell, 2017). The data analysis process was conducted via analysing the transcripts manually.
b) the communalities from the participant responses via data coding and generating themes.

Data coding of the scripts (appendix A3) were conducted by:

a) initially identifying the positive or negative agreement to the proposition of the trans-contextualisation phase, labelled as 'sentiment' (column 2 in table A3);
b) in case of *positive* responses, categorising the meaning units (column 3 in table A3) as participants' first level justification to their sentiment (coded yellow), second level justification (coded green), and third level justification (coded blue). In case of *negative* responses, the meaning units were categorised as participants' first level justification to their sentiment (coded grey), second level justification (coded purple), and third level justification (coded red);
c) Interpreting meaning units based on the key emphasis given by the participants, labelled as first level coding (column 4 in table A3);
d) Identifying communalities in the first level coding and clustering them under second level coding (column 5 in table A3), and
e) Based on the clustering of second level coding, the 3 general, overarching themes were identified (column 6 in table A3).

Validity and reliability

Similar to the initial interviews, the final interview instrument was initially validated by two science education researchers with expertise on qualitative research method and semi-structured interviews. Based on the suggestions from the experts, the interview constructs were revised (i.e., including an initial construct to establish the familiarity with the 3-stage model). In addition, two pilot interviews were undertaken. The responses obtained from the pilot interviews confirmed that the instrument allowed the authors to obtain meaningful data based on the research questions and thus the instrument was considered valid.

A data interpretation procedure was generated by one of the authors and the coding reviewed independently by the other authors. In case of disagreement with respect to the interpretation, consensus by all authors was obtained via discussions. By this process, the final version of the interpretation was considered to be reliable and possible to replicate.

4. RESULTS

4.1 SSI and the 3-stage model

This study primarily sought to identify the main attributes of SSI and their contribution to promoting a desired citizenry. In so doing, the narrative SSI literature review led to 10 heavily cited attributes of SSI (table 1, paper 1) and their potential contribution to promoting desired citizenry (table 2, paper 2). In addition, the study also sought to identify the teacher perceived importance and practice of SSI-based 3-stage teaching in promoting citizenship attributes via science education (as indicated in section 3.1.2).

Interpretation of the findings

Based on teacher interview findings (paper 2), the major interpretations were as summarised in the following:

Teacher perceived importance:

In general, group A, B and C (see section 3.1.2) teachers pointed out that they perceived the importance of promoting SSI was to:

a) address students' interest and motivation to learn the topic, and address students' understanding of the nature of science;
b) promote student scientific problem-solving skills,
c) develop decision making skills, and promote social skills (explained in figure 3) via decision-making process;
d) enable students' engagement and smooth integration into the society; becoming global citizens, etc.

Group D teachers emphasised the importance of incorporating social issues in science teaching, although they saw less opportunities to enact this in their practice.

Teacher perceived current practice:

Group A, B, C teachers responded:

a) it is possible for them to use relevant social contexts in science teaching quite frequently, through a need-based situation;
b) in their opinion, undertaking SSI-based teaching can take more than a year.

Group D, teachers, however, mentioned that they haven't yet incorporated SSI in science teaching.

With respect to their perceived practice of incorporating SSI-based teaching, all participant teachers reported that:

a) teachers' perceived importance, preparedness and willingness were seen as the main factors to frequently include social components in science teaching;
b) teachers' perceived importance regarding incorporating social contexts overcomes potential barriers of teacher's experience level, curriculum load, or number of students;
c) involvement in professional development programmes (in this case, in-service or pre-service courses) has a significant impact on teachers' perceived importance in incorporating social contexts in their teaching.

In further interpreting teachers' interviews, codes were generated by NVivo through inductive analysis on constructs and their sub-divisions derived from the interviews, as illustrated in figure 3.

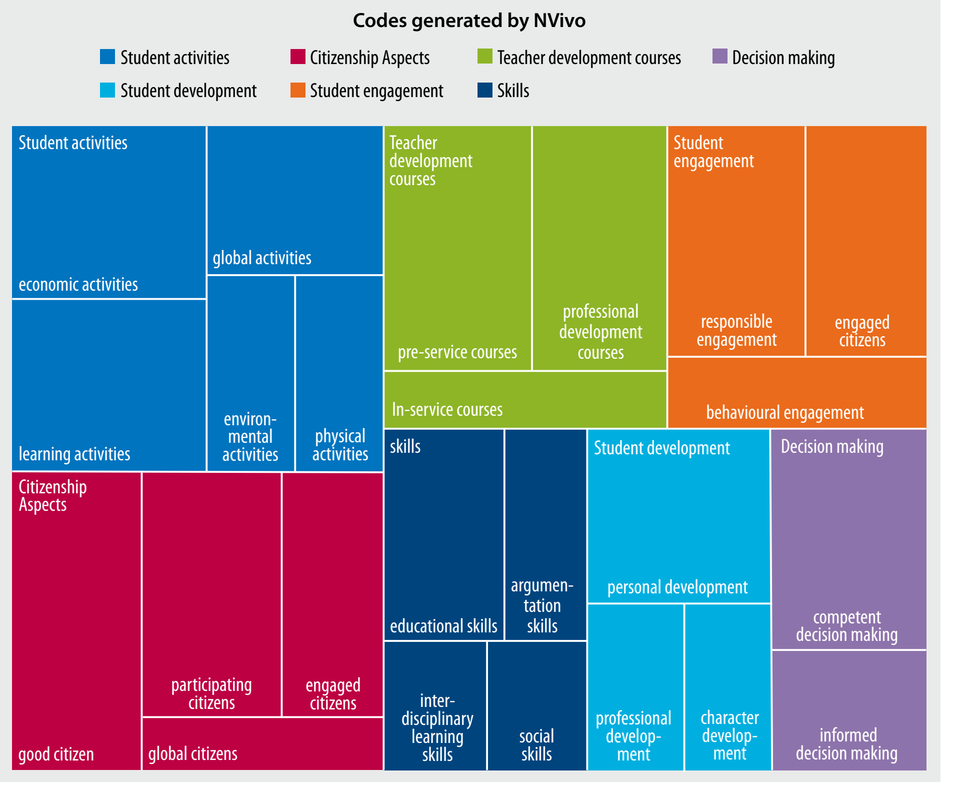


Figure 3: Code identification derived from the initial teacher interviews

Interpretation of the analysis

The findings from the NVivo analysis give an indication of dominance of the topics discussed (illustrated by the size of the box in the above figure 3). The 7 wider topics identified by the analysis were further amplified:

Student activities

Although all participant teachers generally agreed that the 3-stage model is intended to promote student involvement in activities, teachers' perception of the type of student activities differed, for example:

a) Group B and D teachers, perceived student activities as simply 'learning activities'.
b) Group A and C teachers, demonstrated a deeper understanding of types of student activities and saw activities as student scientific problem solving and active participation in socio-scientific decision making.

Conceptualising citizenship attributes

In conceptualising citizenship attributes to be promoted through SSI-based teaching:

a) Group A, B and C teachers perceived the role of SSI-based teaching as being important towards the promoting of student citizenship attributes.
b) Group B teachers perceived SSI-based teaching as promoting students as 'good citizens'.
c) Group A and C teachers referred to the citizenship aspect as being able to engage and participate in socio-scientific discourse related to global concerns.
d) Group D teachers, having no experience in socio-scientific issue-based teaching, were not able to conceptualise the role of SSI on promoting citizenship aspects.

Teacher development programmes

All participating teachers emphasised the role of teacher development programmes in enabling effective teaching of SSI-based modules. Such teacher development programmes were identified as,

a) pre-service courses (courses undertaken prior to teaching career);
b) in-service courses (courses undertaken during teaching practice), and
c) professional development courses as supplementary seminars, workshops or even courses which teachers willingly choose and participate.

Conceptualising decision-making

SSI-based teaching was perceived as important to promote students' socio-scientific decision-making by all participant teachers. However, while amplifying the attributes of decision-making:

a) Group B and D teachers emphasised the importance of 'informed decision-making', perceiving the role of conceptual science as the dominant in making a socio-scientific decision.
b) Group A and C teachers on the other hand, perceived the importance of 'competent decision-making', which they described as, decision-making in a consensus, democratic way, taking into consideration the role of not only science, but also social values, ethics, environment, economy and society.

Student development

All participating teachers emphasised the role of SSI-based teaching to enable student development. Such development was identified within three categories:

a) character development: perceived as promoting the social, or cultural values, morals and ethics through socio-scientific discourse;
b) personal development: perceived as students' understanding the role of science in their everyday lives, conceptualising nature and history of science, and making decisions based on scientific argument; and
c) professional development: perceived as students enabled to practice cooperation, teamwork, communication, critical thinking through SSI-based teaching.

Student engagement

With reference to student engagement, all the teachers perceive that socio-scientific decision-making initiates the students' realisation of their role in addressing social concerns. However,

a) Group A, B, and C teachers emphasised the need for enabling students to undertaking behavioural and responsible actions through SSI-based teaching.
b) Group A teachers further stressed the need to initiate, through SSI-based teaching, students' engagement within the society as citizens.

Target skills

With reference to target skills, to be promoted through SSI-based teaching,

a) Group A teachers emphasised the need to promote social skills, perceived as the skills to collaborate, communicate, or even influence other members of the society to undertake responsible behaviour to address societal concerns.
b) Group B and D teachers perceived that SSI-based teaching enables students' argumentation skills.

c) Group C teachers showed a wider perception of the target skills, referring to as educational or interdisciplinary learning skills. They emphasised the need to promote students' skills to reconcile dilemmas and preparing them as being able to undertake responsible actions to address societal concerns.

4.2 AIC and reflections beyond the 3-stage model

In seeking to identify to what extent science education should and could contribute to promoting citizenship, paper 3 undertook a synthesis of the literature, taking into consideration both the science education literature and policy documents (i.e., European Commission (EU), 2015; OECD, 2018b; UNESCO, 2015; United Nations, 2015) put forward an all embracing concept of Active Informed Citizenry.

In compiling the AIC conceptualisation, the three components were seen as encompassing, within a science educational construct, the three domains of global citizenship educational outcomes put forward by UNESCO (2015) – cognitive (informed), behavioural (active) and socio-emotional (citizenry). These three components were as summarised in the following table 3:

Table 3: Components of Active Informed Citizenry

Terminology used:	Informed	Active	Citizenry
Science learning domain:	Cognitive	Behavioural	Socio-emotional
Attribute	Learners are able *to conceptualise science* and its role in societal concerns	Learners are willing to and able *to undertake scientifically influenced action* in resolving societal concerns	Learners are able *to identify a sense of community, collaborate and cooperate within a wider community as a collective body*
Reference to literature	Duschl et al. (2013); Kahn and Zeidler (2019); Rundgren and Chang Rundgren (2018); Pelch & McConnell (2017)	Hadjichambis et al. (2019); Maass et al. (2021); Marques and Reis (2017); Dumont et al. (2012)	European Commission, (2015); Evagorou and Dillon (2020); Espeja and Couso (2020); OECD (2019b), Kolstø (2008)

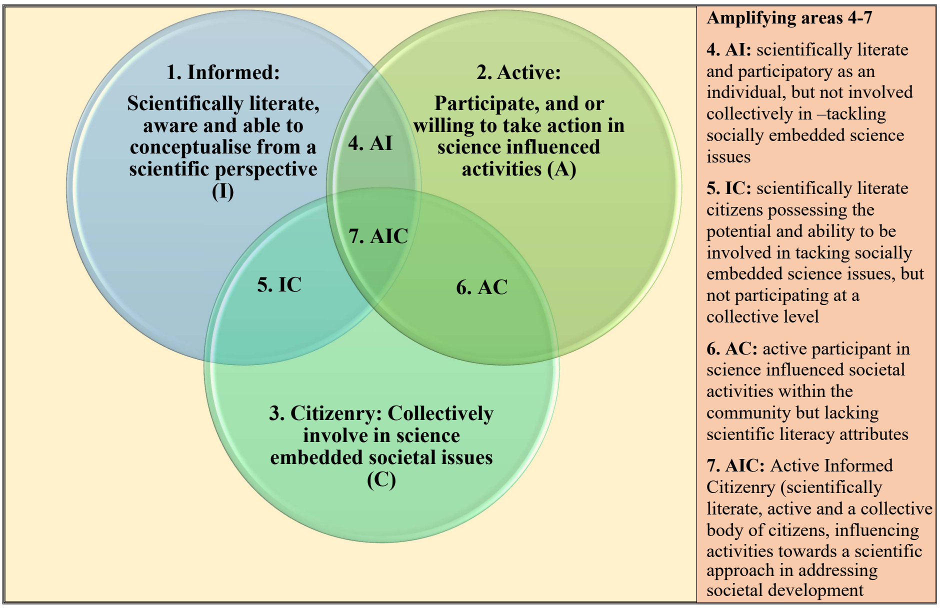


Figure 4: A model of Active Informed Citizenry (AIC) and its sub-components, synthesised based on science education literature

In conceptualising attributes needed to build a desired citizenry model, to be achieved through science education, 6 sub-components were conceived as leading to the desired active, informed citizenry (AIC) target, as indicated in figure 4.

Paper 3 further explained the components of AIC, from a terminological and attributional point of view.

In promoting active informed citizenry via science education, this study further put forward an added 4th phase to the literature identified, 3-stage model by Holbrook and Rannikmäe (2010) (figure 1), namely trans-contextualisation. This is further amplified in figure 5.

Prior to this research, Hagger and Chatzisarantis (2012) proposed a trans-contextualisation model of motivation (TCM) to indicate the need to transfer student motivation towards physical activity from a physical education to a leisure time context. As opposed to TCM, the trans-contextual model in this research was seen as a major construct of science education, not only transferring student motivation, but also their conceptual science learning, plus scientific evidence-based, socio-scientific decision-making learning, to a beyond-classroom, societal context, particularly for addressing societal concerns.

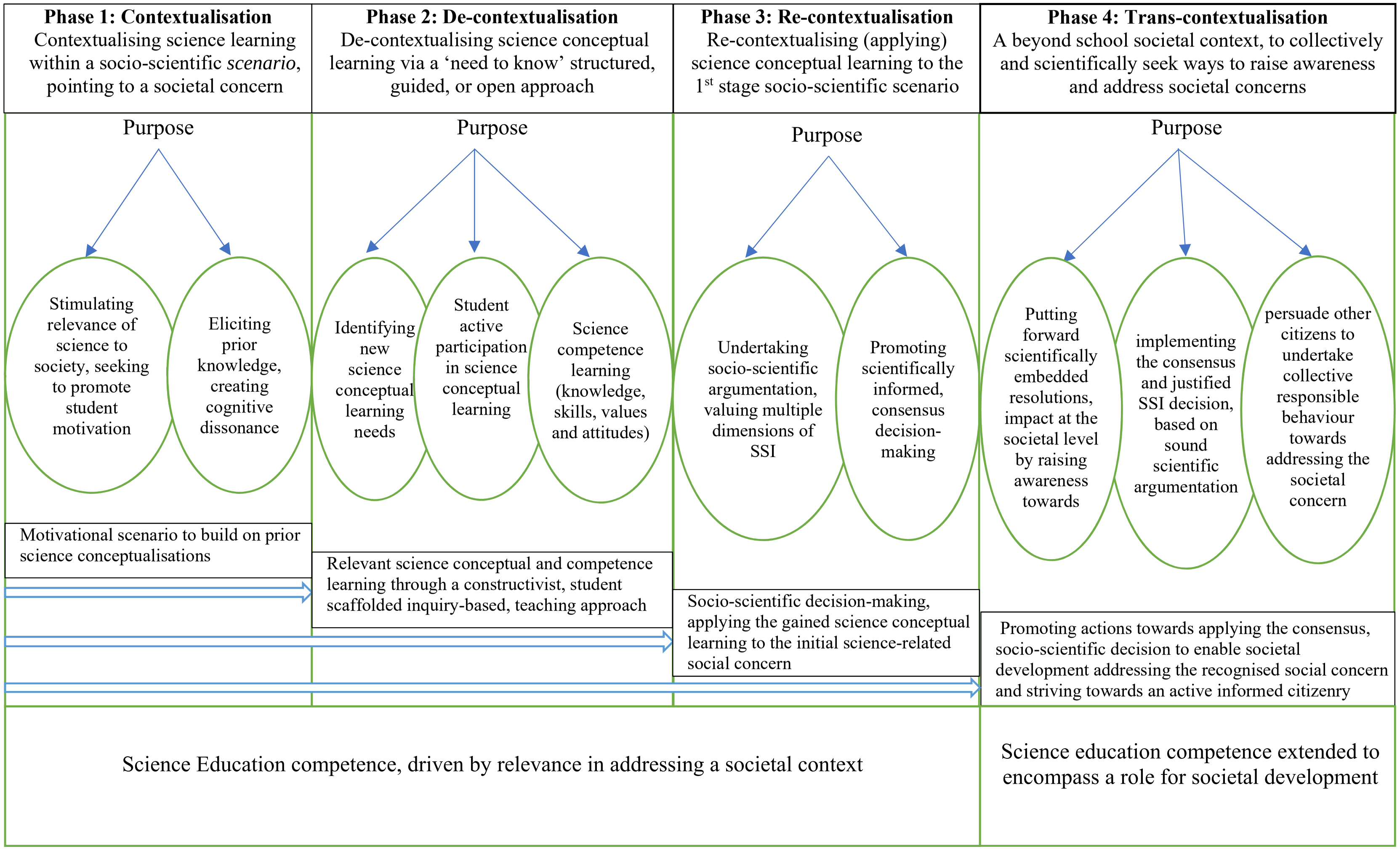


Figure 5: A model of 4-phase school science teaching-learning in promoting AIC, based on Constructivism-Humanism approach (paper 5)

As indicated in figure 5, the incorporation of the 4th, trans-contextual phase aimed to enable learners to:

a) transfer their meaningful, creative, collaborative and scientifically sound resolutions to a beyond-classroom context;
b) actively and cooperatively participate in creative ideas for raising awareness of, and putting forward meaningful approaches, to execute their proposed resolutions;
c) impact, at the societal level, by raising awareness of scientifically embedded societal concerns by implementing consensus and justified SSI decisions, and
d) seeking to persuade other citizens to undertake collective responsible behaviour towards addressing such societal concerns, based on sound scientific argumentation, for the betterment of society.

The above involved, therefore, a mechanism, or mechanisms for enabling the trans-contextualisation process to motivate members within the society to discuss, debate and even interact with the proposed consensus decision. The mechanism or mechanisms needed to instigate and develop a sustainable movement in line with promoting an active, informed citizenry. Examples of such mechanisms were perceived as:

a) drawing attention to the scientific evidence-based consensus decision through the devising of a society-impacting activity, seeking to initiate a movement supported by social media;
b) devising an action plan, geared to the justified decision and hence based on sound scientific argumentation, to target and persuade society leaders to support and raise awareness within the society for further 'informed action';
c) initiate an awareness campaign, derived from scientifically informed decisions, (for example via social media) soliciting society support for this initiative by recognising its value in promoting an active, informed citizenry.

The 4th, trans-contextualisation phase was seen as bridging the gap between science and society, allowing learners to transfer their science learning from the classroom to a beyond-school societal context, seeking to initiate a students' collective, and scientifically influenced activity so as to address societal development, by promoting active informed citizenry.

In seeking to identify teacher perception of importance and practice towards the 4-phase teaching approach in promoting AIC, a primary instrument was developed by the researcher, modified by experts, and further revised based on the findings from a pilot study. Although the pilot study was undertaken to establish the validity and reliability of the instrument, the findings from the pilot study showed the promising contribution in addressing the research aim of the study. Table 4 indicated the descriptive results from the pilot study undertaken on the 5 constructs.

Table 4: Findings from the pilot study

Construct 1: **Perceived importance** Items	**Strongly Agree (value 5)**	**Agree (value 4)**	**Neutral (value 3)**	**Disagree (value 2)**	**Strongly Disagree (value 1)**
Indicate the degree of perceived importance to linking the teaching of each science topic to concerns within the society so as to:					
1.1 motivate students in the learning of each new science topic.	70 (63.1%)	39(35.1%)	2(1.8%)	–	–
1.2 facilitate the development of science concepts.	64(57.7%)	41(36.9%)	6(5.4%)	–	–
1.3 apply gained science learning in making justified decisions which revolve around a concern with the society.	57(51.4%)	44(39.6%)	8(7.2%)	2(1.8%)	–
1.4 initiate the transfer of learning in science subject lessons to the taking of action outside of school.	52(46.8%)	46(41.4%)	12(10.8%)	1(1%)	–
Construct 2: Perceived current practice **Items**			**Always (value 3)**	**Sometimes (value 2)**	**Never (value 1)**
I try to include the following in your science subject teaching:					
2.1. using a student familiar, societal concern, when introducing a new science topic.			47(42.3%)	64(57.7%)	–
2.2 after having involved students in science learning within a topic (scientific problem-solving, scientific experiments, etc.), extend the learning by guiding students to relate the science learning to a student familiar societal concern.			33(29.7%)	77(69.4%)	1(0.9%)
2.3 include a social concern, which is related to the specific science learning, so that students can use their science knowledge and skills in making decisions on the social concern.			32(28.8%)	74(66.7%)	5(4.5%)
2.4 encourage students to transfer their science learning from the classroom to the society, outside the school context.			60(54.1%)	48(43.2)	3(2.7%)
Construct 3: Perceived feasibility **Items**			**Always (value 3)**	**Sometimes (value 2)**	**Never (value 1)**
In my teaching, I find it possible to					
3.1 using a student familiar, societal concern, when introducing a new science topic.			53(47.7%)	58(52.3%)	–
3.2 after having involved students in science learning within a topic (scientific problem-solving, scientific experiments, etc.), extend the learning by guiding students to relate the science learning to a student familiar societal concern.			61(54.9%)	50(45.1%)	–
3.3 include a social concern, which is related to the specific science learning, so that students can use their science knowledge and skills in making decisions on the social concern.			59(53.2%)	52(46.8%)	–
3.4 encourage students to transfer their science learning from the classroom to the society, outside the school context.			61(54.9%)	50(45.1%)	–

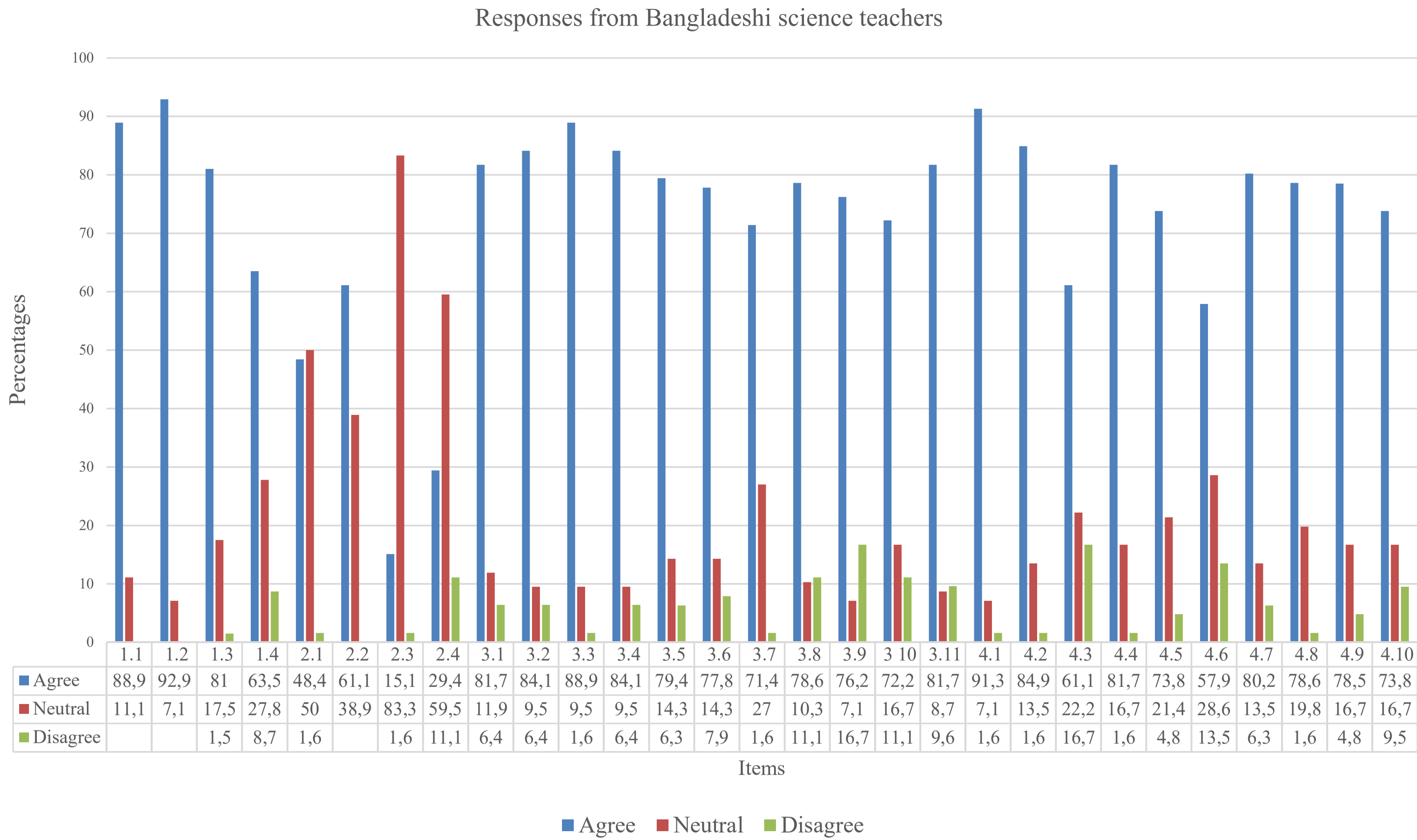
Construct 4: **Perceived importance** Items	**Strongly Agree (value 5)**	**Agree (value 4)**	**Neutral (value 3)**	**Disagree (value 2)**	**Strongly Disagree (value 1)**
Indicate, in your opinion, the importance of science teaching in promoting social competences by indicating the degree to which you are:					
4.1 introduce students to social, economic and political aspects of socially embedded science issues.	73(65.7%)	37(33.3%)	1(1%)	–	–
4.2 engage students in group discussions regarding social issues which relates to the science topic.	74(66.7%)	34(30.6%)	3(2.7%)	–	–
4.3 support students in searching for related information regarding socially embedded science issues.	69(62.1%)	41(36.9%)	1(1%)	–	–
4.4 involve students in making justified decisions about socially embedded science issues.	68(61.2%)	40(36%)	2(1.8%)	1(1%)	–
4.5 enable students' discussion about socially embedded science issues.	67(60.4%)	39(35.1%)	5(4.5%)		
4.6 promote students' argumentation skills in discussing/debating socially embedded science issues.	81(73%)	29(26%)	1(1%)		
4.7 encourage students to express and develop opinions about socially embedded science issues.	87(78.4%)	20(18%)	4(3.6%)		
4.8 promote students' investigations on socially embedded science issues.	70(63.1%)	38(34.2%)	3(2.7%)		
4.9 promote students' collaboration in resolving socially embedded science issues.	71(64%)	37(33.3%)	3(2.7%)		
4.10 promote in students a democratic attitude while resolving a social issue.	84(75.7%)	24(21.6%)	3(2.7%)		
4.11 promote students' responsible actions towards society.	85(76.6%)	23(20.7%)	3(2.7%)		
4.12 develop students' critical reasoning skills about socially embedded science issues.	79(71.1%)	31(27.9%)	1(1%)		
Construct 5: **Perceived importance** Items	**Strongly Agree (value 5)**	**Agree (value 4)**	**Neutral (value 3)**	**Disagree (value 2)**	**Strongly Disagree (value 1)**
Indicate the degree to which you agree that it is important to promote students as "active informed citizenry", through their science learning, by:					
5.1 support students in applying science learning to everyday life situations.	76(68.5%)	31(27.9%)	4(3.6%)	–	–
5.2 encourage students to use science learning for future life decisions.	78(70.3%)	30(27%)	3(2.7%)	–	–
5.3 promote awareness among the students regarding the need to act responsibly towards community, society and global issues.	83(74.8%)	25(22.5%)	3(2.7%)	–	–
5.4 stimulate students to propose and plan actions for the benefit of their community.	81(73%)	26(23.4%)	4(3.6%)	–	–
5.5 promote students' argumentation skills in order to influence other citizens' beliefs/ viewpoints on socially embedded science issues.	76(68.4%)	29(26.1%)	5(4.5%)	1(1%)	
5.6 engage students in activities seeking to resolve social issues related to science topics.	75(67.6%)	32(28.8%)	4(3.6%)		
5.7 facilitate the transfer of science learning to promote sustainable development in society.	78(70.3%)	30(27%)	3(2.7%)		
5.8 promote students' active engagement in science-related social activities for the benefit of their community.	78(70.3%)	31(27.9%)	2(1.8%)		
5.9 encourage students to take collective actions for the benefit of their community.	76(68.5%)	33(29.7%)	2(1.8%)		
5.10 enable students through science learning to influence other citizens to undertake collective actions for social good.	69(62.2%)	37(33.3%)	4(3.5%)	1(1%)	
5.11 prepare students to be willing and able to take socio-scientific actions collectively for the benefit of the society.	75(67.6%)	31(27.9%)	4(3.5%)	1(1%)	

Interpretation of outcomes from the pilot study for finalising the instrument for the main study:

a) Based on the findings, and after expert consultation, it was evident that participants perceived constructs 2 and 3 as the same. While the intention of construct 2 was to explore teachers' perceived feasibility to address the 4 orientations of context based social frame in science teaching, construct 3 intended to explore the current practice. Between these two constructs, it was decided (see appendix A2 for explanation) that construct 2 should be eliminated, based on the lower average Cronbach alpha value and also relating to the objective of the study as seeking teachers' current practice of addressing the 4 orientations within a context-based social frame.
b) In addition, the overall correlation matrix (appendix A1) showed some items exhibiting a high correlation with each other, indicating that these items explored similar teacher attributes. This led to items 4.8 and 5.10 being eliminated.
c) The findings from the pilot study also seemed to show that participants had difficulty interpreting the 5-point scale e.g., the same aspect applied to strongly disagree and disagree. Thus, based on expect advice, and in consultation with the participants from the pilot study, a 3 point, rather than a 5-point Likert scale, was used in the main study, undertaken with Bangladeshi teachers.

The main study, using a revised instrument, sought to explore teachers' perceived importance and perceived current practice to incorporate a trans-contextual science education, towards promoting active informed citizenry through science education.

The findings from the main study were given in paper 4 and are summarised graphically below in figure 6, based on teacher responses identified as value 1 – disagree, value 2 – neutral, and value 3 – agree.



	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	3 10	3.11	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	4.10
Agree	88,9	92,9	81	63,5	48,4	61,1	15,1	29,4	81,7	84,1	88,9	84,1	79,4	77,8	71,4	78,6	76,2	72,2	81,7	91,3	84,9	61,1	81,7	73,8	57,9	80,2	78,6	78,5	73,8
Neutral	11,1	7,1	17,5	27,8	50	38,9	83,3	59,5	11,9	9,5	9,5	9,5	14,3	14,3	27	10,3	7,1	16,7	8,7	7,1	13,5	22,2	16,7	21,4	28,6	13,5	19,8	16,7	16,7
Disagree			1,5	8,7	1,6		1,6	11,1	6,4	6,4	1,6	6,4	6,3	7,9	1,6	11,1	16,7	11,1	9,6	1,6	1,6	16,7	1,6	4,8	13,5	6,3	1,6	4,8	9,5

Figure 6: Results from the main study soliciting teacher perceptions

Interpretation of the analysis

The findings from figure 6 indicated that,

a) More than 90% of the participant teachers perceived high importance to facilitating students' development of scientific concepts (item 2). However, in addressing student motivation, socio-scientific decision-making and transferring their learning to wider contexts, the teachers' perceived importance decreased progressively (less than 90% for item 1, approximately 80% for item 3 and less than 65% for item 4).
b) Participant teachers only sometimes found it possible to embed the science learning within a social context (approximately 50% in all four cases). However, the perceived current practice of scientific problem-solving was more prominent (more than 60% always) than addressing students' motivation (less than 50%), socio-scientific decision-making (approximately 15%) and transferring the learning outside the classroom (approximately 30%).
c) There is a contrast between teacher perceived importance and perceived current practice, for example participant teachers indicated a higher perceived importance of promoting student motivation through relevant social concern (more than 90% agree, item 1.1) and less perceived current practice of always introducing a science topic with a relevant social concern to intrigue student motivation (less than 50% always, item 2.1). The participant teachers also indicated a higher perceived importance of promoting the transference of the science learning in a 'beyond school' context (approximately 60% agree, item 1.4) and less perceived current practice to always enable the students to do so (approximately 30% always, item 2.4).
d) Participant teachers had the least agreement towards the importance of promoting students' responsible action and active engagement towards solving a science-related social concern (approximately 60% agree, item 4.3, 4.6).

To determine the correlation between teacher perceived importance (construct 1) and perceived current practice (construct 2), a Spearman correlation analyses was undertaken. The findings are illustrated in figure 7.

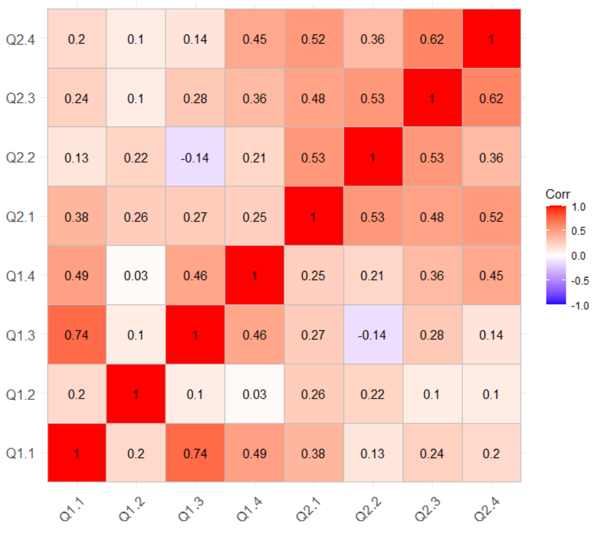


Figure 7: Visualization of Spearman correlation between teacher perceived importance and perceived current practice (p value demonstrated in appendix A1)

Interpretation of the analysis

Considering, the results from figure 7 did not show strong correlation in all four items, the null hypothesis (H_0) appeared to be more strongly supported by data confirming that there was *no strong correlation* between teacher perceived importance and current practice. However, three correlations from figure 7 were further interpreted:

a) teacher perceived current practice in promoting science conceptualisation (item 2.2) had a negative correlation ($r = -0.14$) with teacher perceived importance of promoting student socio-scientific decision-making (item 1.3). This implied that teachers who emphasised science conceptual learning in their teaching practice, tended to have less perceived importance towards promoting student socio-scientific decision-making.

b) teacher perceived importance of promoting student motivation (item 1.1) to learn science was strongly correlated ($r = 0.74$) with teacher perceived importance of promoting student socio-scientific decision-making (item 1.3). This implied that teachers who positively valued the promoting of student motivation were likely to positively value promoting student socio-scientific decision-making.

c) teacher perceived current practice of promoting student socio-scientific decision-making (2.3) was strongly correlated ($r = 0.62$) with teacher perceived current practice of promoting student transference of science learning to a beyond-school context (2.4). This implied that teachers who practiced promoting student socio-scientific decision-making were likely to also practice promoting student transference of science learning to a beyond-school context.

4.3 A trans-contextual societal focus within the teaching of science education

Paper 5, based on the final interviews with researchers, curriculum developers and teacher educator, sought to identify the feasibility and value of incorporating a trans-contextual societal focus within the teaching of science education. In addition, the paper sought to identify the potential challenges. In so doing, the interviews were constructed based on four constructs, as amplified in section 3.3.

Interpretation of the findings

The first construct, establishing the familiarity of the participants towards the 3-stage model, was undertaken to facilitate the discussion. Based on the interview findings detailed in paper 5, the major interpretations for the constructs 2, 3, and 4, were summarised the following:

1. *Perceived need for extending the 3-stage model:*

a) The participant teacher educator perceived that learning via the 3-stage model met the cognitive curriculum expectations, and partly agreed with respect to engaging secondary school learners in resolving societal concerns.
b) Participant curriculum developer 1, with expertise on curriculum content, perceived the need for enhancing the purpose of science education (i.e., extending the learning beyond the 3-stages), this having implication for changes within the society.
c) Participant curriculum developer 2, with expertise on learning theories, perceived the need to extend science learning beyond the 3-stages, in preparing students, via science learning, to be involved in focusing on societal development.
d) Participant science education researcher 1, with expertise on teacher professional development within relevance, science conceptual learning and socio-scientific decision-making, perceived a limitation within the 3-stage model with respect to enabling students to address, as well as suggest, ways to resolve societal concerns.
e) Participant science education researcher 2, with expertise on teacher designed SSI-based modules, perceived the need to enhance the goal of science education so that it reflected on the implications for the society.

2. *Perceived value of the 4^{th} trans-contextualisation phase in science learning:*

Paper 5 (table 5) indicated that all participants perceived a value for science education playing a role in societal development via trans-contextualising science education, thus enabling learning to extend from a classroom context to a ‘beyond-school, societal environment’. Based on a manual coding analysis (amplified in section 3.3), the following figure was developed in order to identify developments promoting trans-contextualising science learning, perceived as valued by participants. The complete coding transcript was attached in appendix A3, and the interpretation of the data coding was illustrated in figure 8.

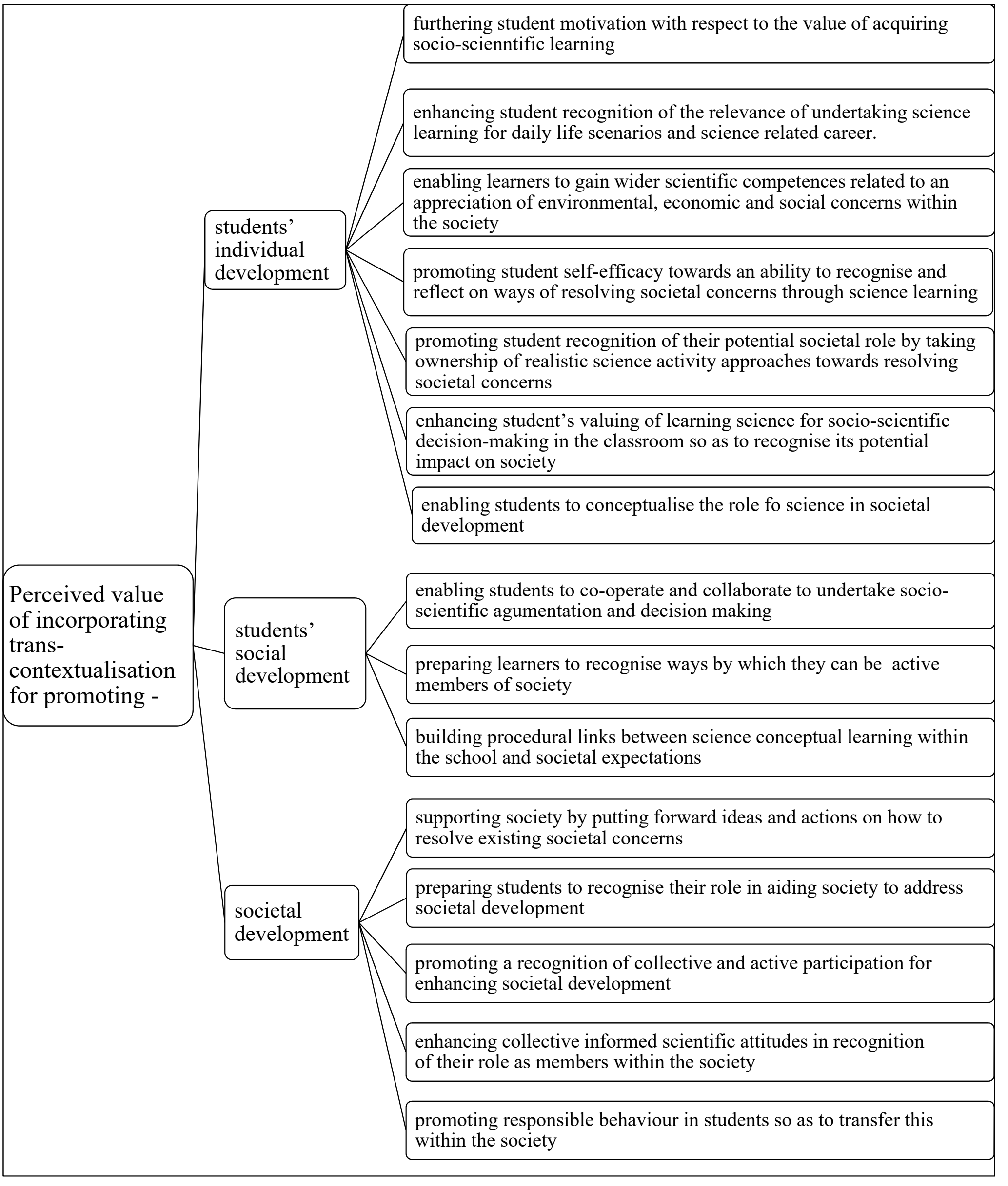


Figure 8: Collective interpretation of participant responses, with respect to the perceived value of incorporating trans-contextualisation

The interpretation of the results (figure 8) further implied that the purpose of trans-contextual science teaching learning was perceived to impact at three different developmental levels.

a) student individual development (i.e., science conceptualisation, employable scientific skills, scientific values and individual attitude towards science);
b) student social development (i.e., collaboration, cooperation, having a sense of community, argumentation, or group decision-making), and
c) societal development (i.e., supporting society to resolve societal concerns via active, collective, and scientifically influenced engagement, promoting collective scientific attitude towards resolving socio-scientific dilemma via logical persuasion).

3. *Perceived feasibility and challenges with respect to incorporating trans-contextualisation within teaching-learning activity:*

Paper 5, (table 6) indicated that all participating science education experts perceived the incorporation of trans-contextualisation as feasible, but at the same time, they were aware of potential perceived challenges seen by teachers in implementing such additional phase. The interpretation of the findings with respect to perceived challenges were summarised as:

a) lack of familiarity, importance, and eagerness with promoting wider aims of science education (i.e., societal development).
b) lack of motivation by the students, towards resolving societal concerns.
c) lack of professional development for teachers.
d) perceived resistance from teachers due to the dominance of a traditional teaching approach.
e) lack of teacher ability to evaluate learning outcomes from a 4th phase.
f) lack of value by teachers towards promoting trans-contextualisation.
g) teacher preference to traditional teaching approach irrespective of society needs.
h) teacher perceived emphasis on external, content-oriented examination rather than valuing the educational gain.
i) curricular content overload causing a teacher level challenge of limited instructional time.

The above interpretation indicated that the potential challenges, with respect to trans-contextualising science teaching-learning for societal development, could be categorised at 3 levels.

a) teacher level challenges (i.e., lack of familiarity, value, ability, and willingness);
b) curriculum level (i.e., content overload and emphasis on only science conceptual learning in external examinations), and
c) student level (i.e., perceived lack of student motivation to engage in resolving societal concerns, perceived lack of student ability to resolve societal concerns).

5. DISCUSSION

5.1 The contribution of SSI in promoting citizenry

This research sought to establish the value of science education in preparing learners towards meeting the needs of a constantly-changing and sustainable-oriented society (OECD, 2018a; UNESCO, 2020; United Nations, 2015), seen as contributing to the wider societal development. In so doing, Socio-scientific issue (SSI) was identified in the research as a key aspect of the contextual framework through which science education could built a procedural link between science conceptualisation on the one hand and its role within the resolving of societal issues on the other (Ekborg et al., 2013; Espeja & Lagarón, 2015b; Reis & Galvão, 2004; Romine et al., 2017). Hence, this research initially sought to identify the contribution of SSI towards promoting citizenry, as is conceptualised by the literature and practicing teachers.

Contribution of SSI in promoting citizenry, identified by the literature (re-RQ 1a)

Based on the narrative literature review of the literature within the scope of SSI and its potential role in promoting citizenship, 10 commonly perceived attributes of SSI were seen as promoting attributes valuable for citizenship (table 1, paper 1). For example, the controversiality and ill-structured attributes of SSI were seen, in the literature, as contributing to promoting students' science-influenced argumentation (Zeidler et al., 2009), moral reasoning (Sadler & Donnelly, 2006) and informed decision-making (Yacoubian & Khishfe, 2018). In line with this, Sadler (2011) pointed out that the conceptualisation of any potential course of action with respect to SSI was influenced by,

> 'a variety of factors, which, from a *social* perspective, including politics, economics, and ethics' (p. 4).

Hence, the science learning within SSI instruction not only related to the conceptualisation of science, but also to its interrelatedness with existing societal concerns (Oulton et al., 2004; Reis et al., 2020b). This implied the importance of SSI in contributing to promoting students as informed individuals, able to conceptualise a socio-scientific concern from a scientific, ethical, moral, economic, or other value-laden points of view (Han-Tosunoglu & Ozer, 2021; Kahn & Zeidler, 2019; Karahan & Roehrig, 2017).

The findings indicated that such multi-faceted attributes of SSI, leading towards deriving educationally-sound, consensus points of view, were seen as potentially contributing to enabling science education to play its role in promoting a sense of citizenry (Oulton et al., 2004; Reis et al., 2020b). Nevertheless, the results also showed that the literature being very much oriented both to personal and social viewpoints, might lead to conflict in the decisions made, i.e., the decisions differing from person to person (Bossér & Lindahl, 2017a; Cinici, 2016; Grace et al., 2015; Gresch et al., 2017; Shea et al., 2015; Tidemand & Nielsen, 2017). These findings implied a potential limitation of SSI, expressed in paper 1, towards promoting a collective, participatory form of citizenry from instructions in science classrooms, but, at the same time, leading towards individual students being unprepared to deal with *authentic,* or science-related issues, related *to everyday life* (Shea et al., 2015).

Despite its limitations, the results (table 2, paper 1) indicated that SSI was seen as beneficial in promoting four dimensions of citizenry via science education, e.g., personally responsible (Vesterinen et al., 2016), participatory (Zeidler & Sadler, 2007, 2010), justice oriented (Badri, 2016; Oulton et al., 2004), or even politically concerned citizens (Owens et al., 2017; Yahaya et al., 2016). However, Morin et al. (2017) and Lewis and Leach (2006) pointed out that although SSI provides an opportunity to practice decision-making skills within the classroom, the decision making on socio-scientific issues within the classroom did not necessarily lead to students undertaking science-influenced actions outside the classroom within a society context, and thus lacked an actual mechanism to focus on promoting citizens. Such findings implied the need to systematically incorporate, within science teaching learning activities, a science-influenced, action-based stage within a beyond-school, societal context (Hodson, 2011, 2020).

Contribution of SSI in promoting citizenry, identified by teachers familiar with the SSI-based 3-stage model (re-RQ 1b)

Based on the strong literature support for SSI in promoting citizenry (paper 1), this research, through undertaking teacher interviews, sought to identify practising teacher perceptions (both in terms of importance and perception of practice) towards incorporating SSI within their teaching (paper 2). All participant teachers in this study were familiar with the key constructs of an SSI-based, 3-stage model, e.g., student motivation, scientific problem solving, and socio-scientific decision-making (chapter 2).

The outcomes from the teacher interviews indicated that teachers, who have been involved in teacher development programmes, perceived the inclusion of socio-scientific situations as being important in addressing student motivation for science learning. This was seen as significant and perceived to be line with the literature. For example, Albe (2008), Bennett and Lubben (2006), Zeidler et al. (2009) and Hewitt et al., (2019), in their studies found that teachers, after implementing SSI-based teaching, perceived significant improvement in student motivation with respect to the learning of science. The interviewed teachers, who had been involved in teacher development programmes, further indicated that they perceived the importance of SSI within science learning as promoting relevance in their students. Again, the SSI literature, in researching relevance of the learning e.g., Lewis and Leach (2006) and Zeidler et al. (2011), was in agreement with the teachers' perception of relevance of SSI teaching positively impacting on students. This contrasted with outcomes from interviewed teachers with no involvement in teacher development programmes, who indicated that they did not perceive the value of incorporating SSI to promote student motivation, or more specifically providing relevance towards the learning of science. In fact, Hancock et al. (2019) and Kara (2012) pointed out that teachers, who were not familiar with SSI-based teaching via any teacher development programmes, found it challenging to identify the relevance of SSI in line with science curricular topics. Hence, this research, being in line with the literature indications, implied that appropriate teacher development programmes played a strong role in teacher perception towards the importance of the inclusion of SSI in science teaching.

The results from the teacher interviews indicated that all participant teachers perceived the importance of SSI in forming a meaningful introduction to the teaching of a science topic, seen as a prelude from which students were able to perceive the need to participate in undertaking scientific problem-solving (paper 2). Other research also suggested similar findings (Yu et al., 2015), implying that an SSI-based, initial teaching motivational phase, supported students' active participation in science conceptual learning, and aided scientific problem-solving in the development of scientific literacy (Böttcher & Meisert, 2013; Galvão et al., 2011).

Additional outcomes from the teacher interviews indicated that participant teachers perceived the importance of the inclusion of socio-scientific issues in their teaching in promoting students' decision-making abilities (paper 2). However, differences in their perceptions of socio-scientific decision-making were noted (figure 3). The interviewed teachers, who had not been involved in teacher professional development programmes, tended to emphasise the role of conceptual science learning in socio-scientific decision-making, thus referring to the importance of promoting '*informed decision-making*'. In contrast, teachers who had been involved in teacher professional development programmes, tended to emphasise the need to promote '*competent decision-making*', referring to the need to promote democratic, consensus decisions, whereby the decision-making not only took into consideration science conceptual learning, but also personal values and ethics, plus environmental, economic and society aspects (section 4.1). Unfortunately, the literature tended to be ambiguous, supporting both an informed decision-making emphasis (Yacoubian & Khishfe, 2018), and a democratic decision-making emphasis (Kolstø, 2008). In explaining the contrast among the teacher perceptions, Ekborg et al. (2013), Espeja and Lagarón (2015) and Reis and Galvão (2004) pointed out that teacher development programmes (in-service, pre-service courses or involvement in projects) enhanced teachers' conceptualisation of SSI seeing this as also including a science informed element. Hence, the findings from this study implied there was a strong need to provide teachers with SSI-oriented, teacher professional development programmes, guiding them to recognise the value of including SSI teaching for promoting, in particular, students' meaningful socio-scientific decision-making.

Recently graduated teachers, during the teacher interviews, indicated that they did not perceive any contribution of SSI to promoting learners' citizenship attributes. This was seen as understandable considering they have had very limited teaching experience and, as such, could not necessarily foresee the longitudinal impact of SSI on promoting students' citizenship attributes. Experienced teachers, even without involvement in teacher development programmes, indicated that they perceived SSI instruction as enabling students to engage in socio-scientific argumentation, from a perspective of seeing the perceived quality of a 'good citizen' (figure 3), whereas the teachers with more than 10 years of experience further elaborated that SSI was perceived as important for enabling students to obtain the skills to collaborate, communicate, or even influence other members of the society to undertake responsible behaviour to address societal concerns, eventually preparing learners as 'engaged citizens' (figure 3). Furthermore, teachers, who had recently completed pre-service or in-service programmes, indicated that they perceived SSI instruction as playing an important role in promoting students as 'participating citizens', seeing this as developing students' skills to reconcile dilemmas and enabling them to undertake 'responsible actions' when addressing concerns within the society (figure 3).

The literature frequently associated considerations of socio-scientific issues with potentially enabling students to undertake informed decisions, taking into account societal values and thus promoting students' ability to contribute to 'citizenship attributes', namely – promoting responsible (Garrido Espeja & Couso, 2020), competent (Rundgren & Chang Rundgren, 2018), global (Kim et al., 2020) or environmental citizenship (Iversen & Jónsdóttir, 2019). Bearing this in mind, a major implication for the teacher interviews was that the participant teachers possessed different perception towards the kind of citizenship attributes science education should promote e.g., good citizens, participatory citizens, engaged citizens (figure 3). In fact, the deriving of the model for 'Active Informed Citizenry' (section 4.2), was founded on the existing science education literature indicating that not only teachers, but also science educators, held different positions on the kind of citizenship expected to be promoted through science education (table 3, referring to active, or informed citizens, both with respect to individualistic citizens or a collective citizenry).

The findings from the teacher interviews drew attention to the contrast between, on the one hand, teacher perceptions of importance and on the other, their perception of the practice of incorporating SSI in their teaching. For example, teachers who had at least 2 years of teaching practice, regardless of their involvement in teacher development programmes, reported that they did *not* always find it possible to incorporate SSI in their teaching, specifically suggesting that a successful implementation of only one socio-scientific issue could be implemented per year. The outcome also indicated that these teachers only used SSI when it was perceived to be relevant to the science topic, further pointing out that SSI was often omitted, or *only* used, initially, to promote student motivation. This tended to lead to such teachers disregarding student involvement in a socio-scientific decision-making learning stage. Taking into consideration that these teachers showed a very high perceived importance towards incorporating SSI-based teaching contexts (section 4.1.2), their current practice, based on a limited or unsystematic use of SSI, could be seen to be of concern. In fact, although it could be expected that teachers' perceived value of incorporating SSI-based teaching activities reflected on their practice, findings from this research (figure 7) implied that the teachers' perceived importance did not influence their practice. This apparent contrast between high perceived importance and low perceived current practice of incorporating SSI in science teaching, was also apparent in the literature e.g. Lee et al. (2006), Nida et al. (2020) and Sadler et al. (2006) who all indicated that even though teachers found SSI important to incorporate within science teaching, often they did *not* include it in their practice, because of a perceived lack of time. The implication of this research, in line with the research findings and the literature, indicated that in order to enable teachers to become aware of including relevant and appropriate SSI components in their teaching, teachers needed to be provided with suitable SSI-based instructional materials in line with the curriculum, which included systematically designed, teaching resources (i.e. SSI-based teaching modules, involving relevant ICT-web-based content), assessment guidelines for SSI-based teaching, and other supporting resources (e.g. additional reports, statistics) (Brunner & Abd-El-Khalick, 2020; L. Chen & Xiao, 2021; Davis & Krajcik, 2005).

5.2 The role of science education on societal development

In seeking to establish the role of science education in promoting societal development, this research put forward models conceptualising 'active informed citizenry' (AIC), and a 4-phase teaching approach for the promotion of AIC (section 4.2.1), and sought to establish such models based on the literature, practising teacher perceptions, and justification from science education researchers, curriculum developers and teacher educators.

AIC and the 4-phase model: justification from the literature (re-RQ 2a)

Based on an integrative literature review, an 'Active Informed Citizenry' model was devised, encompassing three key dimensions of citizenry, seen as critical to be promoted through science education (section 4.2). The model (table 3) addressed the need for science education to go beyond promoting solely 'informed citizenship', as suggested by Bossér and Lindahl, (2017), Duschl et al., (2013) and Kahn and Zeidler (2019) and solely 'active citizenship', as suggested by Foster-Fishman et al. (2007), Hadjichambis et al. (2019) and Marques and Reis (2017). Such an AIC model also reflects on the importance of incorporating scientifically informed and active engagement within the society, alongside, or even encompassing, collectiveness as suggested by Hodson (2014), democratic attitudes as suggested by Symington and Tytler (2004), responsible behaviour as suggested by OECD (2019c) and a global perspective as suggested by Kohl et al. (2012) and Lee et al. (2013).

Generally, the literature agreed that preparing learners as *only* scientifically informed citizens was insufficient to address societal concerns. Vesterinen et al.

(2016) and Hodson (2014, 2020) pointed out the role of science education was also to promote learners as participatory, personally responsible citizens, prepared to apply their scientific and technological skills to resolve societal issues (i.e. environmental, social, economic, etc.). Also there was agreement to a perceived need to promote, via science education, a sense of community and collectiveness so as to resolve societal concerns, and enhance societal development (Cohen et al., 2020; Felt, 2017; Furman et al., 2020; Jeong et al., 2021; Mudaly, 2020; Valladares, 2021).

In addressing the need to promote active informed citizenry via science teaching-learning, a 4th, trans-contextual phase was put forward (figure 5), adding to the literature established 3-stage model (figure 1). The proposed, constructivism-humanism oriented 4-phase approach, not only addressed scientifically informed citizenry, as advocated by Duschl et al. (2013), or active citizenry as advocated by Foster-Fishman et al. (2007), but the added trans-contextualisation phase potentially enabled the transference of scientifically informed decisions to a beyond-school collective action phase (figure 5), thereby enabling science education to play an important role in promoting a desired active informed citizenry. Such a trans-contextualisation phase was seen as addressing the limitations of the 3-stage model (section 2.3), identified within theoretical, contextual, and developmental points of view, as amplified in the following.

From a theoretical point of view, the science education literature separately advocated the need to encompass constructivism (Bingle & Gaskell, 1994; Develaki, 2021; Lima & Nascimento, 2022; Sánchez Gómez, 2021) and a humanism theory of learning (Allgaier, 2010; Li et al., 2022; Santos, 2009; Scantlebury & Milne, 2020; Sharma, 2012). While decision-making within socio-scientific issues actively engaged students within situated learning, especially if approached in a constructivist manner (Sadler, 2011), educationalists argued that such an approach lacked an emphasis on promoting students' empowerment (Tangney, 2014) when addressing social concerns (Tobolowsky, 2014). With this in mind, the addition of *humanism* theory (Huitt, 2009) was included in the 4-phase model so as to facilitate learners' acquisition of social and affective skills through co-operative and collaborative learning. Thus the constructivism-humanism theory based 4-phase model was seen as addressing not only critical thinking and positive changes in attitudes, but also logical and persuasive actions (Hale, 2020), while also focusing on stimulating responsible, justice oriented and democratic behaviour among learners (Tangney, 2014). Such an approach was seen as further supporting citizen argumentation on value-laden, social concerns (Alexander & Bushnell, 1997). Furthermore in addressing society development, the humanism addition was seen as placing emphasis, within science education, on promoting socio-scientific decisions through active and collective participation within the society, potentially leading to dialogue among citizens (Liu, 2013). In particular, this approach was seen as a way of addressing 'societal transformation' via scientific literacy (Santos, 2009; Scantlebury & Milne, 2020; Sharma, 2012) by encompassing a humanism theory in science teaching and learning (Cohen et al., 2020; Felt, 2017; Furman et al., 2020; Jeong et al., 2021; Mudaly, 2020; Valladares, 2021).

From a contextual point of view, the 4th, trans-contextual phase, also addressed the need for enabling students to transfer their motivational, science conceptual and socio-scientific decision-making learning to a 'beyond-classroom' societal context, as advocated by Lima & Nascimento (2022), and Morin et al. (2017). Such science influenced, collective action within a wider community was seen as crucial in promoting not only active or informed individual citizens, but a collective body of citizenry who were willing and able to undertake scientifically sound, responsible actions in addressing societal concerns, as advocated by the European Commission (2015), OECD (2018b), UNESCO (2015), and the United Nations (2015).

From a developmental point of view, the 3-stage model was seen as enhanced *students' individual development*, for example in their science conceptualisation, scientific problem-solving skills, socio-scientific values and attitudes, and in *students' social development* via scientifically sound argumentation and socio-scientific decision-making (Bolte et al., 2012b; Holbrook & Rannikmäe, 2010, 2014). However, in addressing a wider, *societal development* focus, as suggested by Evagorou and Dillon (2020), Garrecht et al. (2018) and Mudaly (2020), the 4th trans-contextual phase was seen as a major way forward in enabling students to learn to resolve societal concerns in a scientific, active and collective manner.

AIC and the 4-phase model: teacher perception, and justification from science education researchers, curriculum developers and teacher educator (re-RQ 2b and 2c)

In identifying perception of importance, and practice, towards accepting the value of the proposed 4-phase model, this study initially administered a pre-piloted questionnaire, with the validated questions administered to science teachers in Bangladesh, and in addition, undertook interviews with teacher educator, curriculum developers and science education researchers.

Findings from the questionnaire indicated that there was, in general, a lack of perceived importance towards promoting student transference of science learning to a beyond-classroom context, as opposed to promoting science conceptual learning (construct 1, section 3.2.2). This outcome was not surprising, noting that the Bangladesh Education Policy (Ministry of Education of Bangladesh, 2010) did not recognise attributes of scientific literacy, except for science conceptual learning, and did not emphasise the need to promote socio-scientific decision making, nor recognised the enabling of student transference of science learning to a beyond-school, societal context. Similar to the findings from this research, several studies reported that teachers' practice of embedding science cognition, within a societal context, was strongly influenced by the teachers' perceived need to scaffold students in acquiring science conceptual learning (Herman et al., 2017; Levinson & Consortium, 2017; Tidemand & Nielsen, 2017). Furthermore, participant science education researchers and the teacher educator, in the final interview (section 4.2.3), pointed to a teacher perceived challenge, likely to be faced when considering the science curricula, in handling content overloaded, thus leaving little flexibility for teachers to undertake science-related learning for social development, or even an overall science-involved, societal development approach (paper 5). An implication of such findings was that, for teachers to perceive the importance of promoting student socio-scientific decision-making, plus student transference of science learning for a societal benefit, the education policies and curricula needed to reconsider the vision of scientific literacy beyond science conceptual learning.

The findings from the questionnaire also indicated a contrast between responses from the pilot teachers and the teachers from Bangladeshi with respect to their perceived importance towards promoting students' decision-making skills through contextualising science education, within societal aspects. In seeking to explain the contrast in the responses, it should be noted that participant teachers from the pilot study were familiar with the concept of socio-scientific issue and its implication through participating in the 'We Act' project (Baptista et al., 2018). On the other hand, the Bangladeshi participant science teachers could not be expected to be familiar with socio-scientific issues, as neither the education policy, the curricula, nor any teacher professional development programmes were oriented towards this (paper 4). In fact, a recent review of SSI-based literature pointed out that SSI-based instructions were explicitly emphasised in science curricula within the European/American context, and much less explored in Asian contexts (Chen & Xiao, 2021). This implied a potential direction not only for Bangladesh, but also other developing countries, in recognising the importance of emphasising socio-scientific issue-based instruction within the relevant education policy and curricula so as to further promote students' socio-scientific decision-making skills.

Findings from the study indicated that the majority of participants from the pilot study, but comparatively less from the Bangladesh study, indicated agreement with items which referred to preparing students towards transferring science learning, undertaking individual or collective actions for the benefit of the society. An important finding from this study was that participant teachers from the pilot study, who had undergone teacher professional development programmes through the project, 'We Act', focussed on orienting science education towards students' participation in socio-scientific activities (Baptista et al., 2018; Reis, 2014, 2020; Reis et al., 2020a). This could be seen as influential towards enabling these teachers to envisage a wider aim of science education such as towards promoting students' active engagement in the society, and hence, showing a strong agreement towards promoting students' citizenship attributes. As proposed in the AIC model (section 4.2), active engagement by students in dealing with socio-scientific issue-related societal concerns, contributed, at least to some extent, towards preparing students collectively to become an Active Informed Citizenry. In mitigation for the Bangladeshi teachers not in agreement to a focus on socio-scientific activities, even although 60% of the Bangladeshi science teachers reported that they had participated in teacher development programmes, their responses revealed that these programmes were poorly related to science education, and more oriented to promoting content development through multimedia, ICT, etc. The outcomes from this research implied that there was a need to provide science teachers with suitable teacher professional development programmes, specifically oriented to the changing visions of science education, thus enabling teachers to perceive wider aims of science education, such as AIC.

Findings from the questionnaire also indicated that although a majority of Bangladeshi teachers reported a perceived high importance, and a high perceived possibility towards embedding science education within a societal context, yet only few teachers indicated that they always utilised such an approach when incorporating socio-scientific decision-making. Findings from Hancock et al. (2019), Zangori et al. (2018) indicated similar findings, pointing to much teacher hesitance in interrelating science learning within social, moral or ethical concerns in their teaching practice. In explaining teachers' hesitance to use socio-scientific decision-making, Tidemand and Nielsen (2017) found that teachers tended to reduce socio-scientific, issue-based decision-making in their science teaching practice, expressing their concerns that they did not perceive socio-scientific argumentation or decision-making competences as exclusively within the realm of science education. The contrast between teacher indicated perceived importance of the science learning with their indication of actual current practice within the present study, as well as within the literature, implied that, despite positive responses to the questionnaire and interviews, teachers actually lacked recognition of the perceived importance of initiating conceptual science education within a familiar, or stimulating science-related, societal context. Thus, teachers seemingly failed to recognise its motivational value as well as the need to be aware of the role of conceptual science in undertaking socio-scientific decision-making. This pointed to a need to widen the scope of science education so as to play a wider role than promoting only student individual development, and appreciating its possible role in student social development and also the greater societal development (as indicated in figure 8).

Findings from the questionnaire indicated that teachers perceived their practice towards promoting science conceptual learning as more dominant compared with promoting student motivation, socio-scientific decision-making, and transference of science learning to a beyond-classroom, societal context. In line with this, the interviewed science education researchers pointed out that the initiating of science learning via a context-based socio-scientific setting required a shift towards a more student-centred, constructivist approach and hence teachers were resistant to such a change, as they were used to a teacher-led, subject focused, teaching practice. Generally, the literature agreed with such perception (Belova & Eilks, 2016; Ekborg et al., 2013; Lee & Yang, 2019; Vázquez-Bernal et al., 2012). The existing literature also suggested that the lack of teacher willingness to incorporate SSI in their teaching was based on the predominance of promoting conceptual science only through closed questions or activities, plus having no flexibility in their approach to promote students' divergent thinking (Vázquez-Bernal et al., 2012). Lee and Yang (2019) argued, in terms of teachers' perception of time limitation associated with the use of SSI, that teachers were more accustomed to using lecture-based instructions, and hence, they found it difficult to allowing students to play a stronger self- determining role in promoting science conceptual learning, perceiving more time was needed to enable students to explore relevant SSIs. Other studies linked teachers' lack of willingness and preparedness to incorporate SSI with teacher insecurity in terms of handling control over to students (Belova & Eilks, 2016; Ekborg et al., 2013; Lee & Yang, 2019). These circumstances raised serious concern, as it appeared teachers were orienting their science teaching towards only promoting science conceptual learning. The findings from this study advocated that there was a need to place more emphasis on SSI-based decision-making through not only education policies, but also via curriculum learning outcomes and appropriate professional training.

Findings from the questionnaire further indicated a gap in teacher perceived practice with respect to the need to practice the promoting of students' ability to transfer their gained science learning to a 'beyond-school' societal context. This pointed to a lack of familiarity by these teachers with the need for trans-contextualisation of the science learning. This was not surprising given that in both the science education curriculum guidelines and the education policy, there were no explicit indication for teachers to undertake activities which enabled transferring science learning to a 'beyond the classroom context'. In fact, even the science education literature tended to cite few examples in this direction. However, the present study was perceived to be in line with the international policy documents seen as promoting the need for students to apply their science learning so as to address local, social or even global concerns (European Commission, 2015; Mahundu, 2020; OECD, 2019c; United Nations, 2015). This study thus related to a perceived aim of science education as being to systematically incorporate learning activities which enabled students to undertake collective and responsible action, based on their science conceptual learning and thereby aimed to recognise the important role of science education in the resolving of societal concerns. It further suggested the need to promote science education policy and curricula to more actively address societal concerns and for further research to be undertaken to explore ways to enhance teachers' perceived importance, and promote practice towards, embracing trans-contextualisation. Thus, the proposed aim was seen as to embrace an envisaged goal of science education as being the promoting of an active informed citizenry.

In the interview with participant science education researchers, curriculum developers and teacher educator all indicated that that there was a potential resistance from teachers to incorporate the 4-phases in teaching, speculating teachers were expected to perceive no value from such an approach. Reis and Galvão (2004) and Sadler et al. (2006) found similar results, noting that teachers indicated they did not practice socio-scientific decision-making as they did not perceive promoting such issue-based discussions or decision-making as their responsibility. This pointed to the need to familiarise teachers with a wider vision of scientific literacy through appropriate teacher professional development, as advocated in policy documents (OECD, 2018b) and to take steps to enable them to perceive the importance of promoting student socio-scientific decision-making through science education.

A constructivism approach to learning strongly advocated that student motivation led to effective and self-regulated learning (Bandura et al., 1999; Bruner, 1966), and further recognised the role of the teacher in providing 'contexts' in which students could develop their knowledge and skills (Fensham et al., 1994). However, the participant teacher educator from the final interview pointed out that teachers might be resistant to such constructivism or humanism approach to teaching, considering their preferred approach to teaching is mostly traditional lecture-based teaching (section 4.3). To undertake a constructivism-humanism approach, based on the research findings, this research advocated that science education practitioners, particularly teacher educators, needed to not only familiarise teachers with such an approach, but also support teacher professional development programmes to undertake such approaches in contributing to societal development.

Findings from the final interviews pointed out that teachers' perception of a lack of time to incorporate SSI in their science teaching could be linked to a perceived overloaded curriculum, and specifically to a teacher's fear of getting behind in curricula coverage. This was in line with the literature (Belova & Eilks, 2016). Furthermore, Zande et al. (2012), Ekborg et al. (2013) and Hancock et al. (2019) pointed out that curriculum dominance of external examinations on memorisation of conceptual science appeared as a challenge for the teachers to incorporate SSI in their science teaching. Nevertheless, a contradictory result was also documented by (Tidemand & Nielsen, 2017), who found in their study that the participant biology teachers tended to limit the incorporation of SSIs in their science teaching, even though SSI-related competence was strongly emphasised in the Danish Biology curriculum. These results implied that familiarity, acknowledgement or appreciation, or even instruction indicated within the curriculum towards incorporating SSI might not be a sufficient reason for the teachers to seriously and systematically address socio-scientific issues in their practice. This pointed to the need for an added emphasis on the importance of promoting SSI through teacher development programme to enable teachers to systematically incorporate specific approaches such as the 4-phase model towards promoting student socio-scientific decision-making.

6. CONCLUSION

This research recognized the need for, and sought to widen the perceived science education-society dimensions to be encompassed within the development of scientific literacy. In the following, a summary of conclusions is put forwards in line with the research questions.

Based on the narrative literature review, this research concluded that the controversial nature of socio-scientific issues was seen in the literature as enabling students to conceptualise the complexity of societal concerns, undertake scientifically sound argumentation and informed decision on scientifically embedded societal issues. Such attributes of SSI were perceived in the literature as contributing to promoting personally responsible, participatory, justice oriented and politically concerned citizens.

Based on the initial teacher interviews, this research concluded that participant teachers, who were familiar with the SSI-based 3-stage model, perceived that need-based incorporation of socio-scientific issues addressed the relevance of science with respect to societal concerns, which further motivated the students to gain science competences in addition to informed decision-making. Participant teachers identified such learning as contributing to the promotion of students as citizens. However, the participant teachers' perception of importance and perceptions of practice towards implementing an SSI-based, 3-stage teaching approach differed based on their involvement in teacher development programmes. Although all participant teachers agreed to the contribution of SSI in promoting citizenship attributes, their perceptions with respect to the kind of citizen to be promoted via science education were not consistent. The participant teachers also pointed out an inconvenience in implementing SSI-based instructions due to a time constraint.

Based on the integrative literature review, this research concluded that in identifying a wider role of science education in societal development, there was a need to promote learners not only as scientifically informed individual citizens, but also actively and collectively engaging citizens in resolving societal concerns. In so doing, this research derived and justified a 4-phase, trans-contextual science teaching learning approach in promoting active informed citizenry, by complementing constructivism theory with the humanism theory of learning, and incorporating cognitive, behavioural and socio-emotional components in science teaching learning.

Based on the quantitative study, this research concluded that participant teachers showed moderately perceived the importance, yet low perceived practice of incorporating the derived 4-phase model, in promoting active informed citizenry. This research further concluded that participant teachers' perceived importance of promoting conceptual science was significantly higher than their perceived importance of enabling students to transfer their science learning to a beyond-classroom societal context. This was seen as a barrier to addressing societal development via science education.

Based on the final interviews with science education researchers, curriculum developers and teacher educators, this research concluded that trans-contextual science education was seen as having value in contributing to three dimensions of development – student individual development (i.e. learning conceptual science, employable scientific skills, scientific values and individual attitude towards science), student social development (i.e. collaboration, cooperation, having a sense of community, argumentation, or group decision-making), and societal development (i.e. supporting society to resolve societal concerns via active, collective, and scientifically influenced engagement, promoting collective scientific attitude towards resolving socio-scientific dilemma via logical persuasion).

From the above, this research is seen as contributing to:

a) theory: A combination of constructivism-humanism theory;
b) research: A validated instrument for identifying teacher perception of importance and practice towards promoting science for societal development;
c) practice: A 4-phase science teaching learning approach, with an exemplary module validated by experts;
d) society: A societal development emphasis in science teaching learning.

LIMITATIONS

The limitations of the study were seen as the following:

The 4-phase teaching approach was not implemented in a school as a part of the study. Hence, to what extent teachers were able to implement such an approach in the face of obstacles was not determined. This could be considered in conducting future studies, identifying the classroom impact of the 4-phase approach in promoting AIC.

The sample size for the main study was limited, caused by the limitation in collecting data from a distance.

The study did not compare data based on country contexts (i.e., Estonia, Bangladesh or pilot study participants' countries). This was because there was no intention to determine which context promotes scientific literacy more appropriately, but rather the intention was to value a perceived global role of science education in addressing societal development, irrespective of context.

RECOMMENDATIONS

In envisioning a wider dimension of science education towards promoting an active informed citizenry (beyond a traditional science conceptual learning emphasis, and embracing a constructivism-humanism vision of science education), this research recommends the following to be undertaken:

a) amendments made necessary in education policies (as necessary), so as to establish the value of trans-contextualising science education in promoting active informed citizenry for addressing societal development;
b) undertake a curricular shift towards a continuous assessment of competences, with respect to not only student conceptual learning, but also student socio-scientific decision-making, and trans-contextualising of science learning;
c) promote teacher preparation and CPD programmes with respect to familiarising teachers with a wider society-dimension of science education, and SSI-based teaching strategies (particularly with respect to trans-contextualisation).

It is further recommended that an exemplary teaching-learning module be created consisted of the following sections, based on a 4-phase teaching learning approach (appendix A4):

a) Overall context of the module: General overview of the module, its context (based on a concern), target science education competences, illustration of the 4-sequential phases so that students are able to use their learning so as to appreciate and address the problem.
b) Student Activities: Based on a provided scenario (provided by the module), the suggested activities indicated the learning tasks in which the students are guided to be involved.
c) Teaching guide: Suggests a teaching approach and learning targets and gives suggested formative/summative assessment strategies.

SUMMARY IN ESTONIAN

Kontekstiülese loodusteadusliku hariduse edendamine aktiivse ja teadliku kodanikkonna kujundamiseks

Ühiskond muutub pidevalt ning seisab silmitsi majanduslike, sotsiaalsete ja keskkonna-alaste väljakutsetega (United Nations, 2015). Haridus peab õpilasi valmistama ette toimetulekuks ühiskondlike muutustega, loomaks uusi väärtusi, lahendamaks vastuolusid ja võtmaks vastutuse otsuste tegemise eest (OECD, 2019). Loodusteaduslik haridus, mille eesmärgiks on kujundada loodusteaduslikku kirjaoskust, peab tagama, et õpilased suudaksid rakendada oma pädevusi elulistes kontekstides, käsitleda jätkusuutlikkusega seotud probleeme ja toetada üldist heaolu (OECD, 2018).

Uuringud näitavad, et loodusainete tundides keskendutakse eelkõige sellisele teadmiste kontrollile, mis paneb proovile õpilaste mälu, mitte aga nende kontseptuaalsed teadmised (Zande et al., 2012; Ekborg et al., 2013; Hancock et al., 2019). Seetõttu ei ole loodusteaduslik haridus õpilaste jaoks ühiskondlikult oluline ega seostu nende igapäevaelu või karjäärivalikutega (Dillon, 2016; Dorph et al., 2018; Levrini et al. al., 2021). Chen ja Xiao (2021) rõhutavad, et õpetajad ei väärtusta loodusteadusliku hariduse raames ühiskonna arengule tähelepanu pööramist. Seetõttu tõstatub kaks kriitilist küsimust:

a) kuidas ja mil määral peaks loodusteaduslik haridus tagama õpilaste kontseptuaalsete teadmiste ülekandumise ühiskondlike probleemide lahendamiseks?
b) Kuidas õpetajad hakkavad väärtustama ja rakendama loodusteadusliku hariduse rolli ühiskondlike probleemide lahendamisel.

Uurimistöö eesmärk oli selgitada, kuidas õpetajad väärtustavad ühiskondlikult oluliste loodusteaduslike teemade käsitlemist loodusainete õpetamisel ning kuidas loodusteaduslikud teadmised kanduvad koolikontekstist üle igapäevaellu.

Doktoritöö põhineb viiel artiklil.

Esimeses artiklis antakse ülevaade ühiskondlikult oluliste loodusteaduslike teemade käsitlemisest teadusartiklites. Selgus, et uurijad juhivad tähelepanu ühiskondlikult olulistele probleemidele, mille lahendamine eeldab loodusteaduslikke teadmisi (edaspidi SSI) ja mis on õpetamise ja õppimise protsessis kriitilise tähtsusega (Eş & Öztürk, 2021; Herman et al., 2019; Ke et al., 2021). Arutatakse ka SSI lähenemisega seotud õpimoodulite ja materjalide kitsaskohti, kuna neid mooduelid ja materjale võidakse pidada vastuolulisteks (Khishfe et al., 2017) ja halvasti struktureerituks (Zeidler et al., 2009), samuti võivad neis ilmneda teaduseetika alased lahkhelid (Han-Tosunoglu & Ozer, 2021). Samas peeti SSI materjalide puhul kasulikuks nende rakendamist õpilaste argumenteerimisoskuse kujundamiseks rõhutades vastutustundlikkust, aktiivset osalust ja poliitilist teadlikkust (Es& Öztürk,2021).

Teaduskirjanduses viidatakse SSI rakendamisel kontekstipõhise õpikäsituse kolmeastmelisele mudelile: (a) kontekstualiseerimine; (b) dekontekstualiseerimine; (c) rekontekstualiseerimine (Holbrook & Rannikmäe, 2010). Kontekstualiseerimise etapi eesmärk on suurendada õpilaste motivatsiooni ja saada ülevaade nende eelteadmistest, tutvustades loodusteaduslikku SSI stsenaariumit. Dekontekstualiseerimise etapis keskendutakse loodusteaduslike baasteadmiste kujundamisele uurimusliku õppe abil. Rekontekstualiseerimise etapis võimaldatakse õpilastel rakendada loodusteaduslikke teadmisi ja oskusi esialgses SSI stsenaariumis, et arendada sotsiaalteadusliku argumenteerimise ja otsuste tegemise võimet.

Selgitamaks välja õpetajate hinnanguid kolmeastmelise SSI-põhise mudeli rakendamisest igapäevatöös, viidi läbi intervjuupõhine kvalitatiivne uuring kümne loodusteaduste õpetajaga (artikkel 2). Tulemused näitasid, et vastajad tajusid täiendkoolituste tähtsust SSI õppetöös rakendamisele. Õpetajate poolt tajutav tähtsus, valmisolek ja tahe ei olnud siiski ainsad tegurid sotsiaalsete komponentide kaasamisel loodusteaduste õpetamisse. Oluliseks osutus ka õpetajate varasem kogemus ja õppetöö koormus.

Artikkel 3 on kirjanduse ülevaate teemaline artikkel. Selles väidetakse, et jätkusuutlikkuse alaste ühiskondlike probleemide lahendamiseks ei piisa vaid teaduslikku infot omavatest ühiskonnaliikmetest (Kahn & Zeidler, 2019) või aktiivsete kodanike tegevustesse kaasamisest (Marques & Reis, 2017). Püüdes selgitada, mil määral on võimalik ja kuidas peaks teadusharidus õpilasi ette valmistama, käsitles artikkel 3 hariduspoliitilisi dokumente (Euroopa Komisjon (EL), 2015; OECD, 2018; United Nations, 2015)Selles artiklis on defineeritud aktiivse informeeritud kodanikkonna mõiste (‘active informed citizenry’ AIC): *‘koos tegutsev kollektiivne kodanikkond, kes on sisukalt informeeritud, haritud, loodusteadusliku kirjaoskusega,. ei edenda ainult aktiivselt rolli riiklikul tasandil, vaid osaleb ka aktiivselt ühiskonnaelus ning on valmis võtma omaks laiemaid globaalseid probleeme, teadvustades, et need võivad mõjutada ka riiklikku või isegi kohalikku tasandit.’* (Chowdhury et al., 2020)

AIC kontekstis järeldati artiklis 3, et klassiruumis toimuv SSI-ga seotud otsuste tegemine ei ole piisav, et võimaldada õpilastel üle kanda loodusteaduslikke teadmisi ja oskusi klassiruumist väljapoole (Morin et al., 2017). Selle probleemi lahendamiseks lisati kolmeastmelisele mudelile ka neljas aste – kontekstiülese loodusteadusliku hariduse mõõde. See on tuletatud ja täiustatud varasemast 3-astmelisest kirjanduse mudelist (Holbrook & Rannikmäe, 2010). Kontekstiülese loodusteadusliku hariduse aste defineeriti järgmiselt:

‘Liikumine ühiskonna koolikesksest õppekeskkonnast laiemale arenguplatvormile, millesse võivad olla kaasatud suured muutused sotsiaalses käitumises. Seda tehes püütakse koolikeskkonnas tugineda õpilaste teadlikele otsustele, et laiendada mudelit laiemale ühiskondlikule auditooriumile, püüdes seeläbi ergutada aktiivset tõenduspõhist tegevust ja võimaldada ühiskonna säästvat arengut.’ (Chowdhury et al., 2020)

See etapp keskendub õpilastele, võimaldades:

- esitada loomingulisi, koostööpõhiseid ja teaduslikult põhjendatud otsuseid;
- osaleda aktiivselt kavandatavate otsuste elluviimises;
- tõsta teadlikkust ja veenda teisi kodanikke vastutustundlikult käituma ühiskonnaprobleemide lahendamisel, toetudes usaldusväärsetele teaduslikele argumentidele.

Artikkel 4 annab ülevaate uuringust, mille eesmärgiks oli välja selgitada õpetajate tajutud enesetõhusus loodusteaduste õpetamise praktikast, arvestades 4-astmelise õpetamisviisi kaasamist aktiivse informeeritud kodanikkonna edendamise protsessi.

Lähtudes eelnevast koostati instrument, mis valideeriti ekspertide rühma poolt. Instrumendi piloteerimisel osales 111 õpetajat, kes olid tuttavad SSI ja SSA mudelitega. Pilootuuringu järel viidi valideeritud instrumendi abil läbi põhiuuring 126 Bangladeshi loodusainete õpetajaga. Ilmnes, et Bangladeshi õpetajate tajutud enesetõhusus tähtsuse ja praktika vahel oli erinev.See tulemus ei olnud üllatav, sest Bangladeshi haridusstrateegia (Ministry of Education of Bangladesh, 2010) ei sisalda teadusliku kirjaoskuse komponente (välja arvatud loodusteaduste kontseptuaalne õpe) ega rõhuta vajadust arendada või võimaldada SSI otsuste tegemist. Samuti ei rõhuta see õpilaste teadmiste ja oskuste ülekandmise vajalikkust koolivälisesse ühiskondlikku konteksti. Selleks, et õpetajad tajuksid õpilaste SSI otsuste tegemise ja loodusteaduste õppimise ülekandmise tähtsust ühiskonna hüvanguks, oleks hariduspoliitikas vaja laiendada loodusteadusliku kirjaoskuse käsitlust loodusteaduste kontseptuaalsest õppest kaugemale.

Viiendas artiklis tutvustatakse täiendavat uuringut, mis viidi läbi 4-astmelise mudelipõhise õppematerjali valideerimiseks, et selgitada välja loodusteaduste õpetajate arvamus ühiskonna arengu edendamise kohta teadushariduse abil. Kasutades kvalitatiivset meetodit intervjueeriti üht õpetajakoolitajat, kaht õppekava koostajat ning kaht loodusteadusliku hariduse valdkonna teadustöötajat. Tulemused näitasid, et loodusteaduste õppimise eesmärke tajuti kolmel erineval tasemel: (a) õpilaste individuaalne areng (st loodusteaduste kontseptuaalsete teadmiste õppimine, rakendatavad teaduslikud oskused ja väärtused ning isiklik suhe loodusteadustega); (b) õpilaste sotsiaalne areng (st rühmatöö, koostöö, kogukonna tunne, argumenteerimine või grupiotsuste tegemine); (c) ühiskondlik areng (st aktiivne ühiskonna toetamine ühiskondlike probleemide lahendamisel kollektiivse ja teaduslike mõjude kaasamise kaudu, edendades kollektiivset teaduslikku hoiakut lahendamaks SSI dilemmasid). Selline arusaam ühiskonna arengust on kooskõlas humanistliku õppimiskäsitusega ja arvestab humanistlikku lähenemist, mis toetab õppijate ettevalmistamist ühiskondlike probleemide lahendamisel (Tobolowsky, 2014), edendab loogilistes ja veenvates tegevustes positiivseid kollektiivseid muutusi (Hale, 2020) ning muutusi ühiskonnas tervikuna (Santos, 2009; Scantlebury & Milne, 2020; Sharma, 2012).

Teadusharidus ei ole ühiskonnast isoleeritud ning kindlasti ei tohiks piirduda ainult kontseptuaalsete teadmiste kujundamisega. Püüdes vastata pidevalt kasvavatele ühiskondlikele väljakutsetele, peaks loodusteaduslik haridus võimaldama viia loodusteaduste õppe klassiruumist üle koolivälise ühiskonnaga seotud konteksti. Samas võib selle eesmärgi taotlemine põhjustada õpetajate vastuseisu. Siiski soovitatakse täiendkoolitusi õpetajatele, mis selgitaksid vajadust konstruktivistlik-humanistliku lähenemisviisi järele ja aitaksid rakendada seda praktikas, võimaldades õppijatel kontseptuaalsete teadmiste omandamise kõrval arendada ka SSI-l tuginevate otsuste ülekandmist koolivälisesse konteksti, et tagada teaduslikult laiapõhjaline ning jätkusuutlik ühiskond.

APPENDICES

Appendix A1: Item correlation from pilot data collection instrument (section 3.2)

Variable		1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	4.10	4.11	4.12	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	5.10	5.11
1.1	Pearson's r	—																																		
	p-value	—																																		
1.2	Pearson's r	0.676	—																																	
	p-value	< .001	—																																	
1.3	Pearson's r	0.673	0.525	—																																
	p-value	< .001	< .001	—																																
1.4	Pearson's r	0.605	0.517	0.576	—																															
	p-value	< .001	< .001	< .001	—																															
2.1	Pearson's r	0.251	0.135	0.284	0.309	—																														
	p-value	0.008	0.156	0.003	< .001	—																														
2.2	Pearson's r	0.197	0.168	0.272	0.326	0.712	—																													
	p-value	0.038	0.077	0.004	< .001	< .001	—																													
2.3	Pearson's r	0.278	0.371	0.320	0.312	0.438	0.627	—																												
	p-value	0.003	< .001	< .001	< .001	< .001	< .001	—																												
2.4	Pearson's r	0.065	0.115	0.253	0.174	0.326	0.331	0.410	—																											
	p-value	0.498	0.228	0.007	0.068	< .001	< .001	< .001	—																											
3.1	Pearson's r	0.085	0.111	0.141	0.157	0.600	0.507	0.479	0.367	—																										
	p-value	0.374	0.244	0.140	0.099	< .001	< .001	< .001	< .001	—																										
3.2	Pearson's r	0.058	0.137	0.102	0.147	0.319	0.446	0.436	0.341	0.694	—																									
	p-value	0.548	0.151	0.285	0.124	< .001	< .001	< .001	< .001	< .001	—																									
3.3	Pearson's r	0.125	0.185	0.207	0.162	0.297	0.344	0.453	0.374	0.502	0.605	—																								
	p-value	0.190	0.051	0.029	0.089	0.002	< .001	< .001	< .001	< .001	< .001	—																								
3.4	Pearson's r	0.084	0.168	0.182	0.207	0.367	0.401	0.400	0.319	0.575	0.533	0.623	—																							
	p-value	0.379	0.078	0.055	0.030	< .001	< .001	< .001	< .001	< .001	< .001	< .001	—																							
4.1	Pearson's r	0.483	0.346	0.409	0.293	0.056	0.086	0.156	0.297	0.123	0.105	0.244	0.064	—																						
	p-value	< .001	< .001	< .001	0.002	0.562	0.368	0.103	0.002	0.199	0.271	0.010	0.506	—																						
4.2	Pearson's r	0.404	0.364	0.366	0.257	–0.002	0.055	0.282	0.200	0.098	0.173	0.176	0.041	0.611	—																					
	p-value	< .001	< .001	< .001	0.007	0.982	0.568	0.003	0.035	0.306	0.070	0.065	0.667	< .001	—																					
4.3	Pearson's r	0.353	0.372	0.366	0.272	–0.065	0.015	0.254	0.164	0.088	0.125	0.130	0.154	0.571	0.685	—																				
	p-value	< .001	< .001	< .001	0.004	0.500	0.876	0.007	0.085	0.358	0.191	0.175	0.106	< .001	< .001	—																				
4.4	Pearson's r	0.501	0.405	0.378	0.378	0.060	0.084	0.132	0.145	0.017	–0.015	0.078	0.098	0.612	0.382	0.518	—																			
	p-value	< .001	< .001	< .001	< .001	0.532	0.380	0.168	0.128	0.856	0.876	0.414	0.308	< .001	< .001	< .001	—																			
4.5	Pearson's r	0.505	0.379	0.417	0.348	0.055	0.136	0.294	0.202	0.174	0.208	0.256	0.181	0.682	0.621	0.646	0.598	—																		
	p-value	< .001	< .001	< .001	< .001	0.567	0.156	0.002	0.034	0.067	0.028	0.007	0.057	< .001	< .001	< .001	< .001	—																		
4.6	Pearson's r	0.552	0.392	0.454	0.427	0.200	0.120	0.167	0.137	0.123	0.065	0.270	0.160	0.547	0.499	0.495	0.562	0.574	—																	
	p-value	< .001	< .001	< .001	< .001	0.036	0.211	0.080	0.152	0.198	0.496	0.004	0.094	< .001	< .001	< .001	< .001	< .001	—																	
4.7	Pearson's r	0.545	0.491	0.411	0.366	0.102	0.040	0.263	0.268	0.128	0.246	0.303	0.270	0.504	0.592	0.529	0.523	0.597	0.685	—																
	p-value	< .001	< .001	< .001	< .001	0.287	0.677	0.005	0.004	0.180	0.009	0.001	0.004	< .001	< .001	< .001	< .001	< .001	< .001	—																
4.8	Pearson's r	0.412	0.361	0.328	0.238	0.055	0.095	0.308	0.139	0.200	0.313	0.329	0.252	0.488	0.566	0.624	0.413	0.733	0.558	0.583	—															
	p-value	< .001	< .001	< .001	0.012	0.567	0.324	< .001	0.147	0.036	< .001	< .001	0.008	< .001	< .001	< .001	< .001	< .001	< .001	< .001	—															
4.9	Pearson's r	0.554	0.404	0.390	0.349	0.108	0.191	0.365	0.184	0.149	0.270	0.218	0.176	0.535	0.548	0.639	0.485	0.720	0.570	0.626	0.738	—														
	p-value	< .001	< .001	< .001	< .001	0.258	0.045	< .001	0.053	0.118	0.004	0.021	0.065	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	—														

Variable		1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	4.10	4.11	4.12	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	5.10	5.11
4.10	Pearson's r	0.494	0.411	0.439	0.364	0.135	0.063	0.250	0.274	0.240	0.245	0.376	0.304	0.633	0.579	0.583	0.569	0.674	0.600	0.754	0.634	0.678	—													
	p-value	< .001	< .001	< .001	< .001	0.159	0.513	0.008	0.004	0.011	0.009	< .001	0.001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	—													
4.11	Pearson's r	0.339	0.308	0.329	0.256	0.084	0.052	0.140	0.259	0.187	0.200	0.222	0.258	0.505	0.460	0.601	0.462	0.506	0.499	0.592	0.418	0.597	0.657	—												
	p-value	< .001	0.001	< .001	0.007	0.383	0.586	0.142	0.006	0.049	0.035	0.019	0.006	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	—												
4.12	Pearson's r	0.442	0.356	0.333	0.384	0.152	0.101	0.182	0.204	0.161	0.162	0.262	0.259	0.549	0.465	0.569	0.557	0.699	0.718	0.692	0.591	0.638	0.682	0.661	—											
	p-value	< .001	< .001	< .001	< .001	0.111	0.293	0.057	0.032	0.092	0.089	0.005	0.006	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	—											
5.1	Pearson's r	0.437	0.395	0.441	0.219	0.150	0.113	0.172	0.210	0.144	0.246	0.284	0.182	0.441	0.430	0.355	0.384	0.476	0.460	0.521	0.381	0.515	0.474	0.523	0.497	—										
	p-value	< .001	< .001	< .001	0.021	0.115	0.238	0.070	0.027	0.131	0.009	0.002	0.056	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	—										
5.2	Pearson's r	0.496	0.485	0.481	0.277	0.183	0.123	0.255	0.203	0.132	0.251	0.319	0.246	0.395	0.356	0.377	0.440	0.419	0.587	0.605	0.469	0.640	0.525	0.575	0.553	0.798	—									
	p-value	< .001	< .001	< .001	0.003	0.055	0.197	0.007	0.033	0.169	0.008	< .001	0.009	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	—									
5.3	Pearson's r	0.443	0.334	0.421	0.218	0.113	0.035	0.189	0.224	0.186	0.290	0.388	0.182	0.507	0.429	0.423	0.428	0.563	0.546	0.670	0.583	0.594	0.733	0.606	0.591	0.655	0.714	—								
	p-value	< .001	< .001	< .001	0.021	0.239	0.713	0.047	0.018	0.051	0.002	< .001	0.056	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	—								
5.4	Pearson's r	0.382	0.389	0.404	0.327	0.253	0.172	0.138	0.167	0.229	0.344	0.348	0.277	0.376	0.245	0.295	0.339	0.436	0.451	0.477	0.390	0.589	0.533	0.582	0.528	0.588	0.710	0.652	—							
	p-value	< .001	< .001	< .001	< .001	0.007	0.072	0.149	0.079	0.016	< .001	< .001	0.003	< .001	0.009	0.002	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	—							
5.5	Pearson's r	0.401	0.422	0.281	0.460	0.199	0.156	0.273	0.101	0.067	0.146	0.232	0.247	0.327	0.243	0.252	0.491	0.400	0.583	0.566	0.377	0.439	0.473	0.378	0.579	0.421	0.550	0.486	0.533	—						
	p-value	< .001	< .001	0.003	< .001	0.036	0.102	0.004	0.291	0.482	0.127	0.014	0.009	< .001	0.010	0.008	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	—						
5.6	Pearson's r	0.486	0.381	0.495	0.365	0.164	0.157	0.242	0.165	0.193	0.288	0.329	0.256	0.461	0.417	0.405	0.427	0.490	0.589	0.542	0.458	0.561	0.529	0.578	0.519	0.656	0.659	0.610	0.668	0.583	—					
	p-value	< .001	< .001	< .001	< .001	0.086	0.100	0.011	0.084	0.042	0.002	< .001	0.007	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	—					
5.7	Pearson's r	0.430	0.427	0.456	0.400	0.148	0.123	0.190	0.203	0.201	0.251	0.419	0.246	0.464	0.324	0.275	0.440	0.508	0.550	0.504	0.437	0.481	0.559	0.471	0.481	0.546	0.604	0.646	0.645	0.472	0.659	—				
	p-value	< .001	< .001	< .001	< .001	0.121	0.197	0.046	0.033	0.035	0.008	< .001	0.009	< .001	< .001	0.004	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	—				
5.8	Pearson's r	0.461	0.399	0.388	0.331	0.211	0.155	0.223	0.227	0.190	0.280	0.316	0.241	0.460	0.282	0.406	0.440	0.543	0.545	0.568	0.501	0.680	0.556	0.645	0.663	0.711	0.778	0.754	0.783	0.502	0.665	0.675	—			
	p-value	< .001	< .001	< .001	< .001	0.026	0.103	0.018	0.017	0.046	0.003	< .001	0.011	< .001	0.003	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	—			
5.9	Pearson's r	0.396	0.336	0.429	0.369	0.311	0.250	0.305	0.257	0.296	0.336	0.378	0.334	0.357	0.288	0.374	0.409	0.418	0.593	0.544	0.404	0.613	0.530	0.583	0.558	0.615	0.712	0.655	0.720	0.663	0.763	0.611	0.753	—		
	p-value	< .001	< .001	< .001	< .001	< .001	0.008	0.001	0.006	0.002	< .001	< .001	< .001	< .001	0.002	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	—		
5.10	Pearson's r	0.423	0.429	0.331	0.329	0.216	0.179	0.314	0.179	0.210	0.312	0.308	0.291	0.300	0.371	0.383	0.435	0.484	0.510	0.639	0.549	0.690	0.544	0.560	0.534	0.523	0.689	0.582	0.646	0.648	0.686	0.610	0.702	0.751	—	
	p-value	< .001	< .001	< .001	< .001	0.023	0.060	< .001	0.060	0.027	< .001	0.001	0.002	0.001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	—	
5.11	Pearson's r	0.365	0.400	0.342	0.391	0.236	0.162	0.264	0.151	0.148	0.231	0.270	0.287	0.249	0.305	0.318	0.369	0.322	0.553	0.540	0.369	0.492	0.408	0.453	0.520	0.609	0.699	0.572	0.622	0.743	0.759	0.556	0.680	0.826	0.745	—
	p-value	< .001	< .001	< .001	< .001	0.013	0.089	0.005	0.113	0.120	0.015	0.004	0.002	0.008	0.001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	—

Appendix A2: Cronbach's Alpha for the pilot questionnaire

The reliability of the data within each construct was determine using Cronbach Alpha as illustrated in tables 1–5.

Table 1. Cronbach alpha data associated with Construct 1: Teacher perception

Reliability Statistics				
Cronbach Alpha		Cronbach Alpha based on Standardized Items		No. of Items
.840		.884		4
Item-Total Statistics				
	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach Alpha if Item Deleted
Q1.1	13.7273	2.818	.788	.774
Q1.2	13.7273	2.818	.788	.774
Q1.3	14.0000	2.400	.472	.932
Q1.4	13.9091	2.091	.860	.704

Table 2. Cronbach alpha data associated with Construct 2: Teacher's perceived possible frequency

Reliability Statistics				
Cronbach Alpha		Cronbach Alpha Based on Standardized Items		No. of Items
–.978		–.802		4
Item-Total Statistics				
	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach Alpha if Item Deleted
Q2.1 Q2.2	3.1818 3.8787	.564 .872	–.533 –.434	.516 –.1.762
Q2.3	2.9091	.291	–.083	–1.625[a]
Q2.4	3.3636	.255	–.179	–1.429[a]

This result (Cronbach Alpha value –.978) and Cronbach Alpha if items deleted shows this construct lacks reliability for having similar items and average negative covariance (Nichols, 1999). Considering the negative value, this construct was deleted later.

Table 3. Cronbach alpha data associated with Construct 3: Teachers' current practice

Reliability Statistics				
Cronbach Alpha		Cronbach Alpha Based on Standardized Items		N of Items
.877		.880		4
Item-Total Statistics				
	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach Alpha if Item Deleted
Q3.1	6.8182	1.564	.626	.890
Q3.2	7.0000	1.400	.838	.799
Q3.3	7.0909	1.491	.829	.805
Q3.4	7.1818	1.764	.677	.866

Table 4. Cronbach alpha data associated with Construct 4: Teacher Willingness/preparedness

Reliability Statistics				
Cronbach Alpha		Cronbach Alpha based on Standardized Items		N of Items
.974		.973		12
Item-Total Statistics				
	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach Alpha if Item Deleted
Q4.1	52.6364	16.655	.940	.969
Q4.2	52.6364	16.655	.940	.969
Q4.3	52.6364	16.655	.940	.969
Q4.4	52.6364	16.655	.940	.969
Q4.5	52.6364	16.655	.940	.969
Q4.6	52.4545	18.673	.649	.976
Q4.7	52.4545	18.673	.649	.976
Q4.8	52.6364	17.655	.658	.977
Q4.9	52.6364	16.655	.940	.969
Q4.10	52.5455	17.273	.898	.970
Q4.11	52.5455	17.273	.898	.970
Q4.12	52.5455	17.273	.898	.970

Table 5. Cronbach alpha data with Construct 5: Perception/importance of transferring science learning to an out-of-school context

Reliability Statistics				
Cronbach Alpha		Cronbach Alpha Based on Standardized Items		N of Items
.973		.975		11
Item-Total Statistics				
	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach Alpha if Item Deleted
Q5.1	47.6364	15.655	.779	.973
Q5.2	47.4545	15.873	.925	.969
Q5.3	47.4545	15.873	.925	.969
Q5.4	47.5455	16.073	.728	.974
Q5.5	47.4545	15.873	.925	.969
Q5.6	47.6364	15.855	.724	.975
Q5.7	47.4545	15.873	.925	.969
Q5.8	47.4545	15.873	.925	.969
Q5.9	47.5455	15.473	.905	.969
Q5.10	47.5455	15.473	.905	.969
Q5.11	47.5455	15.473	.905	.969

Appendix A3: Data coding for inductive analysis from final interviews (coding process amplified in section 3.3)

Participant background	*Sentiment*	*Meaning unit*	Primary coding	Secondary coding	Final coding
SEE1	*From partly to strong agreement*	*I partly agree because, maybe this (referring to 3stage model) is lacking this kind of actual activities, put in a context of solving the problem*	Perceiving the need for addressing gap in the present science teaching learning practice with respect to enabling students to resolve societal concerns	Perceiving role of science teaching learning activities in preparing learners to resolve societal concerns (6)	Establishing the value of science education in promoting societal development (14)
		This is important because I think that this is also important for motivation, that you can actually see that there is some effect, in the society. And take the discussion out of school into some actions	Perceiving the need for addressing student motivation for science learning	Perceiving role of science teaching learning activities in enabling student motivation towards science learning (2)	Establishing the value of science education in student individual development (15)
			Perceiving the need for promoting student relevance of science teaching-learning with respect to the society	Perceiving the role of science teaching learning activities in enabling student relevance of science learning (1)	Establishing the value of science education in student individual development
			Perceiving the need for enabling students to transfer their science learning to acting in society	Perceiving the role of science teaching learning activities in enabling students to transfer their science learning beyond classroom for societal development (5)	Establishing the value of science education to enhance student development towards addressing societal development (10)
		They can see that they could solve that. That that's their solution took also place and the adults and the real decision makers take them seriously	Perceiving the need for enabling the learners to conceptualise the role of their science learning in resolving societal concerns	Perceiving the role of science teaching learning activities in enabling student conceptualisation of science learning having an impact on resolving societal concerns (3)	Establishing the value of science education in student individual development
			Perceiving the need for enabling learners to integrate to the society as a member of the society	Perceiving the role of science teaching learning activities in preparing learners as a part of society (5)	Establishing the value of science education to enhance student development towards addressing societal development

Participant background	*Sentiment*	*Meaning unit*	Primary coding	Secondary coding	Final coding
		There is this extra stage (referring to the 4th stage) where they (students) put forward this initiative for families and society and communities about how to deal with the plastic waste. I think that this stage is very smooth way to integrate to the society.	Perceiving the need for addressing gap in the present science teaching learning practice with respect to enabling students to solve societal concerns	Perceiving role of science teaching learning activities in preparing learners to resolve societal concerns	Establishing the value of science education in promoting societal development
			Perceiving the need for enabling learners to integrate to the society as a member of the society	Perceiving the role of science teaching learning activities in preparing learners as a part of society	Establishing the value of science education to enhance student development towards addressing societal development
		if the students are just doing that within the class and peers and other students, it's maybe not enough. we also want that they will also do with other class, other school or community. These are good skills to learn. But maybe if we don't try to this kind of systematically organised (referring to 4th stage), or demand that there is this kind of 4th step, actually to influence the environment or surrounding, we don't have a good scientific literacy.	Perceiving the need for enabling students to transfer their science learning to acting in society	Perceiving the role of science teaching learning activities in enabling students to transfer their science learning beyond classroom for societal development	Establishing the value of science education to enhance student development towards addressing societal development
			Perceiving the need for promoting collaboration and communication via science education	Perceiving the role of science teaching learning in enabling learners to gain scientific competence (3)	Establishing the value of science education in student individual development
			Perceiving the need for addressing gap in the present science teaching learning practice with respect to enabling students to solve societal concerns	Perceiving role of science teaching learning activities in preparing learners to resolve societal concerns	Establishing the value of science education in promoting societal development

Participant background	*Sentiment*	*Meaning unit*	Primary coding	Secondary coding	Final coding
		It adds something that ways of influencing the society and they will know how the society works.	Perceiving the need for enhancing the vision of scientific literacy with respect to addressing societal concerns	Perceiving role of science teaching learning activities in preparing learners to resolve societal concerns	Establishing the value of science education in promoting societal development
			Perceiving the need for enabling learners to integrate to the society as a member of the society	Perceiving the role of science teaching learning activities in preparing learners as a part of society	Establishing the value of science education to enhance student development towards addressing societal development
SEE2	*Strong agreement from the beginning*	at that stage you emphasized I see it as an addition, from the third stage, to transfer and to reflect what they learned in their lives. This is the one reflecting trans-contextualisation of SSI based consensus decision to society… it's reflecting upon it, it's showing how and why reflection is very high stage of learning for students, it's self efficacy	Perceiving the need for enabling students to transfer their science learning to acting in society	Perceiving the role of science teaching learning activities in enabling students to transfer their science learning beyond classroom for societal development	Establishing the value of science education to enhance student development towards addressing societal development
			Perceiving the need for enabling students to reflect their science learning with respect to the society	Perceiving the role of science teaching learning activities in enabling student conceptualisation of science learning having an impact on resolving societal concerns	Establishing the value of science education in student individual development
			Perceiving the need for promoting student self-efficacy towards resolving societal concerns with science learning	Perceiving the role of science education in promoting student self-efficacy towards resolving societal concerns with science learning	Establishing the value of science education in student individual development
		They will feel that it's like 'I have ownership for it. So I will like to tell everybody, look how wonderful it is pleased study. It's it's great.' This is ownership, somehow you feel part of it	Perceiving the need for promoting student ownership of science learning towards resolving societal concerns	Perceiving the role of science education in promoting student ownership of science learning towards resolving societal concerns	Establishing the value of science education in student individual development

Participant background	*Sentiment*	*Meaning unit*	Primary coding	Secondary coding	Final coding
		I think it’s compulsory for the teachers… they have to make their students able to transfer the science to the society it’s very important to transfer this knowledge to everyone	Perceiving the need for science teaching to play a role in influencing society with respect to enhancing scientific attitude	Perceiving the role of science education in enhancing collective scientific attitude within the society (2)	Establishing the value of science education in promoting societal development
		Firstly we have to ask ourselves, what do we want? Let’s go back. Let’s go back and ask ourselves, what do we want to achieve from this science teaching? Do we want students to just know science? I don’t think it’s enough. We have to think bigger… we have to think that there is a role of science in the society	Perceiving the need for enhancing the purpose of science education, having implication to the society	Perceiving role of science teaching learning activities in preparing learners to address societal development	Establishing the value of science education in promoting societal development
		Scientific literacy is not just science knowledge, it has to make students citizens, who are able to solve social problems	Perceiving the need for enhancing the vision of science education with respect to addressing societal concerns	Perceiving role of science teaching learning activities in preparing learners to address societal development	Establishing the value of science education in promoting societal development

Participant background	*Sentiment*	*Meaning unit*	Primary coding	Secondary coding	Final coding
TE	*In the beginning he didn't see it important, after asking more and more question he saw it important*	We didn't see it important going beyond that (referring to 3 stage) because we used in Ireland with students in the 15–16 year old age group. You know they are teenagers. So you will get a scenario at the beginning to get them involved with the topic, you know. Then the various activities, inquiry based activities, that involved them. And if you get them into third stage, into discuss the results, then you are doing very well.	Perceiving the learners as not developed enough to engage in the society		
			Perceiving the need for science education, limited within socio-scientific decision-making within the classroom	Perceiving the role of science teaching learning activities to enhance student's socio-scientific decision-making in the classroom (2)	Establishing the value of science education in student individual development
		To go beyond that I could see it would be interesting but it would be very challenging to go to a 4th stage so that perhaps they would try to implement some of what they've learned, in their own lives.	Perceiving the implementation of trans-contextualisation as challenging		
		Now you represent this stage 4 as an operation initiated from stage 3 decision-making. I wonder if there will be quite a bit of overlap between stage 3 and stage 4. Because as for stage 3, when students learn to make decision, we can expect that they will make the decision outside school too	Perceiving the need for enabling the students to make socio-scientific decision in the classroom already means students will apply the learning outside classroom	Perceiving the role of science teaching learning activities to enhance student's socio-scientific decision-making in the classroom	Establishing the value of science education in student individual development
		but in the 4th stage, yes, I think it adds to the profiles… because we can actually see if the student is making the same decision when they go out of school	Perceiving the need for ensuring the transference of student socio-scientific decision-making beyond the classroom	Perceiving the role of science teaching learning activities in enabling students to transfer their science learning beyond classroom for societal development	Establishing the value of science education in student individual development

Participant background	*Sentiment*	*Meaning unit*	Primary coding	Secondary coding	Final coding
		Now I am thinking that it is actually very important aspect… Because if we don't succeed to change the mindset of our students and teachers then we have wasted our time. We would hope that some of what we have taught them within the modules, will be absorbed into their minds, and will result in change in attitude, and most important part of all a changed practice in the society. and we cant really just assume, we have to see… They go out of the classroom and they forget what you taught in the classroom. That they should take it from school and do it outside school, that would be the key area, I think, the most important to do, I think.	Perceiving the need for ensuring the transference of student socio-scientific decision-making beyond the classroom	Perceiving the role of science teaching learning activities in enabling students to transfer their science learning beyond classroom for societal development	Establishing the value of science education in student individual development
		Because the 4th part of the model is the crucial one. Because it builds the sort of bridge between the science and society The 4th stage is essential. In PROFILES, we didn't have the follow up in the society. Because in the PROFILES we stopped the teaching and we hoped that we	Perceiving the need to bridge science teaching and societal development	Perceiving the role of science teaching learning to build procedural link between science conceptual learning and societal expectations	Establishing the value of science education to enhance student development towards addressing societal development
			Perceiving the need for preparing learners as members of society via science education	Perceiving the role of science teaching learning activities in preparing learners as a part of society	Establishing the value of science education to enhance student development towards addressing societal development

Participant background	*Sentiment*	*Meaning unit*	Primary coding	Secondary coding	Final coding
		implanted the ideas in the students' minds. But your idea, what to do in the 4th stage is very interesting, it connects the science with the society. It is really to ensure that when they take their place in the society, they will be well educated citizens, and they will be influencing other citizens. And what you have taught them in this module will have an effect on their attitude and the society. I think it is necessary.	Perceiving the need for enhancing role of science education to enable students influence the society to enhance collective scientific attitude	Perceiving the role of science education in enhancing collective scientific attitude within the society	Establishing the value of science education in promoting societal development
		most important of all, the question is, that, what will you do in your life with this science knowledge, and how will you help solve the big problems in the society, for example plastic pollution	Perceiving the need for enhancing a wider purpose of science education towards resolving societal concerns	Perceiving role of science teaching learning activities in preparing learners to resolve societal concerns	Establishing the value of science education in promoting societal development
CD1	*Agreement but argu-ments are not strong*	*I think that in our national curriculum, we pointed it all the curriculum and pointed out that you have to you have to connect the everyday teaching of everyday life so the students can see that their science knowledge is useful for their life.*	Perceiving the need to promote student relevance of science teaching-learning with students' everyday life	Perceiving the role of science teaching learning activities in enabling student conceptualisation of science learning having an impact on resolving societal concerns	Establishing the value of science education in student individual development
		Because we want to try to increase student motivation related to everyday life	Perceiving the need for addressing student motivation for science learning	Perceiving role of science teaching learning activities in enabling student motivation towards science learning	Establishing the value of science education in student individual development

Participant background	*Sentiment*	*Meaning unit*	Primary coding	Secondary coding	Final coding
		Because we want to achieve this competency-based curriculum, and this 4th stage will make the students responsible citizens	Perceiving the need for attaining curriculum goals of enhancing scientific competences through trans-contextualisation	Perceiving the role of science teaching learning in enabling learners to gain scientific competence	Establishing the value of science education in student individual development
			Perceiving the need for promoting learners as responsible citizens via science education	Perceiving the role of science teaching learning in promoting responsible citizens for addressing societal concerns	Establishing the value of science education in promoting societal development
		It kind of checks all the boxes of scientific competence that we want to promote	Perceiving the need for promoting scientific competence through trans-contextualisation	Perceiving the role of science teaching learning in enabling learners to gain scientific competence	Establishing the value of science education in student individual development
CD2	Agreement but more on social focus	*If you make the students act in the society, it in a way addresses this equality, justice, and democracy and the other one was social equilibrium… because students are going to the society to bring change… because they are making decisions democratically and they becoming citizens… this will bring a social equilibrium when the students are connecting science and society*	Perceiving the need for promoting learners as citizens via science education	Perceiving the role of science teaching learning in promoting learners as members of society (citizens)	Establishing the value of science education to enhance student development towards addressing societal development
		if those we don't make the students go to the society then there is no holistic change, the segregated change will not bring any qualitative change in the whole system	Perceiving the need for students to address societal development	Perceiving role of science teaching learning activities in preparing learners to resolve societal concerns	Establishing the value of science education in promoting societal development

Participant background	*Sentiment*	*Meaning unit*	Primary coding	Secondary coding	Final coding
		We don't want to just reproduce scientific knowledge in science education, we want to make students tackle the social problems			
		If you think, why are we teaching science, what is the purpose… not only students, but also local education authorities, school leaders, academic leaders, and community leaders, society in general, and also parents, everyone have to be connected… otherwise it's just isolated science knowledge	Perceiving the need for bridging science education and different agencies of society for collective engagement towards societal development	Perceiving the role of science teaching learning to build procedural link between agencies within the society	Establishing the value of science education to enhance student development towards addressing societal development
		The world is moving forward, they are thinking how can we make the students tackle sustainable development… we have to make this, this activity a part of science education to able them	Perceiving the need for addressing the gap in the present science teaching learning practice with respect to promoting active engagement for societal (i.e. sustainable) development	Perceiving the role of science teaching learning in promoting student active engagement for societal development	Establishing the value of science education in promoting societal development
		Learning has to be in a social setting, so it is not just sitting in the society, it is also learning for the society	Perceiving the need for preparing students to address societal development	Perceiving role of science teaching learning activities in preparing learners to address societal development	Establishing the value of science education in promoting societal development

Appendix A4: Exemplary teaching module

Abstract of the module:

Our obsession with plastics: Promoting responsible use of plastics within the Society A Grade 10 module on the Plastics and their impact on the Environment, the Economy and our Way of Life

Abstract: One reason people favour the use of plastics over other materials is its durability, which is the same reason for plastics being harmful to the environment considering is its non-degradable. Plastics are examples of polymers. These polymers can be divided into two categories, thermo-sets and thermoplastics. Once formed, thermosets, as the name suggests, cannot be altered. Thermoplastics, on the other hand, can be reshaped over and over again, but it is difficult for both to undergo degradability.

This non-degradability gives rise to plastic trash leading to a major source of pollution in the world's oceans. Unfortunately, it is estimated that 90 percent of seabirds are attracted to and eat it. This is a cause of major harm: sharp-edged plastics can kill birds by punching holes in internal organs, while some seabirds eat so much plastics that there is little room left in their gut for food, which affects their body weight, jeopardizing their health.

While some alternative to plastics are identified as glass, stainless-steel, wood, bamboo, natural fibres and so on, there are challenges in raising awareness in the society regarding the negative consequences of the use of plastics of which the above is but one example. Plastics can affect the environment, our health, the economy and more generally, our way of life.

Figure 1: Image collected from National Geographic website on the topic: 'Nearly Every Seabird on Earth Is Eating Plastics'

Sections included:	
1. Overall context of the module	General overview of the module, its context (based on a concern), target science education competences, illustration of the 4-sequential phases so that students are able to use their learning so as to appreciate and address the problem
2. Student Activities (for students)	Based on a provided scenario (provided by the module or by the teacher) the suggested activities indicate the learning tasks in which the students are guided to be involved
3. Teaching guide	Suggests a teaching approach and learning targets
4. Suggested assessment	Gives suggested formative/summative assessment strategies

Curricular Content: Subject: Science (Grade 10), Polymeric materials, Competences involved: formation of plastics, physical and chemical properties of some common plastics, advantages and disadvantages of plastics, considerations of environmental issues involved in the use and misuse of plastics, addressing concerns about the overuse of plastics (thermoplastics) and their resolution

Targeted Competences:

- Realise the relevance of the topic within the social, economic, environmental aspects at a local, national and global level
- Conceptualise the formation and properties of plastics, as well as recognise the positive and negative roles played by plastics
- Plan and undertake inquiry-based science learning to gain science conceptual learning on the topic of plastics, especially thermoplastics
- Reflect on the consideration to scientific, social, moral, political and other aspects related to the topic and make scientific argument-based, and collective decision about the value of plastics, alternative for plastics and whether restrictions are needed on the usage of plastics
- Emphasise students' motivation to participate in classroom learning and beyond classroom application of learning through active engagement in argumentation on socio-scientific issue related to the topic
- Based on science-based arguments based on scientific evidence, decide whether plastics are beneficial
- Take responsibilities through participating in raising social awareness on how to enact the decision made on overuse of plastics to mitigate its impact on society, the economy and especially environmental aspects with clear scientifically argument-based ideas and plans within a beyond-school, societal context

Student activities: Conceptualising plastics, inquiry-based science learning via experimentation on the making and use of plastics, scientific argument-based, and collective decision making in addressing the environmental concern related to plastics, undertake responsible actions and put forward creative solutions to raise awareness of decision made to address the social, economic, environmental consequences of plastic overuse at a local, national and also a global level

Anticipated time: The module has been developed based on an anticipation that the learning process can take up to 5 lessons, but open to modification based on the context.

Expected prior knowledge of the students: Stating of Use of plastics in everyday life, aware of different types of plastics, causes plastics waste, the concept of pollution.

Structure of the module:

The present module is composed of 4 interrelated elements of a Context-based Socio-scientific Framework (CbSF). CbSF seeks to embed science education learning within a science related, social issue orientated, consideration towards economic, environmental and societal (sustainability) concerns, striving to promote the following four areas of focus: student motivation to learn, students' science conceptualisation via scientific problem solving, argumentation skills via students' socio-scientific consensus driven, decision-making based on sound science conceptualisation, and transferring the science competence (decision-making) learning to impact on the wider socio-scientific contextual framework for the benefit of, for and with the collective society.

This module is promoted in four phases with an aim to prepare students as scientifically literate, actively engaged in beneficial societal reform. These 4 phases are:

1. Enhancing relevance of the topic, motivating students to learn about the concerns associated with the topic of plastics and exploring their prior learning and views (student motivation)
2. Undertake, using an inquiry-based science learning approach, the gaining of relevant science competences (knowledge, skills and attitudes/values) associated with the topic of plastics (science learning)
3. Undertake scientific argument-based, and collective decision-making on the issue (identified in phase 1) using justified and meaningful science conceptual argumentation seeking to derive a consensus, well-argued decision among all students involved (decision making in socio-scientific issue)
4. Undertake responsible actions and put forward creative solutions to implement the scientific argument-based, and collective decision that can be a step towards guiding or enabling science-based collective actions based on meaningful recognition of environmental, economic and social value aspects at a local, national and/or global level (transferring the learning to societal context).

Student activity:

Our obsession with plastics: Promoting responsible use of plastics within the society

Student Activities:

Scenario: Mariyam has been always fascinated with different type of birds. At her home, she has cockatiel, cockatoo, doves and budgerigars as pets. One vacation, while she was enjoying the beach at Cox's Bazar, a beautiful seabird caught her attention. As she saw that bird was trying to eat a bottle cap, made from plastics, she started to run towards the bird so that she could stop it. Also, before she could reach the site, the bird started chocking and then died. Mariyam brought the dead bird to her home. As she learned how to dissect animals in her science class, she thought she could see what was inside

Figure 2: Image source 'The Guardian' website

the bird. To her surprise, there were so many plastics materials inside the bird, it was even surprising that the bird was still alive arriving at the beach.

Mariyam had so many questions. It wasn't understandable to her why the birds would try to eat plastics material. It was even more confusing to her, why the plastics were not digested inside the bird. What can be done to protect the seabirds? How can the oceans be protected from excessive plastics? How much of consumed plastics is too much? What can be alternatives to plastics, which has low cost, is decomposable and unharmful to the environment, or wildlife? How can she participate in addressing the plastics pollution concern?

Students' Tasks:

Phase 1 (lesson 1)

- Discuss among you group colleagues and seek to conceptualise (a) why seabirds may consider plastics as food, (b) how plastics in waste come to impact on sea-going animals and (c) suggest whether there any other consequences of plastics pollution in the ocean? (Motivational and gathering student views)
- Homework suggestion: Seek answers to the questions – What are plastics? Are they single substances? (prior knowledge)
- And Explore in your home, consulting with your peers and family members, as appropriate, to determine the variety of uses of plastics. Prepare a list of uses to which plastics are put. Classify plastics that is discarded in your home into categories e.g. bags, containers, wrappers, clothing, etc. (Motivation and prior knowledge)

Phase 2 (lesson 2 and 3)

- As groupwork, devise a plan so as to undertake a range of tests (on teacher supplied and named plastics) to explore differences, based on their properties (e.g. test for strength, behaviour when heated, whether it burns, solubility in cold/hot water, (indicate both apparatuses, testing material and procedure including safety aspects). (New science learning based, as appropriate, on prior knowledge of scientific procedures)
- After teacher's approval and with appropriate safety precautions, carry out the investigation to find out more about different plastics. Record your findings and reclassify the collected plastic materials based on the results of the tests. (New science learning)
- Explore disposal of different plastics, degradability of objects, its effects on environment, and plan an experimental set-up to determine the biodegradability of different plastics.
- Homework: Find out, using the internet, textbook and/or library resources, (a) the reasons why different plastics have different properties, (b) the common or commercial names for plastics used for bottles, kitchenware, piping, electrical insulation, (c) the advantages in using plastics. (New science learning) (d) the production cost of plastics, and similar/alternative components in general

Phase 3 (lesson 4)

- In your discussion use meaningful and accurate science-based evidence from your prior learning for your argumentation and follow up with the group opinion on whether plastics are overused and is there any need to promote more responsible consumption of plastics. If the decision is yes, discuss what could be the alternative way forward and how can the alternative be economically beneficial? Then, in groups, put forward your decision and arguments and seek to determine a collective outcome reflecting on scientific, economic, environmental and social value related aspects.
- In groups discuss the following: 'Why are Humans obsessed with plastics, especially thermoplastics? How detrimental are they to wildlife? Should there be a ban/restriction on the use of plastics? Are there alternatives?' Seek to establish a collective view (with clear reasoning based on sound science) on the concerns and actions needed related to the use of plastics.

Phase 4 (lesson 5)

- Devise a group plan, based on the consensus decision from Phase 3, how can you go about persuading the society to be more socially responsible, both individually and collectively, to promote not only awareness towards the mechanisms for discarding, disposal, or alternatives to use of plastics, but also to put forward potential actions to resolve the current plastics issue responsibly. (taking on to consideration a sustainable environment and sustaining the economy
- Based on the authenticity of information, presentation of the topic and appeal to the target groups, evaluate the plans across groups based on the authenticity of information, presentation of the topic and appeal to the target groups.
- With the help of the teacher, determine and put forward the most appropriate way to implement the plan towards raising awareness in the community towards the issues associated with plastics such as discarding and disposal of plastics, and putting forward innovative and society acceptable (with suggested persuasive approaches) solutions to solving the current plastic pollution issue in a collective, responsible, science-based, economically and environmentally viable manner at a local, national and international level

Teacher guide:

Our obsession with plastics: Promoting responsible use of plastics within the Society

Focus:

- Plastics are an integral part of science teaching in many countries.
- The manner in which plastics are handled after use is a growing concern.
- Plastics can be economically recycled, but multiple recycling has problems that scientists have yet to address on a large scale
- Thus, plastics use has grown largely from an economic rather than an environmental focus
- And now, 'How to deal with the Plastics issue' is an area of concern in many societies.

Teaching suggestions:
In phase 1, it is expected that teachers:

- seek to motivate students, through providing a student-relevant and interesting scenario, and encourage students to be willing to engage in learning about plastics and especially their desirability, also the potential impact of discarded plastics on the environment, wildlife and even our health.
- gain insights into the students' prior knowledge on what are plastics, how we use plastics, benefits of plastics (i.e. the cost-efficiency or desirable properties) and the degree of environment pollution caused by plastics

Possible outcomes from phase 1: The teacher is able to stimulate students' motivation and identify their prior knowledge through putting forward a motivational and student-relevant scenario, raising or even answering questions (for example, why seabirds consider plastics as food, how consuming plastics may compromise seabirds' health, how do plastics end up in the ocean, why do plastics float, etc.) From the discussion, the teacher is able to intrigue the motivation among the students to know what are plastics, how are they produced, why are they so useful and why are they a source of concern?

In phase 2, it is expected teachers:

- support (scaffold) students to undertake individually, or in groups, scientific inquiry/ investigations to find out through scientific process, the physical and chemical properties of plastics, plastics formation and their multiple types – based on a single monomer/mixed monomer, thermoplastics/thermosetting

Possible outcomes from phase 2: The teacher is able to promote students' conceptual science and practical skills learning and identify through verbal/written interaction or observation through group activities, indicating students' understanding of properties of plastics, how the properties have an impact on the use of plastics and give rise to the concern for the environment, economy, health and wild-life, and so on.

In phase 3, it is expected that teachers:

- promote students' scientific argument-based, and collective decision-making on 'whether plastics are good or bad, is there any concerns related to their use or overuse?' from a scientific, social, economic, ethical, moral, political point of view. Ensuring that, if bad, what are alternatives to plastics and/or what steps can be considered to limit or ban the use of plastics, (enable the students to be able to relate to the plastics concept with the sustainability of wildlife/the environment, the economic development of the society and the society's cohesiveness/collective concern/ supportive of scientific argument-based, and collective actions based on the decision made)

Possible outcomes from phase 3: The teacher is able to identify students' science-based argumentation through group discussion, for example, students' conceptualisation of non-degradability of plastics may lead to their decision on a ban of plastics for being detrimental to wild-life or plastics are important (i.e. good) but limitations made to persuade the public, the authorities, etc to view the use of plastics from a perspective of sustainability of the environment, sustainability of the economy and the sustainability of societal cohesion and benefit through determining ways to promote science-based collective actions

In phase 4, it is suggested that teachers:

- From the decision-made, enable students to realise the implications of the decision made, i.e. the importance and the most effective way of promoting scientific argument-based, and collective or individual decisions and actions on the use of plastics in a wider context (i.e. the local community, national or international scenario).
- Thus, guide students to put forward (plans and possible ways of implementation) for positive changes (standpoints/views) in their or in the lives of the society members' real lives; by empowering students to think critically, effectively and creatively (from a scientific argument-based, and collective action standpoint) and put forward a plan (based on the consensus view) not only to raise awareness in the society about aspects of plastics (such as concerns related to plastics pollution (or the economic potential for plastics recycling) but on putting forward concrete actions (based on sound science) that can be considered; and
- ensure students evaluate their plans of action based on its suitability, acceptability, applicability and scientific authenticity by facilitating students' actualisation of their plan of action from a beyond class-room context, such as environmental, economic, social valued sustainability perspective so as to potentially be motivated to engage in volunteer activities to raise awareness of (the good and bad of plastics) and to promote through a science education 'beyond-school, societal context' vision, a meaningful way, or ways of impacting from considerations from school learning to impacting on the society related to (for example) health as an overall social benefit, the economy and/or the environment.

Possible outcome from phase 4: The teacher is able to identify students' transference of science learning from the classroom learning to their own and society lives through students projected plan of personally taking individual/ collective responsibility to view the development/use/discarding of plastics from a sustainability of the environment, the economy and the maintenance or enhancement of social values point of view. The strategy, for example, can be for science-based collective action by reflecting on the use of plastics and ways of raising awareness in the society e.g. through setting up separate disposal systems for plastic wastes in their community, writing letters to newspapers, demonstrating posters/play/wall-magazines in the community regarding plastic pollutions and how to ensure the support of the general public within the society as well as community leaders for such actions.

Suggested Teaching Strategy

Introduce the topic of plastics (by means of a student-relevant motivational scenario) with the intention of (a) drawing attention to commonality of plastics and where we use (and misuse) plastics, (b) drawing attention to its role in promoting an environmental imbalance, (c) developing students' background in conceptualising plastics, (d) what happens with plastics after use with the idea of seeing if students recognise the urgency of the concern, and its implication individually, socially, nationally and globally to promote scientifically informed collective initiatives

- Enhance conceptual and procedural science knowledge by activating (in phase 2) student scientific inquiry to learn about the formation, physical and chemical properties of plastics. In order to enable students to undertake scientific inquiry, the teacher may need to provide student resources, such as handouts, practical equipment, textbook, authentic websites, library books from which students can gain science-based evidence regarding the current situation on plastic pollution.

- Following phase 2, students become aware of many different plastics and thus many different properties and potential uses of plastics. The teacher can initiate the student interactive discussion, taking into consideration the role of science on social, economic, ethical, moral, political point of view, on whether plastics are good or bad? From what viewpoint can all be considered good? Or bad? Should there be a restriction or ban on bad plastics or on the usage of plastics in general? If yes, what could be the alternative for plastic and how the alternative can be economically beneficial? What possible consensus decision is possible based on the following potential viewpoints: economic, environmental, social value – jobs, social adhesion, political, and of course moral/ethical)
- From phase 3, students' conceptualisation that plastics are good if reusable, biodegradable, a mechanism is in place so as to ensure major and repeat recycling and students' recognition that good and bad plastics cannot be separated in most cases, thus there is a need to address the plastic pollution.
- Then as a follow up, enable the students to put forward creative solutions how to enact the decision made, how to deal with plastic pollution and engage in community outreach activities to interact with the society to make contribution in promoting social awareness about how to deal with plastics – the good and bad. The teacher is expected to evaluate how the learning can be transferred from a classroom context to a wider and beyond school context (trans-contextualising the learning). In so doing, students can be said to act as an agency of social awareness in promoting scientifically sound collective actions. The important aspect to reflect on is,

The students' own realisation that they are <u>part of the society</u> and that the society needs to be guided or persuaded to act responsibly as active and scientifically informed citizens.

- The teacher is expected to address these aspects, by providing students <u>the opportunity to think critically and propose actions responsibly,</u> how they can apply their gained knowledge and put forward and possibly actively engage in such activities to promote awareness about the concerns related to plastics. The teacher is expected to motivate students to realise the need to apply their science conceptual learning about plastics pollution in their real-life situation and towards solving the perceived social problem. One possible way to do so, is to encourage students to put forward creative solutions (collectively) to address the concerns, and to critically evaluate their plan based on scientific accuracy, applicability and authenticity, and its potential to involve volunteer participation towards executing the plan.

Suggested Assessment:

During the undertaking of the module, students can be assessed from a range of educationally desirable attributes, which can be promoted through science teaching using a collection of simple 3-point scales. The suggestions are examples and not design to be definitive or exhaustive

Suggested assessment for phase 1:

Suggested Criteria for assessment	Students' performance standards		
	Needs more challenging tasks	Needs improvement	Needs special assistance
How well the students can realise the relevance of the topic within the social, economic, environmental aspects?	Able to put forward relevant examples from their everyday lives	Able to articulate relevant examples if asked thought-provoking questions	Unable to articulate concrete or correct relevant examples
How well students can conceptualise the need to know about the scientific, environmental, social, economic aspects of plastics, so as to contribute to address the concern in promoting awareness about the scenario?	Willingly participate in learning activities to gain science conceptual learning	Participate in learning activities after the need to gain science conceptual learning is explained	Unwilling to participate in learning activities to gain science conceptual learning

Suggested assessment for phase 2:

Suggested Criteria for assessment	Students' performance standards		
	Needs more challenging tasks	Needs improvement	Needs special assistance
How well students can plan and undertake inquiry-based science learning to gain science conceptual learning on the topic and its applicability for future learning and action?	Able to devise a plan so as to undertake a range of tests to explore differences, based on their properties, e.g. test for strength, behaviour when heated, whether it burns, solubility in cold/hot water, indicate both apparatuses, testing material and procedure including safety aspects	Able to plan or undertake the tests after consultation with the teacher or peers.	Unable to participate in planning or undertaking the tests
How well students can conceptualise the formation and properties of plastics, as well as recognise the positive and negative roles played by plastics?	Able to explain and interact about (a) the reasons why different plastics have different properties, (b) the common or commercial names for plastics used for bottles, kitchenware, piping, electrical insulation, (c) the advantages in using plastics. (d) the production cost of plastics, and similar/alternative components in general	Needs assistance of teacher or peers to articulate opinion on the formation and properties of plastics, and the positive and negative roles of plastics	Unable to prepare an overview of the formation and properties of plastics or its positive and negative roles.

Suggested assessment for phase 3:

Suggested Criteria for assessment	Students' performance standards		
	Needs more challenging tasks	Needs improvement	Needs special assistance
How well students can reflect on the value of plastics, alternative for plastics and whether restrictions are needed on the usage of plastics within group discussion?	Able to use meaningful and accurate science-based evidence from phase 2 learning, as a resource base for argumentation	Able to reflect on the science-based evidence, but unable to undertake argumentation	Unable to reflect on the science-based learning about plastics and unable to participate in the discussion
How well students can reconcile tensions and dilemmas through undertaking scientific argument-based, and collective decisions, whether or not overuse of plastic is beneficial and the role needed by society in respect to this?	Able to follow up with the group opinion and make scientific argument-based, and collective decision on whether plastics are overused and is there any need to promote responsible consumption of plastics.	Able to undertake an informed decision with the help of peers or teacher	Unable participate in the discussion and make an informed decision within the group

Suggested assessment for phase 4:

Suggested Criteria for assessment	Students' performance standards		
	Needs more challenging tasks	Needs improvement	Needs special assistance
How well students can put forward plans based on science-based argumentation with peers and others towards promoting awareness in the society regarding plastic pollution?	Able to prepare and evaluate plans based on the group discussion and select a target group for execution of the plan, which can benefit from the information	Able to participate with assistance of peers or teacher in preparing plans based on the group discussion	Unable or unwilling to participate in preparing plans based on the group discussion
How well students can take responsibilities through participating in raising social awareness on overuse of plastic and its implication on society, economy and environmental aspects with clear trans-contextual plans and arguments?	Able to create awareness within the society through successfully executing their plans and if necessary discuss and express their opinion based on scientific evidence	Able to participate, after being externally motivated by peers or teachers in creating awareness within the society regarding the plastics pollution	Unable or unwilling to participate in raising awareness through executing the plan

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Holbrook, J., **Chowdhury, T. B. M.**, & Rannikmäe, M. (2022). A Future Trend for Science Education: A Constructivism-Humanism Approach to Trans-Contextualisation. *Education Sciences*, *12*(6). https://doi.org/10.3390/educsci12060413

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