Challenges in K-12 Climate Change Education: A Literature Review

Nimrah Ahmed, University of Alberta, Canada
Mijung Kim, University of Alberta, Canada
Qingna Jinn, Cape Breton University, Canada

Abstract: This article constitutes a literature review on the challenges that students face in understanding climate change. The review contains 29 studies, undertaken using Academic Search Complete and ERIC (Education Resources Information Centre), which examine related research from a social constructivist and ecological systems perspective and highlight the difficulties in preparing this generation for tackling the global challenge of climate change. This review sheds light on the nature of difficulties in understanding climate change faced by students that stem from 1) student knowledge, 2) teacher knowledge, and 3) the lack of external support provided to students and teachers. Student knowledge is impacted by their lack of prior knowledge and misconceptions about climate change. Teacher knowledge impacts students understanding as teachers may lack accurate understanding of climate change. Lastly, the lack of external support in the form of curricular constraints, absence of culturally relevant teaching material and lack of teacher training for the topic of climate change, have also been reported to impact student understanding. Further, the review discusses the lack of introduction of climate change in elementary grades, which negatively impacts students understanding in higher grades. Implications include further investigation of student challenges, cross-curricular teaching of climate change and introduction of climate change education during early years.

Keywords: Literature Review, Challenges, Knowledge, Climate Change, K-12 Education

Introduction

Climate change is one of the complex global challenges deteriorating our environment at an unprecedented pace (Dawson et al., 2022; Schauss & Sprenger, 2021). Viewing this challenge as anthropogenic or human induced is essential to shift attention towards the urgency of responding to climate change as a shared social responsibility (Henderson et al., 2017). A facet of this shared focus is developing an accurate understanding of climate change, which encompasses all its complexities and addresses misconceptions and erroneous beliefs regarding climate change. Understanding of climate change is specifically important and relevant for the young minds who will be confronted with the challenge of decision making and future policy-development (Korfgen et al., 2017).

Climate change education is a K-12 effort to engage students in the process of learning about climate change, in order to address widely held confusions, misunderstandings, and erroneous beliefs (Pruneau et al., 2003). Various international organizations have highlighted its significance. For instance, the Lima Ministerial Declaration in Education and Awareness-Raising, of the United Nations "encourages all governments to include the issue of climate change in curricula" (United Nations Framework Convention on Climate Change Conference of the Parties, 2014, p. 2). The Intergovernmental Panel on Climate Change (2014) considers education to be of key importance in mitigating and adapting to climate change. With the recognition, there has been a clear emphasis of climate change in curriculum development. For instance, the Next Generation Science Standards, a framework of K-12 science education in the United States provides students with meaningful learning opportunities pertaining to climate change (Next Generation Science Standards Lead States, 2013). The topic of climate change has been explicitly emphasized in the new science curriculum in Alberta (Alberta Education, 2023). Furthermore, there are various NGOs that develop students' understandings and aptitudes toward the environment and climate change education such as Alberta Council of Environmental Education (2023). In British Columbia, the longitudinal study (2011-2018) titled Meeting the Climate Change Challenge was conducted to assist the government in identifying areas to meet their targets for a sustainable future (Dale et al., 2019). Across Canada, the Regional Adaptation Collaboratives was established in 2009 to push climate change action to regional and local levels (Natural Resources Canada, 2015).

In order to prepare students for the challenges of the 21st century, climate change curricula have been widely implemented in various contexts, though under different titles including but not limited to, climate change education (da Rocha et al., 2020; Dawson et al., 2022), environmental health (Keselman et al., 2012), environmental education (Nkoana, 2020), climate literacy (Asimakopoulou et al., 2021; Bhattacharya et al.,

2021), climate education (Bush et al., 2018; Dawson et al., 2022), and climate science education (Drewes et al., 2018). Even though the aforementioned titles focus on different aspects of climate change education, the central theme is to promote student understanding of climate issues. Before students can be effectively prepared to learn, understand, and take actions on climate change, educators must discern the existing difficulties students face in understanding climate change. This inquiry is guided by the following research question: What are the challenges that students encounter in understanding climate change in K-12 education?

Theoretical Framework

Our attempt to understand students' difficulties draws from the social constructivist (Vygotsky, 1978) and ecological systems theory (Bronfenbrenner, 2005). These theories suggest that learning is a social activity and students' cognitive understanding develops through interacting with peers, teachers, and learning environments. In social constructivist theory, students first develop their understanding at a social level, and then at an individual level. In other words, social and environmental influences, and interactions that students are embedded in are critical in shaping their understanding, thus, difficulties and challenges in students' understanding are not students' individual abilities but also their situatedness in social and environmental interactions in K-12 classrooms. Ecological systems theory focuses on the embeddedness of an individual in the interactions of broad cultural and social systems. The learners' understanding is deeply embedded in the complex system of the learning community. In K-12 classrooms, individual students develop their understanding of climate change through socialization both inside and outside of the school. The nature of the interactions they receive is nested in an interconnected web of systems, often impacting effective teaching and learning. Thus, student learning is intricately shaped by their interactions with teachers and the broader educational, cultural, and social contexts (Devine-Wright et al., 2007; Holthuis et al., 2014). Grounded in these theories, we acknowledge the intricate nature of challenges and difficulties students encounter in climate change education.

Purpose Statement

The purpose of this paper is to explore the challenges that K-12 students encounter in comprehending the complexities of climate change, informed by the social constructivist perspective (Vygotsky, 1978) and ecological systems theory (Bronfenbrenner, 2005). Therefore, our question on students' challenges in learning climate change extends beyond students themselves to encompass the influential roles of teachers' instructional support, shaped by their pedagogical content knowledge and beliefs (i.e., teacher knowledge and beliefs), and the broader educational context (i.e., external support). Previous studies have emphasized the importance of exploring this intricate nature of student understanding on climate change (Larakia et al., 2011; Shepardson et al., 2009). By examining challenges through the lenses of students, teachers, and learning contexts, this literature review aims to offer a comprehensive understanding of the obstacles impacting student learning of climate change.

Methodology

We used a systematic literature review methodology for this study (Cooper, 2017; Gough et al., 2017; Hannes & Claes, 2007) using the following two databases: Academic Search Complete and ERIC (Education Resources Information Centre). Figure 1 indicates the workflow for the articles from 2000-2022. After reading titles and abstracts, we used the inclusion criteria to identify the relevant studies. The criteria required studies to be: 1) K-12 focused; 2) focused on challenges in understanding climate change faced by students; 3) focused on challenges faced in understanding climate change faced by teachers; 4) from the field of education; and 5) empirical studies. After finalizing the inclusion of 29 studies, as shown in Table 1 below, we read each article and made notes of the main challenges indicated by the author. From some of the coded challenges (e.g., student prior knowledge, student belief, curricular restraints), the most prevalent and frequent ones were compiled under the three main themes of this study (discussed in the results section). We revised and discussed these themes multiple times to ensure reliability. For this review, we coded the first 10 articles separately and then met to discuss our coding process. In our first session, upon reaching the third article, we met with differences in our coding and shared the reasoning for our respective codes. To elaborate, one author identified a challenge as teacher belief while the other identified it as lack of curricular support.

We then continued to work separately and met again to discuss the first 10 articles. This time, we agreed upon the codes and discussed the process of thematization. Developing the three themes mentioned below in the findings section was a unanimous decision.

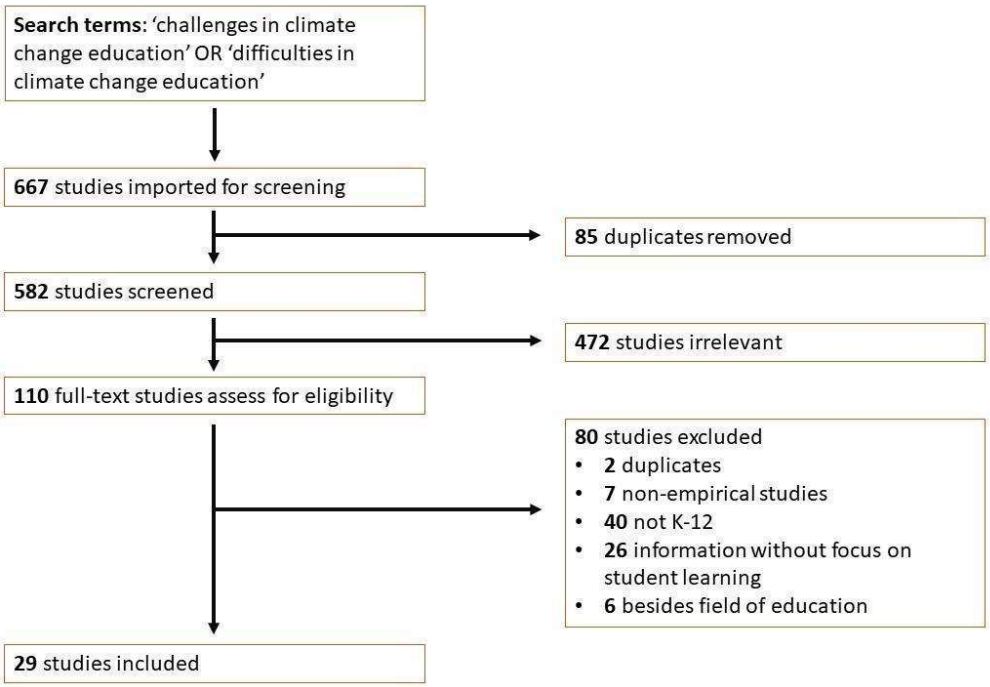

Figure 1: Workflow of the systematic literature review

Table 1: Final Studies

			Focus			
First Author (Year)	*Grades/ Teachers*	*Subject Areas*	*Intervention*	*Teacher training*	*Beliefs and perceptions*	*Knowledge and curriculum*
Ariza et al (2021)	Pre-service	Science and Others		X		
Arya & Parker (2015)	10-12	Science	X			
Asimakopoulou et al (2021)	Teachers	Beyond	X			
Baker et al (2021)	K-12	Beyond			X	
Bopardikar et al (2021)	7-9	Science				X
Brydon-Miller et al (2022)	4-6; 7-9	Beyond	X			
Bush et al (2018)	10-12	Beyond	X			
Bush et al (2019)	Teachers	Geography	X			
da Rocha et al (2020)	Teachers	Others		X		
Dawson et al (2022)	7-9; 10-12	Science, Geography				X
Dijkstra & Goedhart (2011)	7-9; 10-12	Science	X			
Drewes et al (2018)	Teachers	Science		X		
Jurek et al (2022)	7-9; 10-12	Geography				X
Keselman et al (2012)	7-9	Environmental education/health	X			

			Focus			
First Author (Year)	*Grades/ Teachers*	*Subject Areas*	*Intervention*	*Teacher training*	*Beliefs and perceptions*	*Knowledge and curriculum*
Korfgen et al, (2017)	7-9	Beyond	X			
Korsager & Slotta (2015)	10-12	Science	X			
Liarakou et al (2011)	7-9; 10-12	Environmental education/health	X			
Littrell et al (2020a)	10-12	Science	X			
Littrell et al (2020b)	10-12	Science	X			
Mani & Vivekanandan (2020)	10-12	Environmental education/health			X	
Namdar (2018)	Pre-service	Science		X	X	
Nkoana (2020)	7-9	Beyond	X			
Ohman & Ohman (2013)	7-9	Geography and Others			X	
Roychoudhury et al (2017)	7-9, Teachers	Science	X			
Schauss & Sprenger (2021)	10-12	Geography	X			
Tasquier et al (2016)	10-12	Science	X			
Vinuesa et al (2022)	10-12	Beyond			X	X
Yamada et al (2019)	4-6	Biology	X			
You et al (2018)	10-12	Science				X

Findings

Based on the theoretical framework that guided us to understand students' learning and challenges, we found that the literature discussed student learning about climate change in the relationship with teaching and classroom environments. There were three main themes that were identified through coding: 1) student knowledge; 2) teacher knowledge; and 3) external support. Several codes were visible under different studies, and their commonalities and divergences were used to organize the themes. For instance, disbelief in climate change was a factor that impacted the understanding of students (Littrell et al., 2020b) and teachers (Namdar, 2018) as well. The overlaps identified in the studies are explored below as they explain the challenges and difficulties faced by students, which stem from different factors within and outside the classroom.

Student Knowledge

Most studies (22 out of 29, 76%) highlighted difficulties with relevance to student knowledge. A majority of the studies (11 out of 22, 50%) were from high school (i.e., Grades 10-12) and from the subject area of science (n=8). This alludes that the focus of climate change education is the acquisition of conceptual knowledge of climate change. The topic of climate change is introduced in high school grades as older students are believed to carry certain levels of scientific knowledge which is required to understand the complexities of climate change.

As we reviewed the literature, it became apparent that there was a strong relationship between students' prior knowledge and their understanding of climate change. Baker et al. (2021) reported that younger students (Grades 1-3) were unable to initiate conversations about climate change, which was likely due to the complexity of the topic. Whereas Jurek et al. (2022) highlighted that secondary students (Grades 8-12) were factually more aware in comparison to younger students. This was supported by the idea that students tend to learn with age and utilize prior knowledge from different subject areas such as biology and chemistry (You et al., 2018) or math and science (Baker et al., 2021) to understand aspects of environmental science.

It was also reported that students often display confusion between different concepts such as differences between climate change and the greenhouse effect and other environmental concerns (Dijkstra & Goedhart, 2011; Liarakou et al., 2011), global warming and climate change (Dawson et al., 2022; Yamada et al., 2019) and earthquakes, ozone layer depletion, and climate change (Vinuesa et al., 2022; Yamada et al., 2019). These confusions are further exacerbated as students failed to present evidence for their claims such as a lack of elaboration to claims connecting the ocean to global warming (Korsager & Slotta, 2015) and for the erroneous claim that climate change causes earthquakes (Nkoana, 2020; Roychoudhury et al., 2017; Vinuesa et al., 2022). Besides confusions, it was also reported that they hold misconceptions about the utilization of climate models which are often seen as representations of reality, giving rise to a sense of uncertainty (Bush et al., 2018) and about the human induced nature of climate change which may lead to a sense of helplessness, negative feelings, and disbelief in climate change (Littrell et al., 2020b; Mani & Vivekanandan, 2020; Vinuesa et al., 2022). This indicates that their knowledge impacts their beliefs and perceptions about climate change. In addition, student's beliefs also impact their ability to engage in the discussion of climate change. Such beliefs may lead students to perceive climate change as a controversial and politicized topic, impacting its open discussion and thus the development of a strong understanding of the topic (Ohman & Ohman, 2013).

Teacher Knowledge

As students build on their understanding of climate change throughout social interactions (Bronfenbrenner, 2005; Vygotsky, 1978), difficulties in understanding climate change are not only related to students' individual understanding or experiences but also teachers' interactions with students to talk about climate change in the classrooms. In our review, we noted that many researchers reported diverse challenges and difficulties that teachers encountered in their classrooms. These challenges were important to consider as they impact student understanding of climate change. Some studies (8 out of 29, 28%) highlighted challenges and difficulties faced by students in understanding, however these were related to teacher knowledge. Teacher scientific knowledge is critical to their perception and their pedagogical decision making to teach climate change, which therefore impacts student understanding of climate change (Schauss & Sprenger, 2021).

The literature indicated that teachers rely on outdated or inaccurate information in textbooks, often emphasizing global warming and the greenhouse effect in place of climate change (Dawson et al., 2022). Due to reliance on inadequate resources, teachers may carry misconceptions such as viewing climate change as changes in weather for a small period or considering climate change as a consequence of ozone layer depletion (Namdar, 2018). Teacher content knowledge of climate change impacts students understanding as the students are provided inaccurate information about climate change.

For teacher pedagogical practices, which are impacted by their prior knowledge and understanding, it was reported that teachers were sometimes unable to connect climate change to locally and personally relevant aspects of students' lives, resulting in negative impact on student understanding (Brydon-Miller et al., 2022; da Rocha et al., 2020; Korfgen et al., 2017). In the absence of relevant or hands-on engagement, students were often unable to build connections and develop authentic understanding (da Rocha et al., 2020; Keselman et al., 2012). Thus, pedagogical practices of teacher have an impact on student understanding of climate change. Lastly, student understanding was also reported to be impacted by teachers' beliefs. Teachers may consider climate change as a controversial or politicized topic and exclude it from classroom instruction (Namdar, 2018). As indicated, teacher understanding or lack of understanding of climate change has an impact on student understanding. Furthermore, we now turn to the third theme that highlights other factors within the larger education system that were seen to have an impact on student understanding of climate change.

External Support

There were certain factors that posed a challenge to student understanding of climate change. These factors can be seen as external to both students and teachers but have a strong impact on student understanding of climate change. Half the studies (14 out of 29, 48%) highlighted difficulties related to a lack of external support from curriculum, resources, and community, which reside within and beyond K-12 levels. With scientific knowledge alone, students may not understand the complexity of climate change. To develop an authentic and accurate understanding of climate change, teachers and students alike need support from schools and communities.

The review indicated that curricular and time constraints tend to push climate change as an extracurricular, an add-on, or often ignored topic (Asimakopoulou et al., 2021; Bush et al., 2019). Another curricular constraint was the unintegrated teaching of climate change in disciplinary silos, which impacts learners as they struggle to develop a cohesive understanding (Bopardikar et al., 2021; Brydon-Miller et al., 2022; Dawson et al., 2022). In addition, a lack of professional development for teachers, for the topic for climate change has an impact on student understanding as well. Teachers may not receive appropriate training to teach climate change using complex climate models or other educational technologies. The climate models provide students with visuals to understand the complexities of climate change, such as the practices of predicting climate change over the years, the use of historical data to understand trends of climate, and the ability to manipulate data to observe subsequent changes in climate. Without appropriate training, the lack of teacher's technological knowledge consequently impacts student understanding of climate change (Asimakopoulou et al., 2021; Bush et al., 2019).

It was also reported that in the absence of culturally, contextually, and geographically relevant teaching materials and resources, student understanding is impacted. In addition, climate change often appears as an abstract and distant concept that students cannot relate to (Bopardikar et al., 2021; Littrell et al., 2020a, 2020b; Namdar, 2018). Further, a unique set of resources used by different countries for addressing climate change makes global collaborations in projects and the applicability of resources across countries challenging (Brydon-Miller et al., 2020). It has also been reported that there is a lack of age-appropriate resources to teach climate change to younger students from different grades (Bopardikar et al., 2021). Lastly, the lack of support from the community surfaced in terms of dialogue and conversations about climate change. Outside of the school, specifically with parents at home, a conversation about climate change was absent. It was reported that parents avoid the discussion to prevent inducing anxiety and stress in children (Baker et al., 2021; da Rocha et al., 2020).

Discussion and Conclusions

Climate change education has seen growing interest from researchers and scholars in recent years. Mere implementation of climate change education does not guarantee learning, rather it is important to understand the challenges and difficulties that students face when learning about climate change. Fortner (2001) suggested that an understanding of climate change can be effectively enhanced when education is designed in consideration of the difficulties students face such as pre-conceptions, knowledge gaps, perceptions, and misconceptions. With a particular focus on understanding, Bhattacharya et al. (2021) reported that students often carry alternate conceptions about global climate change. These alternate conceptions have been attributed to the complex and complicated nature of climate change (Roychoudhury et al., 2017; Shepardson et al., 2011; Zangori et al., 2017). This indicates that students often do not understand that climate change is human-induced and often fail to understand the different components that impact climate change. Amid the complexities, Schreiner et al. (2005) highlight that education only focuses on learners acquiring "sufficient knowledge" (p. 23) to tackle climate change. Providing sufficient knowledge to students can often become an issue as it can vary in depth and be inadequate. The aim of education should be to equip learners and ensure that their understanding is adequate. Thus, it becomes integral to understand the nature and origins of challenges and difficulties that students face in understanding climate change. Understanding student challenges and difficulties can then make way for effective implementation of climate change education initiatives.

Education initiatives are strongly connected to teachers as they play a critical role in advancing understanding about climate change. However, teachers themselves can face difficulties in understanding or implementing the topic in their teaching due to external factors. From a social constructivist perspective, many of the challenges and difficulties relevant to conceptual understanding of students can be identified and addressed by the teachers themselves. This is possible because student learning emerges from their interpersonal and social relationships with teachers and learning environments (Christmann et al., 2014; Minshew et al., 2017). Additionally, drawing from the ecological systems perspective (Bronfenbrenner, 2005), teachers' strength in addressing the challenges and difficulties faced by students comes from support from a web of interconnected systems such as the school, administrators, and the policies. It can be said that macrosystems that students and teachers are embedded in, can pose challenges and difficulties for students to develop an accurate understanding for climate change.

Education relevant to climate change has seen increased importance across grade levels and subject areas. However, Plutzer and Hannah (2018) highlighted that climate change education is commonly associated with the subject of science and conducted their investigation in middle and high school. Ozdem et al. (2014) also reported that climate change is mostly introduced during middle school under science education, although there is no global uniformity in the introduction of climate change education in school. Our review also reported a heavy focus on science (e.g., Arya & Parker, 2015). We noticed that the *science of climate change* is often misunderstood as the discipline of science being solely responsible for climate change education. In many places, the cross-curricular and cross disciplinary nature of climate education is diluted to the subject of science (Hestness et al., 2011). Science is held accountable for misunderstandings and inactions towards climate change (O'Neill & Ohman, 2013). Even though science is expected to focus on climate change, it is often overcrowded with other content that is prioritized such as atomic theory, natural selection, or Newton's law (Dawson et al., 2022). Even in the Canadian province of Alberta, that is oil and gas rich, the topic of climate change is often skipped as it is an interdisciplinary topic and teachers do not receive interdisciplinary training regarding environmental issue (Wynes &Nicholas, 2019). It is important to consider climate change education as a cross-disciplinary topic to ensure it is taught and addressed in a cross-curricular fashion.

The review also indicated that climate change education has been under-researched in K-6 grade levels. Most of the studies in the review were undertaken at the high school level. A heavy focus on high school overshadows the pivotal role of elementary grades to set the stage for intellectual growth for students (Dijkstra & Goedhart, 2011; Korsager & Slotta, 2015). Climate change education at high school level is introduced considering the increased ability to grasp complex concepts, initiate conversations and actively

engage in mitigation and adaptation of climate change (Jurek et al., 2022). On the contrary, there has been a growing emphasis on poor climate change knowledge and understanding of high school students (e.g., Baker et al., 2021). Here we can notice a developmental trend where the absence of climate change education from earlier grades can be connected to difficulty in understanding at high school level. With a lack of research in early grades that focus on climate change, it becomes important to identify the challenges and difficulties posed during early years. This will also encourage an early introduction of climate change education to build a strong foundational knowledge for higher grade levels. Further recommendation can be for policy makers, who can include climate change as a topic for elementary grades, while including it across the curriculum. In addition, there can be a focus on development of culturally and locally relevant materials to make climate change relatable for students. It is also recommended that teacher educators explicitly focus on teaching of climate change, including the interdisciplinary teaching of climate change and a focus on the use of climate models. Lastly, it is recommended that elementary teachers create opportunities for students to learn about climate change in different subjects.

Limitations

This study only included articles published between 2000-2022 with a focus on challenges encountered by students in K-12 educational settings. We encountered studies that discussed difficulties not directly relevant to students in this review such as difficulties faced by higher education institutions. Due to the limited scope, we excluded these studies from our review. However, we acknowledge that studies beyond the K-12 setting are equally important and deserve attention. These areas may offer valuable insight into the difficulties carried by individuals into adulthood and can contribute to a more comprehensive understanding of challenges faced in learning about climate change in school. We also acknowledge that we used two search engines (i.e., ERIC and Academic Search Complete) which may have not returned exhaustive literature relevant to the research question. We also acknowledge the limitation of our keywords and search terms, as certain relevant studies may have used different keywords. This may have resulted in our findings that focused limited themes. Furthermore, it is important to acknowledge that our study encountered challenges in the grouping of grade levels due to variations in the classification systems used in different studies. Many of the studies included in our review were from North American, African, and European countries, and each country has its own division of grade levels. As a result, our search for K-12 settings might not have aligned with the classification used in many studies, potentially leading to the exclusion of some relevant research. We recommend future research be mindful of these differences in grade levels in different countries. Our study highlighted articles related to climate change and provided recommendations for future research within a limited scope.

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ABOUT THE AUTHORS

Nimrah Ahmed: Nimrah is a third year PhD student in the department of elementary education at the University of Alberta. Her research interests include problem solving and computational thinking with lower elementary students.

Dr. Mijung Kim: Mijung Kim is a professor in science education at the Faculty of Education, University of Alberta, Canada. Her research areas include science inquiry, scientific and socioscientific argumentation, and reasoning and visualization in STEM education.

Dr. Qingna Jinn: Qingna Jin is an assistant professor at the Department of Education, Cape Breton University, Canada. Her research interests include dialogical argumentation in school science and STEM learning contexts, scientific and socioscientific reasoning, children's critical problem solving in the information age, and children's metacognition in learning.