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Elementary Students' Online Information Problem Solving (IPS) in a Science Classroom

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Supporting students to become critical consumers of online information is one of the most urgent agendas in education today. In schools around the world, students are engaging in online information problem solving (IPS) tasks to develop critical thinking and problem-solving skills by searching and evaluating online information. This qualitative case study explored how 5th and 6th Grade students experienced online IPS using their metastrategic knowledge—that is, knowing why and how to use certain strategies in specific instances. Data collection methods included classroom observation, classroom video recording, fieldnotes, the think-aloud strategy, interviews, and students' reflections about their writing and artifacts. The study's findings indicated that students actively engaged their metastrategic knowledge during the online IPS processes to understand and examine the validity of information and sources and to effectively communicate their IPS results to others. In the process, students also developed ownership and responsibilities for problem solving with reliable information. Based on the study's findings, this article summarizes the process and discusses the pedagogical implications of elementary students' online IPS.

Aider les élèves à devenir des consommateurs critiques d'information en ligne est actuellement l'un des objectifs les plus urgents en éducation. Dans les écoles du monde entier, les élèves s'engagent dans des tâches de résolution de problèmes d'information en ligne pour développer leur esprit critique et leurs compétences en résolution de problèmes en recherchant et en évaluant des informations en ligne. Cette étude de cas qualitative s'est penchée sur l'expérience d'élèves de 5e et 6e années en matière de résolution de problèmes d'information en ligne alors qu'ils utilisaient leurs connaissances métastratégiques, c'est-à-dire qu'ils déterminaient pourquoi et comment utiliser certaines stratégies dans des cas spécifiques. Les méthodes de collecte de données comprenaient l'observation de la classe, l'enregistrement vidéo de la classe, les notes de terrain, la stratégie de réflexion à voix haute, les entretiens, ainsi que les réflexions des élèves sur leurs écrits et leurs artefacts. Les résultats de l'étude indiquent que les élèves ont activement utilisé leurs connaissances métastratégiques au cours des processus de résolution de problèmes d'information en ligne afin de comprendre et d'examiner la validité des informations et des sources ainsi que de communiquer efficacement ces conclusions aux autres. Au cours de ce processus, les élèves ont également développé l'appropriation et la responsabilité de la résolution de problèmes à l'aide d'informations fiables. Sur la base des résultats de l'étude, cet article résume le processus et discute des implications pédagogiques de résolution de problèmes d'information en ligne des élèves du primaire.

In the current digital era, people need to develop the skills and knowledge to navigate the deluge of information available through their digital devices. Due to a significant amount of false and misleading information online, researchers have reported that many people struggle to engage critically with web content (Breakstone et al., 2018; Wineburg et al., 2016); therefore, efforts are now underway to teach citizens to interact with online information in a meaningful, responsible, and ethical manner (Beach & Cleovoulou, 2014; Bowler, 2010; Gebre, 2018). In schools, students often engage in problem-solving activities such as identifying problems; searching, evaluating, and synthesizing information to arrive at solutions; and communicating information and solutions to others (Brand-Gruwel et al., 2009; Leu et al., 2013; Merritt et al., 2017; Wopereis & van Merriënboer, 2011). These learning activities are collectively defined as *information problem solving* (IPS), and as *online IPS* when the internet is used to develop students' critical thinking and information evaluation skills (Brand-Gruwel et al., 2009). Problem solving or problem-based learning (PBL) approaches are not new in science classrooms where students engage in student-centered, iterative inquiry processes to solve problems through data and information collection within pre-designed curriculum settings (e.g., Akınoğlu & Tandoğan, 2007; Gallagher et al., 1995; Karaçalli & Korur, 2014; Leuchter et al., 2014; Potvin et al., 2012). Yet, in online IPS, students' information searches go beyond the curriculum boundaries, which brings new challenges in the areas of pedagogical design and the practice of problem solving (Mason et al., 2014; Merritt et al., 2017).

To become analytical and responsible problem solvers and consumers of web content, learners need to engage in online IPS in a critical manner. Within education spaces, it is important to develop students' critical thinking competencies beyond procedural and technical skills, such as using search engines (Bowler, 2010). One essential aspect of critical thinking competencies is students' *metastrategic knowledge*, which refers to their knowledge about any cognitive strategies that are applicable to achieve task objectives (Dedić, 2014; Michalsky, 2020; Zohar & Ben David, 2009). Students' metastrategic knowledge includes understanding what strategies help them achieve learning goals, in what way the strategies are helpful, and how to implement those strategies. In the context of online IPS, students' metastrategic knowledge is related to strategies for navigating information online, evaluating the information they find, and communicating the results to solve problems (Barzilai & Ka'adan, 2017; Bowler, 2010).

Elementary Students' Online IPS in Science Classrooms

Recent studies have supported that learners' competencies in searching, evaluating, and synthesizing multifaceted information in digital environments play an important role in developing scientific literacy (Flierl et al., 2018; Greene et al., 2014, 2018). Yet researchers have reported that students experience difficulties in critiquing the information they find online, because of the enormous amounts of information available and the lack of gatekeepers or editors to filter or organize it (Borthwick & Hansen, 2017). Students at various grade levels do not always critically examine the results provided by search engines, but rather tend to accept the suggested websites as reliable sources of information (Hobbs, 2021; Ladbrook & Prober, 2011; Stalker et al., 2019; Walraven et al., 2013). Thus, it is essential for schools and teachers to develop pedagogical strategies for understanding, supporting and developing students' abilities to search for, and critically evaluate, online information (Breakstone et al., 2018; Scoular & Care, 2020; Stalker et al., 2019). Before examining how teachers can instructionally develop students' information seeking and evaluating abilities, we will first explore the process of online IPS and the importance

of metastrategic knowledge.

Most research about students' online IPS has focused on the secondary and postsecondary levels (e.g., Brand-Gruwel et al., 2005, 2009; Flierl et al., 2018; Greene et al., 2018; Scoular & Care, 2020). Working with secondary and postsecondary learners, scholars have proposed models of online IPS, such as the IPS-I (information problem solving using the internet) model (Brand-Gruwel et al., 2005, 2009), which is described in more detail below. Since research is limited on younger learners' online IPS, less is known about the ways in which elementary students develop online information problem solving skills. With the growing propagation of digital technologies and online information adopted by elementary classroom teachers and students, studies in elementary contexts are essential for determining the pedagogical implications of younger learners' online IPS abilities.

Metastrategic Knowledge in Online IPS

Aligning with the literature (e.g., Kuhn, 1999, 2000a, 2000b, 2001a, 2001b; Zohar, 2012; Zohar & Ben David, 2008, 2009), metastrategic knowledge in this study refers to a person's general and explicit knowledge about cognitive procedures and strategies and addresses why and how to use certain strategies in specific instances. This study focused on young learners' conscious metacognitive processes—that is, their explicit awareness of cognitive procedures and strategies during their online IPS (Zohar & Ben David, 2009). Many scholars have claimed that metastrategic knowledge is important for students' cognitive performance, because with the knowledge of strategies and the conditions of knowledge application, students can select appropriate cognitive strategies for achieving learning task objectives (Barzilai & Ka'adan, 2017; Hanin & van Nieuwenhoven, 2020; Kuhn, 1999; Kuhn & Pearsall, 1998; Zohar & Ben David, 2008, 2009).

Online IPS involves cognitive strategies and related metastrategic knowledge (Brand-Gruwel et al., 2005, 2009). For example, during online IPS, students evaluate whether online information is valid and trustworthy. In this process, students require the following metastrategic knowledge: (a) knowing specific strategies for information evaluation (e.g., students know that cross-checking is a strategy for evaluating information), (b) recognizing the necessity and importance of information evaluation (e.g., students know they need to employ strategies because not all online information is valid), and (c) knowing how to use the strategies (e.g., students cross-check with various sources to compare information). After examining online information, students synthesize the information to formulate answers and present results. Similarly, communicating IPS results with an audience involves certain strategies (e.g., employing particular methods of representation to gain the audience's interest) and related metastrategic knowledge (e.g., knowing why and how to use the methods).

In their research with university students, Brand-Gruwel and colleagues proposed the IPS-I (information problem solving using the internet) model, which helps explain how students use strategies during online IPS (Brand-Gruwel et al., 2005, 2009). The IPS-I model outlines a set of steps that information seekers follow, including defining problems, searching for information, scanning information, processing information, and organizing and presenting information. Beyond these procedural steps, higher-level regulation is required, during which students regulate the execution of their procedural skills by monitoring and evaluating their performance during the IPS process (Brand-Gruwel et al., 2009). According to theories and research on metacognition (e.g., Flavell, 1979; Thomas & McRobbie, 2001), this higher-level regulation is

students' application of their metastrategic knowledge to implement their cognitive strategies at the procedural level. This online IPS model emphasizes the importance and impact of students' metastrategic knowledge. Accordingly, this study used a similar model to examine how elementary school learners employ and develop metastrategic knowledge during the online IPS process in science classrooms.

Research Design

Qualitative Case Study

This study, which was approved by the Research Ethics Board at the University of Alberta, was designed as a qualitative case study. Many studies about online IPS have tended to employ quantitative methods, such as measuring students' performance in online problem solving (e.g., Flierl et al., 2018; Greene et al., 2018; Scoular & Care, 2019, 2020) and testing relationships between different constructs such as metacognitive knowledge and performance of information integration (e.g., Barzilai & Ka'adan, 2017). These studies are important for understanding students' online IPS. However, given the features of quantitative methods, these studies have tended to lack description and explanation of the identified causal relationships and they seldom explained participants' actual experiences. Despite students' similar IPS performance outcome scores, variations in micro-interactions occur across students (Pöysä-Tarhonen et al., 2018). Therefore, to holistically understand the process of students' online IPS, we examined students' qualitative interpretations of their interactions with web content.

This qualitative case study had both descriptive and interpretative emphases. Descriptive case studies in education are useful for presenting information about classroom interactions and students' learning (Merriam, 1998). The descriptive data in this study were used to interpret how students experienced and interacted with web content and how their metastrategic knowledge was employed in the process. With the interpretative emphasis, this study aimed to "illustrate, support or challenge theoretical assumptions held prior to the data gathering" (Merriam, 1998, p. 38), such as the existing online IPS models and the importance of metastrategic knowledge for online IPS.

Case studies are sometimes challenged in terms of the validity and generalizability of the research findings. In response, this study employed two approaches recommended in the literature: thick description (Guba & Lincoln, 1989) and triangulation of multiple data sources (Creswell & Miller, 2000). In what follows, we describe the research context in detail so that educators will know what activities students engaged in, and to what extent classroom interactions were related to the findings of this study. We also describe how data from multiple sources were collected and triangulated to achieve the validity of data interpretation.

Curriculum Context

This study was conducted in a Grade 5/6 science classroom in a public school in Canada. Twenty-one students (12 Grade five and 9 Grade six students) and their science teacher, Ms. Johnson (a pseudonym; students' names that appeared in the later sections are also pseudonyms), worked on the Trees and Forests unit for eight weeks. Table 1 provides an overview of the class activities during the research period. During the first weeks, the teacher and students reviewed science concepts based on the provincial curriculum. Then, students were encouraged to think about any

Table 1

Overview of the Classroom Activities

Duration	Main focus of the teaching & learning	Brief description of the classroom activities
3 classes (2.5 weeks)	Reviewing science concepts based on the provincial curriculum	*Students' activities & teacher's scaffolding* The teacher and students reviewed science concepts related to forests and trees based on the provincial science curriculum, such as • types of trees, animal habitats, ecosystems in forests, local trees and forests • diverse values related to trees and forests
2 classes (1 week)	Students framing their research topics	*Students' activities* • Students were encouraged and supported to come up with the trees/forest-related research topics they wanted to investigate • Students shared their questions within peer groups

1 class (0.5 weeks)	Teacher-led whole-class discussion about online IPS (designed and implemented by the teacher)	*Teacher's scaffolding*
		The teacher and students discussed aspects of online IPS, including:
		• whether all online information is valid (fake news, disinformation, etc.)
		• how students could identify reliable online information sources by
		  ○ questioning who the information provider is
		  ○ comparing different information sources' reliability such as governments, universities, YouTube, and Wikipedia

7 classes (3.5 weeks)	Students conducting online research	*Students' activities* • searching online for information about their research topics • evaluating the reliability of the information sources (i.e., various websites) • examining the online sources in terms of their relevance, validity, etc. *Teacher's scaffolding* While students were working on online information searching and evaluation, the teacher asked them questions such as: • "Where (or how) did you find this information?" • "Why do you need this information?" • "Do you think your information is trustworthy? Why?"
3 classes (1.5 weeks)	Students presenting the results of their online IPS	*Students' activities* • choosing the best format to convey the results of their research • preparing presentations through synthesizing and organizing information • presenting final outcomes to each other and students in other classes

questions they wanted to explore within the parameters of the Trees and Forests unit. After students decided on their topics (some students changed topics as their IPS continued), the teacher held a whole-class discussion about fake news and online information evaluation. A few examples of fake news were presented to discuss the validity of online information. Yet, during

the class conversations, we (the teacher and researchers) noticed that while students knew what fake news was, they were unfamiliar with information evaluation strategies. Accordingly, we discussed methods and strategies we could use to help students understand misinformation and which they could practice during their online IPS. We decided to have a whole-class discussion about the importance and difficulties of identifying fake news, and strategies that students could use for reliable problem solving (see Table 1). After the discussion, students started their online research. Some students worked individually, while others collaborated in groups with others who shared the same topic. During students' online IPS, Ms. Johnson provided ongoing scaffolding through prompting questions and comments (see Table 1). At the end of the unit, students presented their investigation results to one another, and also shared their presentations with a larger audience, including parents and students from different grades.

Data Collection and Analysis

We collected data using various methods, including classroom observation, video-recordings of classes, the think-aloud strategy, interviews, researchers' field notes, and students' writing samples and artifacts. Two cameras were used to video-record teacher-student interactions and classroom activities. While students were engaged in their online IPS tasks, we invited them to use the think-aloud strategy to articulate their thinking or to respond to questions posed by the researchers (Branch, 2006). We also collected students' classroom artifacts (e.g., presentation files and dioramas). At the end of the study, all students were asked to write reflections about their IPS process. We invited five students who were actively engaged in classroom activities and writing to participate in individual interviews. During these 20-minute, semi-structured interviews, students clarified the ideas written in their reflection notes and shared their rationale for certain actions or ideas during the project. Of the five students, four were in Grade 5 and one was in Grade 6; four were boys and one was a girl. Two of them (David and James) had worked in the same group, while the others had worked individually. Their investigation topics included Mountain Pine Beetles (MPBs), tree diseases, protected areas and national parks, and tree harvesting.

Data were analysed qualitatively in a multi-step and iterative way. First, for open coding, the research team viewed all video-recorded data, interview transcripts, students' artifacts, and reflection notes. Each research team member individually analyzed the data and developed themes by cross checking the different data sources. For axial coding, the research team came together to share and discuss any similarities and differences in the themes from our individual coding. The differences were then analyzed more deeply to understand where and how different interpretations had emerged. In this process, we noticed that the majority of our coding disagreements were clustered around students' metastrategic knowledge. Thus, through several rounds of discussion, the research team collectively revisited the definition and framework of metastrategic knowledge and achieved consensus on how to identify indicators of the metacognitive process. According to its definition, pertinent metastrategic knowledge is an awareness of the cognitive procedures and strategies used in a specific instance—that is, online IPS in this study. Thus, to discern metastrategic knowledge in our data analysis, it was critical to examine whether students were aware of the strategies in their repertoires and whether they consciously chose (or did not choose) and implemented (or did not implement) these strategies. Examples of verbal indicators of students' metastrategic knowledge of evaluating online information included "I know I need to do something, use some techniques to check and to gather

some good information"; "If I have two websites, I am going to compare the information; if they are the same, then it is good"; and "I gather some information from CBC News, because as the public Canadian broadcast company, they do not report fake news." After axial coding, we moved on to selective coding. During this step, we selected a few episodes to illustrate the themes that we had agreed upon collectively.

Findings

Framing Research Questions and Establishing Ownership

In this study, students were encouraged to choose the topics that they wanted to investigate. Most of the students' self-generated questions derived from their everyday experiences and local contexts; therefore, the topics were personally meaningful to the students and were open ended with diverse answers and solutions. Some examples included "Why does wildfire happen?"; "What should people do in response to a wildfire?"; and "What is the ecosystem in Moose Island [a national park in the community]?" Because students developed these questions based on their personal, everyday experiences, they were motivated and developed ownership over their inquiries. For example, Adam offered the following explanation about his decision to research tree diseases caused by fungi:

> My dad is a liver doctor, and he told me that, one fall, some people ate certain mushrooms, like fungi, and got liver disease. And they had 15 liver transplants that fall … I think it will be cool to learn something about fungi … This is my research, something I need to do … [and] important to me.

Adam generated his research topic from his personal experience and discussions with his father. The personal connection led him to claim that it is his research and important to him, which resulted in a sense of autonomy and ownership of his learning (Bruner, 1996).

As their online IPS continued, with support from the teacher, many students revised their initially broad questions into topics that were more manageable. For example, in the beginning Jared had framed a very broad question: "Why are MPBs (Mountain Pine Beetles) a big problem today?" As he began searching for online information, he realized his topic was unclear. Jared modified and narrowed his question into one that was answerable through online research: "I changed my research, my research [now] … is on what damages MPBs brought, that is my focus … really interests me." The process of "defining problems" enhanced students' interests, connections, and ownership over their investigations.

Throughout their IPS, students came to understand more about their topics and acquired expertise in their areas. They established a community of problem solving based on their research topics, and students' ownership increased as their expertise developed and became recognized by others. The following conversation illustrates how students claimed and recognized ownership and expertise about their research topics:

> Researcher: This is the larva of mountain pine beetles, right?
>
> Jaden: I am not the MPB person … I can answer your questions about engineered woods … [pointing to David and James] They are MPB guys.
>
> James: Oh, yes! That [MPB] is my research … I can answer your questions.

Jaden did not answer the researcher's question about MPBs because it was not his research topic. Instead, he drew the researcher's attention to David and James by acknowledging their research and expertise on MPBs. Jaden called them over to answer the question. James came close to Jaden's desk, claimed his expertise on the topic, and was ready and willing to answer the researcher's questions about MPBs. We observed similar phenomena throughout the study where students increasingly became experts in their own research areas. Their agency in claiming and acknowledging their own and each other's expertise developed over time. Further, based on their acknowledgement of ownership and expertise, students exchanged information to support one another's research. For instance, Lydia found information on wildfires during her online research and shared it with the group researching wildfires, saying, "This is related to your topic. I thought it might be helpful for you." Accordingly, students' ownership and expertise were recognized at the social level, which contributed to collaborative problem solving. When identifying problems, students explained their interests and connections to their own research questions, which further developed their ownership of IPS. This also helped students to recognize their responsibility for problem solving, which we discuss in the next section.

Searching and Verifying Online Information with Various Strategies

When searching for information, students explored various resources, including books, websites, and asking adults; however, their main resource was the internet, which meant they were required to vet the web content. In classroom interactions and interviews, students explained how they employed strategies to verify online information and why these strategies were important. With their metastrategic knowledge of information evaluation, students examined the validity of information and the reliability of sources to make their IPS trustworthy.

Knowing the Importance of Implementing Strategies to Verify Online Information

In their reflection notes and interviews, most students demonstrated an awareness of the importance of applying strategies for verifying information. Students knew they needed to employ or avoid certain strategies to gather trustworthy information—which they called "good information"—because of the existence of misinformation and disinformation online. For example, a group of students working on MPBs found that one website reported the size of an MPB as being unreasonably large compared to many other websites. They shared this case with their classmates and observed that some websites might contain incorrect information. Later, during an interview, James shared that he needed to evaluate the information because he knew "not all the information online is true" and thus, he could not "just copy and paste." Lee mentioned there was "much fake news online, because everyone can post online, everyone can develop a website," so he needed to "do something to collect good information."

Students demonstrated their awareness of responsible IPS processes by explaining the importance of collecting trustworthy information. They knew they would present their investigations to others; therefore, they articulated their responsibility to find and use valid information. Henry mentioned that "when you present your project, you need real information, that is your responsibility … so, you need to think about how to find real information." Likewise, Ivan wrote, "If I use wrong information, if people come to my presentation and spread the information to other people, [then] everyone would have the wrong information, that is not good."

In appreciating the importance of gathering "good information," students engaged in critical analysis of web contents. They were aware of why it was important to implement various strategies for the validity of online information and web sources.

Implementing Strategies for Evaluating the Reliability of Websites

When searching online, students typed their questions and keywords into a search engine (e.g., google.ca), which resulted in a list of webpages. Students usually started by clicking on the pages near the top of the search results, and later went down the search list to review other pages. Once they opened a webpage, they applied their metastrategic knowledge by consciously implementing strategies to determine whether the webpage was a reliable information source and whether they would be able to collect information from that particular page. They checked the authors of websites, looked for signs of copyright, advertisement pop-ups, and so on, and compared contents across different websites.

For instance, David said that he looked for "the government symbol on it [the webpage]." If he saw the government symbol, he would trust the information from that site because he said that the "government is reliable." He also reported that he relied on and gathered information from the CBC News website because "as the public Canadian broadcast company, they do not report fake news." Similarly, Levi examined the URLs and would read webpages ending with ".org" or "gov.ca." Students also compared different information providers' reliability and tended to collect information from the sources they considered more reliable. Nate explained that he seldom collected information from YouTube or Wikipedia because he thought these sources were "not good, because anyone can upload or edit the content, and you do not know who they are." Instead, he preferred to gather information from the websites of universities and other research institutes because he believed "scientists and professors [were] more reliable than other people you do not know who they are." These were strategies (i.e., questioning who authored the information and comparing the reliability of certain information sources) that the teacher had discussed with her students early in the research process; therefore, it is not surprising that students practiced these strategies. However, it was pedagogically meaningful and assuring to notice that students further developed their awareness and strategies on information evaluation in the online research process. Encountering incorrect information, pop-up advertisements in personal blogs, fake photos, and so on, reinforced their metastrategic knowledge in terms of the importance of critical review. This process led students to start ranking websites in terms of reliability. They ranked websites from governments, non-governmental organizations (NGOs), and research institutes as higher than YouTube, Wikipedia, and personal blogs. In this way, during the actual IPS process, students expanded the information evaluation strategies they had learned from their teacher. In addition, we found that students implemented new strategies that the teacher had not mentioned. For example, when Nathan was asked to share his experience of "coming across any resources that were not reliable," he wrote about a new strategy:

> There was a website about tree diseases … but I did not read any of it. David notified me that my computer security was blocking a virus. That website had a virus! If it has a virus, it is not reliable. I started paying attention to that small window in my later [online] searching.

Nathan described implementing a new strategy by consciously paying attention to the virus warning window. During their research, students like Nathan encountered various ideas and

situations that they thought were related to the reliability of websites. Through these situations, they developed further awareness, new strategies, and related metastrategic knowledge to determine whether the websites were reliable information sources.

Implementing Strategies for Evaluating the Validity of Information

During their research, students determined that websites not associated with governments or university research were less reliable. Accordingly, when using these other sources, the research team noticed that students frequently used a "cross-checking" strategy to verify information, which was not something initially discussed by the teacher. Students started to compare information across different sources, as well as with their previous knowledge and their peers' research notes. During the interviews and think-aloud conversations, students explained how cross-checking regulated and assisted them in evaluating the validity of information. They said if various websites showed similar or the same information, they determined it was trustworthy. Henry explained that

> To gather good information, I compared different websites … I compare the information. If I have two websites, if they are saying the same, then it means it [the information included] is good … Because, you want to know whether other people agree with this … if people are all saying that, that is true.

In this explanation, Henry described how he did cross checking (checking whether two web sites explained the same information) and why it was important (to check validity). He thought the validity of information was determined by "whether other people agree." Therefore, to examine the validity of new information, Henry checked whether other websites included the same or similar content. Using the same metastrategic consideration—that is, that the validity of information is determined by consensus—students also evaluated online information by cross-checking with their peers. When students were exploring similar topics, they sometimes discussed their information to collectively examine its validity. In an interview with James, he shared how he and his classmates examined the validity of information about MPBs:

> Sometimes, we checked our information together … he thinks this is true and I don't know about this, we will discuss … if most people think it is true, then it is true … Then, I will have that in my project.

In addition to checking with others, students also checked the new information with their own knowledge. For example, David shared how he examined whether new information was trustworthy in light of his previous knowledge and experience:

> I saw a webpage [that] said an MPB was an inch big, that is wrong! Did not use anything from it. You want to use something true … the teacher brought samples of MPBs, the real ones, but samples. That was very helpful … It is that big [showing the length of an MPB with his fingers: approximately 5 millimetres] … that is true, what I trusted. An inch big?! That is wrong information. I didn't use anything from that website.

Like Henry and James, David emphasized his need for valid information and described how he carefully evaluated the information he encountered online. Instead of checking whether other websites or other students showed the same information, David examined the information in the context of what he had learned in previous science classes. When some information from one

source conflicted with his existing knowledge, David questioned the validity of any information from that source. He did so because he "trusted" what he had learned in science class. In this way, his metastrategic knowledge impacted how he evaluated the validity of information with this strategy (i.e., cross-checking).

Presenting and Sharing Information in Diverse Ways

Once the students had gathered and verified their information, they started preparing their presentations. They knew their purpose was to "introduce [their] work to the audience." With the audience in mind, they planned ways to effectively communicate their IPS results with others rather than simply displaying them. For example, Zhao shared, "You cannot just show them your research notes, you need to organize … and present to your audience." For their presentations, the students pondered specific presentation formats and ways of interacting with others. Their metastrategic knowledge about effective presentation and communication impacted the final outcomes.

Adopting an Appropriate Presentation Format

Students chose various formats, including slide presentations, posters, dioramas, roleplays, and storybooks (see Figure 1 for examples). Students were aware that they needed to choose an appropriate format from among various options and made their decisions through a consideration of their topics, the characteristics of certain presentation formats, and their own capacities and interests. Jared told the research team, "you need to decide which [format] is best … I like poster for this project, because … poster can show everything together, all the images and words. I have many images about MPBs I want to show, so poster is good, best actually." However, Jared also acknowledged that one disadvantage of a poster was its limited space, and he reflected on how he needed to strategically decide which information to include and exclude. He explained, "I had

Figure 1

Examples of Students' Presentations in Diverse Ways

1. Diorama showing the life cycle of Mountain Pine Beetles (MPBs)
2. Storybook written and drawn about MPBs
3. Poster about MPBs
4. Expert interview about the Moose Island ecosystem
5. Puppet show about the history of Moose Island

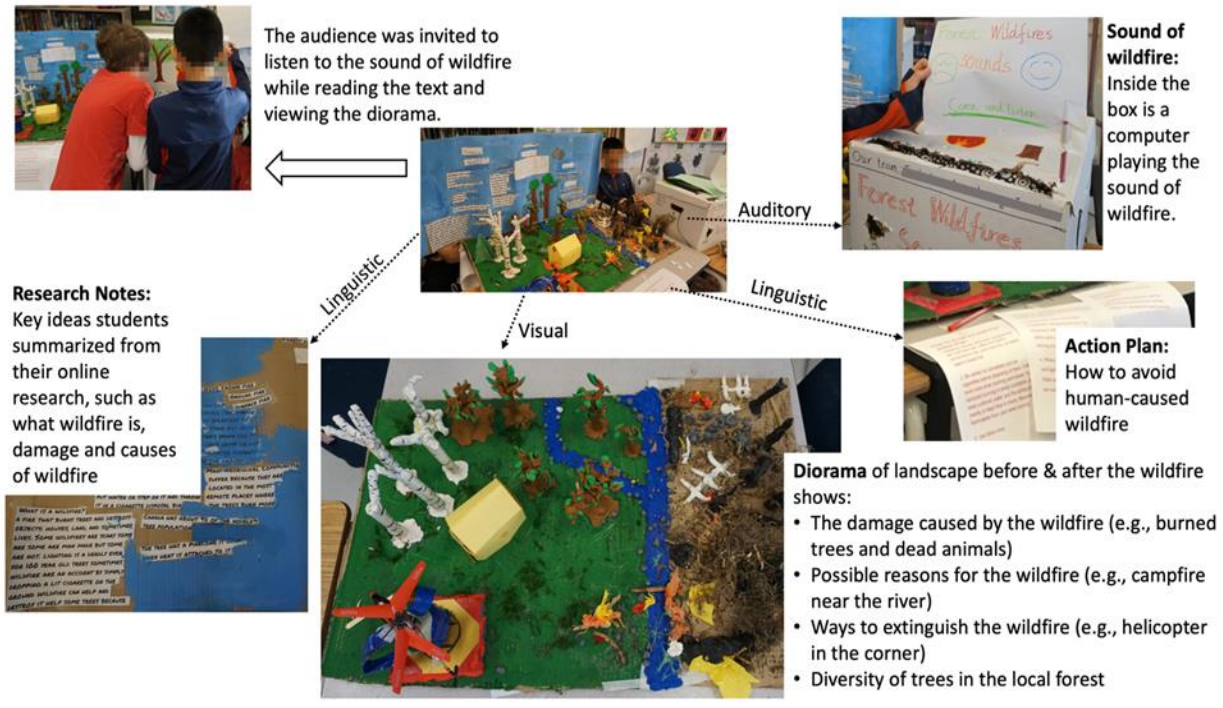
more than 10 pages of [information about] MPBs in my portfolio … For my poster, I cannot just copy and paste … I need to wisely choose what is in." Knowing their own capacities and interests, students also chose a format they were capable of producing and were good at. A group of students who created a storybook reflected that they were good at drawing and loved stories, so they decided to make a book about MPB problems. Using metastrategic considerations and reflections, students chose the presentation format that they thought was suitable for their research and fitted their capacities and interests into that format.

In their presentations, all students incorporated various modes of communication including verbal and written text, visual and auditory representations, and gestural actions. Figure 2 shows an example. With written and visual texts, a diorama and audio sound, a group of students presented the causes of wildfires and the resulting damage to local forests, ways to extinguish wildfires, and action plans to avoid human-caused wildfires. As the main part of the presentation, they created a diorama of green and ashy forests side by side to depict the scene before and after the fire. They also played an audio-recording of a forest fire that they had found online (see Figure 2). The group asked the audience to listen to the sound while viewing their diorama and reading the poster. The students shared the following metastrategic considerations with the research team:

> They [the modes of presentation] are helpful together … people who come to our presentation can see the forests before and after the wildfire [pointing to the diorama], experience the fire [pointing to the box], read our poster with important ideas and the action plan … so they can learn better and more about the wildfire.

Figure 2

Students Shared Their Investigation of Wildfire With Diverse Modes of Information



The students added that they wanted their presentation to motivate others to think about and become aware of the danger of and damage caused by wildfires as much as possible. Students attempted to choose suitable and available formats of presentation to help their audience better understand their IPS results. With these metastrategic considerations and practices, students presented their online IPS results creatively, authentically, and proudly.

Discussion and Implications

Supporting students to become critical consumers of online information is one of the important agendas in education today (Breakstone et al., 2018). Most of the academic research about online information problem solving (IPS) has focused on higher grade levels or adults (e.g., Brand-Gruwel et al., 2009; Hahnel et al., 2020; Scoular & Care, 2020); thus, there is a limited understanding of elementary students' online IPS. Yet today, students of all ages are using the internet to search for information and solve problems on a daily basis (Laidlaw et al., 2022; Stalker et al., 2019); therefore, it is important to understand and develop young students' online IPS knowledge and skills. This study examined how Grade 5 and 6 students developed their online IPS and how their metastrategic knowledge was embedded in information evaluation and sharing. Modifying the steps of the IPS-I model (Brand-Gruwel et al., 2005, 2009), this study engaged elementary students in three main phases: (a) defining and understanding problems, (b) searching and verifying online information, and (c) sharing IPS results.

Students' Metastrategic Knowledge Throughout Online IPS

Throughout the phases of IPS, students applied their metastrategic knowledge to implement and develop strategies for determining whether online information and communication was trustworthy. During the first phase of defining and understanding problems, students reflected on how they were connected to and interested in their research topics. Their personal connections and interests in the research topics developed their ownership and responsibility toward the IPS task. They started identifying "it's my (or their)" research. Their research topic expertise was also recognized and appreciated by their peers, which further developed their ownership and responsibilities of problem solving at the social level. During the students' information search, they sometimes encountered incorrect or dubious information. These experiences enhanced their awareness of the importance of evaluating information and that they had a responsibility to gather reliable information for themselves and others. Through the process, they became increasingly aware of the necessity and importance of implementing strategies to verify the information they encountered.

In understanding the purpose of their presentations, the students examined how best to present their work. They needed to decide which format was effective for sharing their information and the most useful way to organize it in the chosen format. They explained that their aim was to effectively communicate their research to their audience rather than simply displaying what they had found online. By developing this awareness of the audience, the students sought to engage their audience with various presentation strategies. They deliberated over the formats of their presentations by considering the advantages and disadvantages of certain presentation formats, as well as their own capacity to adopt these formats.

Throughout the study, students' metastrategic considerations were critical for developing their IPS process and outcomes. In claiming ownership and responsibility for their research topics

and problem solving, they realized the importance of information evaluation and implemented strategies to achieve their goals.

The Complexity of the Online IPS Process

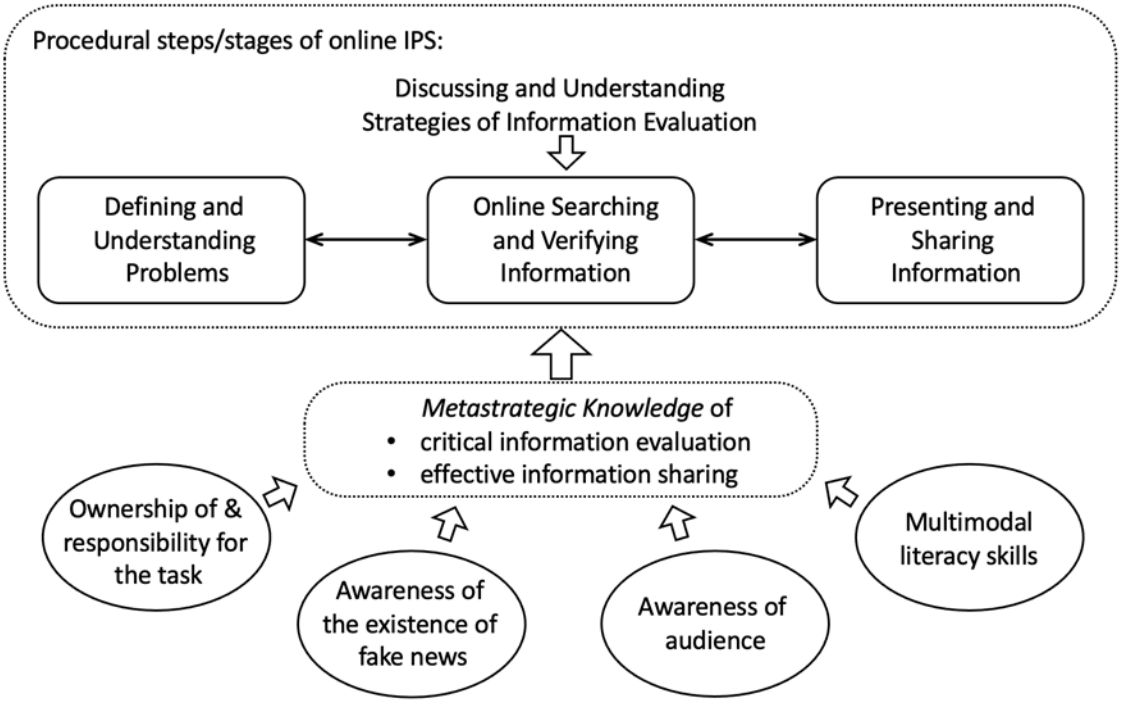
While the three-phase process of online IPS appears to be linear and straightforward, our research showed the process to be recursive, complex, and flexible with students' metastrategic considerations and practice. For example, during the information search, some students realized that not enough information was available to answer their initial questions. Accordingly, they revised their questions and keywords into ones that were potentially more answerable. The process required the students to go back and forth between the phases. We also found that in the process of organizing the information students had collected to prepare their presentations, they sometimes realized they lacked certain information. At this point, students also questioned whether they had good (relevant and valid) information to support their research. Then, they repeated the information searching and verification process to gather more information. Whenever they needed support, the students came to the teacher and/or the researchers and explained what difficulties they had encountered and what help they needed. Students were actively thinking about, reflecting on, planning for, and examining their research questions, information, and strategies to develop their problem-solving abilities.

The complexity of the problem-solving process in this study might seem similar to other problem-solving activities in inquiry-based science classrooms. However, in the online IPS, the phase of "verifying information" made students' problem solving unique, complex, and challenging. At the beginning of the study, students were unfamiliar with information evaluation. They had heard and knew about the word "fake news," but students could not explain how to evaluate information on websites that reported fake news. As reported in previous research (e.g., Breakstone et al., 2018; Hahnel et al., 2020; Wineburg et al., 2016), students in this study initially lacked the knowledge and skills for information evaluation. When the teacher and researchers realized that the students lacked these skills, a whole-class discussion was held to help students become familiar with online information searching and evaluation, including showing examples of fake news and how to identify disinformation on the internet. This process was extremely helpful for the teacher and students to teach and learn the online IPS process. Based on this, we observed that "discussing and understanding strategies of information evaluation" is an important additional step in online IPS to scaffold students' information evaluation practices. As shown in this study, incorporating information evaluation strategies resulted in positive outcomes for students' metastrategic learning.

We have summarized the process of students' online IPS (see Figure 3) to help elementary school educators examine and design appropriate scaffolds to support students' critical and trustworthy online IPS. Teachers' instructional scaffolding could start from any phase of the process. For example, teachers might start a lesson by having a discussion about fake news in everyday lives to cultivate students' awareness of the prevalence of misinformation and disinformation. The teacher could then model information evaluation strategies that can be used to identify trustworthy information and web sources. Teachers might also start with researching students' existing ideas or misconceptions about how to examine information validity (e.g., some students in this study thought "if most people think it [a piece of information] is true, then it is true"). During class discussions throughout the IPS process, students' metastrategic knowledge—that is, knowledge about why and how to use certain strategies in specific instances—needs to be

Figure 3

Elementary Students' Online IPS With Metastrategic Knowledge



encouraged. Teachers can explicitly ask students to share what strategies they know about, which strategies are required in certain contexts, and how to apply those strategies to solve problems. Scaffolding these strategies encourages students' metastrategic thinking and practices, which can in turn reinforce students' IPS tasks and performance.

Overall, this study uncovered the ways in which elementary students demonstrated their awareness of and abilities for information seeking, evaluating, and sharing. It was evident that students were active problem solvers with their metastrategic considerations and knowledge. Even though this study was a small-scale, qualitative case study, it has broad implications for sharing the potential of metastrategic knowledge for IPS and how we encourage students to become better problem solvers in a digital post-truth era. Further studies in broader and more diverse contexts will improve educators' understanding of what other competencies are required for online problem solving and how these skills can be developed in classrooms to benefit students in the future.

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