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Examining the Efficacy of Inquiry-based Approaches to Education

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Educational jurisdictions around the world have introduced curricular initiatives that emphasize the need for students to engage in inquiry-based education. This shift has been met by significant public opposition, particularly in the Canadian context. The conclusion of this research indicates that criticisms of inquiry-based approaches to education are largely directed at discovery learning, which has limited educational value. We note the significant affordances of guided forms of inquiry, such as problem-based learning, and approaches to inquiry aligned with the authentic education movement. Additionally, we highlight the specific instructional supports needed for processes of inquiry to promote elements, such as critical thinking skills and flexible problem solving abilities, necessary for success in a rapidly changing world.

Les milieux d'enseignement partout au monde ont mis sur pied des initiatives pédagogiques qui soulignent le besoin d'une éducation basée sur l'enquête. Ce changement d'orientation a suscité une forte opposition de la population, notamment au Canada. Les résultats de cette recherche indiquent que les critiques des approches en éducation reposant sur l'enquête visent surtout l'apprentissage par la découverte, dont la valeur éducative est limitée. Nous notons les possibilités significatives qu'offrent, d'une part, les formes d'enquête guidée telle que l'apprentissage par la résolution de problèmes et, d'autre part, les approches à l'enquête tenant compte du mouvement de l'éducation authentique. De plus, nous mettons en évidence les soutiens spécifiques à l'enseignement qui sont nécessaires pour que les processus d'enquête favorisent les capacités, comme la pensée critique et les compétences souples en résolution de problèmes, qui sous-tendent la réussite dans notre monde en évolution rapide.

The most recent 2015 Programme for International Student Assessment (PISA) results indicate that Singapore, Japan, and Estonia have become global leaders in education (Organisation for Economic Cooperation and Development [OECD], 2016a). Although these top three performing countries have differing systems of education, they hold in common a commitment to inquiry-based approaches to education. For example, Singapore's 'teach less, learn more' educational approach has reduced the number of outcomes in the programs of studies so that teachers can focus on laying a strong foundation of knowledge and skills involving inquiry-based processes (Ministry of Education Singapore, 2017). Similarly, Estonia's system of education, which is ranked as the strongest in Europe (OECD, 2016a), focuses on lifelong learning by developing interdisciplinary skills such as creativity and entrepreneurship (Lees, 2016). Reflective of this curricular mandate, Estonia's upper secondary school course, *Bases of Inquiry*, provides students with knowledge of investigative work that spans different core subjects (Republic of Estonia Ministry of Education and Research, 2014).

Over the last five years, a number of Canadian provincial jurisdictions of education, including Alberta (Alberta Education, 2013), Ontario (Ontario Ministry of Education, 2013), and British Columbia (British Columbia Ministry of Education, 2013), have introduced policy reforms calling for the organization of education around processes associated with inquiry. This can be seen in Alberta within the Ministry of Education's *Ministerial Order on Student Learning* (2013), which called for a vision of education that will help young people "think critically and creatively, and make discoveries through inquiry, reflection, exploration, experimentation, and trial and error" (p. 1). In a similar vein, British Colombia's *Defining Cross-Curricular Competencies* (2013) document seeks to promote critical thinkers who are "inquisitive, aware of biases, flexible, honest, persistent, willing to reconsider, and focused on inquiry and asking questions" (p. 6). This direction for education has, however, been met with strong resistance by a number of high-profile commentators in both traditional media outlets and educational blogs (e.g., Ashman, 2017; Staples, 2014; Wente, 2013; Zwaagstra, 2017). Drawing on empirical support from the research literature (Hattie, 2009; Hattie & Yates, 2014; OECD, 2016b), these critics argue that shifts towards inquiry-based approaches to education are highly misguided. Accordingly, they have called for a return to traditional forms of education marked by teacher-directed orientations to instruction.

By locating this debate within a wider historical context, this article examines the various claims that critics of inquiry-based approaches to education have made in relation to the research literature. Employing key insights from the learning sciences (Davis, Sumara, & Luce-Kapler, 2000, 2008, 2015; Sawyer, 2014), we demonstrate that these criticisms create unhelpful dichotomies that fail to engage with a large body of research that clearly shows that guided inquiry (Furtak, Seidel, Iverson, & Briggs, 2012; Hmelo-Silver, Duncan, & Chinn, 2007), as well as approaches to inquiry aligned with the authentic education movement (Friesen, 2009; Newmann, Bryk, & Nagaoka, 2001; School of Education, The University of Queensland [SEUQ], 2001) promote higher-order thinking skills, in-depth conceptual understanding, and enhanced problem-solving abilities. These approaches differ from discovery learning, which is marked by minimal student guidance and teacher instruction (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011; Kirschner, Sweller, & Clark, 2006). In the discussion section, we highlight more productive ways for understanding inquiry where key instructional supports are present including ongoing formative feedback loops, as well as having students self-explain and justify their reasoning (Sawyer, 2014, p. 35).

Challenges to Traditional Approaches to Education

Before beginning a discussion around the nature and value of inquiry, it is helpful to locate such debates within a wider historical context. The origins of the word 'inquiry' can be traced back to the 13th century Latin word *inquīrere*, which literally means "to seek for" (Online Etymology Dictionary, n. d.). In the modern era, inquiry approaches to education found a home in the work of John Dewey in the early part of the 20th century. Dewey, a key leader in the progressive movement in education, was critical of transmission-based approaches to teaching that positioned students as passive receptors of static and inert knowledge. In place of such approaches, Dewey encouraged educators to adopt inquiry as the primary teaching strategy in their classrooms. Modeled on the scientific method, the particular process of inquiry Dewey

(1910) advocated involved “sensing perplexing situations, clarifying the problem, formulating a tentative hypothesis, testing the hypothesis, revising with rigorous tests, and acting on the solution” (as cited in Barrow, 2006, p. 266). This notion of inquiry was further reflected by Schwab (1958), who saw inquiry as "a process of problem-detecting, formulating, and solving," rather than "the study of a history or a justification of a current theory" (p. 378).

Although this pioneering work in inquiry was realized in some experimental schools and in exemplary classrooms, education organized around this vision ran counter to prevailing systemic views about teaching and learning that emerged with the introduction of universal schooling in the early part of the 20th century (Davis et al., 2015; Friesen & Jardine, 2009; Sawyer, 2014). In designing a system of education that sought to provide young people with the basic skills and knowledge needed to work in industrial enterprises or highly stratified bureaucratic organizations, educational policy makers sought to standardize all parts of the schooling process. Inspired by a factory model of production, this included curriculum outcomes and materials, as well as approaches to pedagogy and assessment (Davis et al., 2015, p. 65). Within this standardized model of education, learning was generally understood as a linear process of either getting a pre-given body of content into the students’ heads, or breaking down any complex task into “those not-further-divisible ‘bits’ out of which any knowledge was assembled” (Friesen & Jardine, 2009, p. 12). Accordingly, the job of the teacher involved transmitting a static body of content and procedures to students, while success was generally determined by written tests that measured the degree to which students had acquired these basic facts and procedures (Sawyer, 2014, p. 2).

Recent developments, however, have led policymakers to move away from this way of understanding and organizing education. Research demonstrates that contemporary schooling contexts founded on the principles of standardized education possess endemically low levels of student engagement (Gallup, 2016; Willms, Friesen, & Milton, 2009). In a study launched in 2007 surveying more than 32,322 students in schools across Canada, researchers found that poor levels of “engagement,” defined as “a serious emotional and cognitive investment in learning,” were a pervasive problem in educational jurisdictions across the country (Willms et al., 2009, p. 7). This was apparent particularly at the high school level, and more so for boys than girls. In language arts and math, for instance, levels of intellectual engagement in grade 6 averaged close to 60% for girls and 55% for boys, but by grade 10 had dropped to less than 35% and 30% respectively (Willms et al., 2009, p. 19). This same study found that the percentage of students with regular attendance in grade 6 was close to 90%, but dropped to an average of 40% in grade 12 (Willms et al., 2009, p. 18).[1]

Another key reason policy makers are initiating shifts away from standardized approaches to education concerns substantial empirical evidence that many students who have advanced to the high school or post-secondary level are often unable to interpret or explain a phenomenon with which they are not familiar through the lens of a concept or process they have already studied (Gardner, 2008, p. 21). For example, when students, including those at the post-secondary level, are asked to respond to questions in science that require synthesis or application, research suggests that most students are unable to reason using the scientific principles they have studied, and instead rely on informal reasoning drawn from personal experience (Hartley, Wilke, Schramm, D’Avanzo, & Anderson, 2011). Gardner (2008) claimed that the same phenomenon occurs in the area of social studies where students who have studied the complex causes of past events revert to simplistic and singular causal factors when asked to make sense of contemporary events, such as the ongoing civil war in Syria or recent acts of terrorism (p. 22).

These assertions have led educators and policy makers to conclude that traditional forms of education lead to a kind of surface learning that allows students to pass a test, but not to gain the deeper subject area understandings that students will need to successfully meet the myriad challenges and opportunities of a rapidly changing world.

In this regard, recent curricular shifts reflect a belief that the kind of education needed to prepare young people for an industrial economy is inadequate in the knowledge-based economies taking shape in OECD member countries (Darling-Hammond, 2008; Gardner, 2008; OECD, 2005; Sawyer, 2014; Wagner, 2012). Noting the ongoing erosion of the middle class due to the decline of traditional industries, Wagner (2012) argued that there is general agreement among policy leaders that the long term health of economies will be based on fostering a greater amount of innovation because “new or improved ideas, products, and services create wealth and new jobs” (p. x). Along these lines, Darling-Hammond (2008) noted that low-skill, manual labour made up 95% of all jobs in the early part of the 20th century; however, in the early part of the 21st century these jobs made up only 10% of the U.S. economy (p. 1).

While the jobs of the industrial era required the ability to follow straightforward procedures designed by external authorities, as Darling-Hammond (2008) further outlined, new economic realities have created jobs that necessitate more developed skills including the ability to “research ideas; collect, synthesize, and analyze information; develop new products; [and] apply many bodies of knowledge to novel problems that arise” (p. 1). Educational scholars making this argument have additionally asserted that such competencies, moreover, are necessary for young people to participate meaningfully as active citizens in their democracy (Gardner, 2008; King, Newmann & Carmichael, 2009). Specifically, the kind of decision making needed for a democracy to sustain itself requires "interpretation, evaluation, in-depth understanding, and elaborated communication that extends well beyond traditional tests of knowledge" (King et al., 2009, p. 49).

Examining Criticisms of Inquiry-Based Approaches to Education

These, and other arguments, have led policy makers to initiate curriculum reforms away from traditional approaches to education that emphasize memorization and recall or the application of simple algorithms (Barron & Darling-Hammond, 2008, p. 12). However, in the Canadian context, there has been substantive opposition within the popular media to curricular shifts away from the traditional model of education (Staples, 2014; Wente, 2013; Zwaagstra, 2017). In an editorial in the *Globe and Mail* referring to math education, Wente (2013) argued that school systems across Canada "have discarded ‘rote’ learning in favour of ‘discovery,’ a process by which students are supposed to come up with their own solutions to the mysteries of arithmetic" (para. 2). She concluded that such processes should be abandoned as soon as possible as they have left "millions of kids (to say nothing of their parents) baffled and confused" (para. 2). In a recent editorial in the *Calgary Herald*, Zwaagstra (2017) argued that the shift away from teacher-directed instruction to various forms of inquiry and project-based learning with a focus on “the process of learning and not on the content” (para. 9) will lead to a situation where “Alberta’s world-renowned education system will continue to decline" (Zwaagstra, 2017, para. 15).

Drawing on research by Hattie and Yates (2014), Staples (2014) similarly argued that "explicit instruction and diligent practice that leads to automatic recall of basic facts is a prerequisite to young learners being able to make connections and see relationships in a subject area" (para. 19). Staples concluded that calls by Alberta Education to foster curricular shifts towards processes of inquiry and discovery are deeply "out-of-step with modern cognitive science and best practices in teaching" (para. 20). Within the U.S. context, the popular blog Intellectual Mathematics (2016) highlighted a recent OECD study that found students across all 56 countries and economies who reported learning in environments with greater amounts of "enquiry", marked by designing and doing practical experiments, had lower scores on the science component of the PISA test (OECD, 2016b, p. 69). Accordingly, the blog suggests that "teacher-directed instruction is associated with success even more than the school's socio-economic profile, while enquiry-based learning is a surer way to fail than skipping class" (Intellectual Mathematics, 2016, para. 1).

Taken as a whole, these assertions have worked to create a negative public perception of inquiry and therefore, threaten recent curricular shifts towards inquiry-based learning. Accordingly, there is a need to examine these various arguments in relation to the research literature. However, it is first necessary to appreciate that a myriad of conceptual models and approaches falling under the banner of inquiry-based learning have been advanced in the field of education. The most well-researched approaches include discovery learning, guided inquiry, and approaches to inquiry that have grown out of the authentic education movement. As we will show, each of these models offers differing understandings and philosophies around what it means to engage students in inquiry, and moreover, each has been shown to possess varying educational affordances and constraints.

Discovery Learning

Many public commentators who argue for a return to traditional models of education are drawing on an understanding of inquiry that reflects the pedagogical commitments of discovery learning (Alfieri et al., 2011; Kang & Keinonen, 2017; Kirschner et al., 2006; Klahr & Nigam, 2004). This approach to teaching can be traced back to Bruner's (1961) paper *The Act of Discovery*, which claimed, "for whether one speaks to mathematicians or physicists or historians, one encounters repeatedly an expression of faith in the powerful effects that come from permitting the student together for himself, to be his own discoverer" (p. 22). While contemporary definitions of discovery-based learning are contested within the literature (Klahr & Nigam, 2004), reflecting Bruner's thinking around the need for learner autonomy, discovery learning is said to occur whenever a "learner is not provided with the target information or conceptual understanding and must find it independently and with only the provided materials" (Alfieri et al., 2011, p. 4). Accordingly, discovery learning arises when students are not presented with key principles or information, and must discover them on their own through a largely self-directed process (Kirschner et al., 2006).

There is considerable empirical evidence that discovery learning has limited educational value when compared to direct instruction where the concepts and procedures students are expected to learn are fully laid out and explained to them (Barron et al., 1998; Darling-Hammond, 2008; Hattie, 2009; Kirschner et al., 2006; Klahr & Nigam, 2004; Lamon et al., 1996; Mayer, 2004). As Kirschner et al. (2006) argued, a "number of reviews of empirical studies have established a solid research-based case against the use of instruction with minimal guidance" (p. 79). For example, in a study of 112 third- and fourth-grade students, Klahr and Nigam (2004) compared the effectiveness of each approach within the context of a science experiment where students sought to determine how different variables, such as length and steepness, affected the distance that balls rolled down a ramp. The researchers found that 77% of the direct-instruction students achieved proficiency (mastery) of key scientific principles, as compared to only 23% of the discovery-based students. Further, the direct instruction group was able to make broader and richer scientific judgments compared to students who experimented on their own.

Along these same lines, an examination of the 2006 PISA results in science by Kang and Keinonen (2017) found that open inquiry-based learning involving limited teacher guidance or direct instruction was a strong negative predictor of students' achievement. This finding was supported by earlier studies that found students did not gain deep insights into principles related to engineering simply by being given the opportunity to build a bridge or tower (Roth, 2006). Similarly students did not apprehend principles of flight through participating in an activity that asked them to build a rocket (Lamon et al., 1996). In a review of the research on discovery learning, Mayer (2004) analyzed three distinct bodies of literature from the 1960s, 1970s, and 1980s respectively, and found that unstructured inquiry was less educationally effective than approaches to teaching that included significant teacher guidance and direct instruction.

Guided Approaches to Inquiry

Discovery learning can be distinguished from guided or process-based approaches to inquiry that have a strong antecedent in the pioneering work of Dewey. Seeking to identify modes of thinking related to the ways scientific knowledge is created, the particular process of inquiry Dewey initially promoted involved identifying and clarifying perplexing problems, and generating initial hypotheses, which are then tested and revised (Barrow, 2006, p. 266). More recent manifestations of guided inquiry, which have received significant attention in the research, include problem-based learning (Hmelo-Silver, 2004; Lu, Bridges, & Hmelo-Silver, 2014; Savery, 2006), project-based learning (Krajcik & Shin, 2014; Marx et al., 2004; Reiser & Tabak, 2014), and the Biological Science Curriculum Study [BSCS] 5E Instructional Model (Akar, 2005; Boddy, Watson, & Aubusson, 2003; Bybee et al., 2006; Coulson, 2002).

Although these models are distinct, as a group they can be distinguished from discovery learning in that they do not involve an unstructured process whereby students must learn key processes or insights on their own. They can be equally distinguished from rigidly linear approaches to inquiry that do not reflect how "aspects of inquiry interact in complex ways" (Cuevas, Lee, Hart, & Deaktor, 2005, p. 341). Accordingly, within these modes of inquiry, the paths teachers take to address particular problems or tasks can involve different routes or methods, all of which could lead to different outcomes that are equally credible (Firestein, 2016; Hodson, 1998; Hofstein & Lunetta, 2003).

Originating out of Barrows and Tamblyn's (1980) work in the medical field, problem-based learning seeks to help students collaborate with their peers to address open-ended, complex and ill-structured problems that are realistic and resonant with students' experiences. According to Barron and Darling-Hammond (2008), problem-based learning involves a teacher-facilitated process where students are exploring "meaningful problems, identifying what they need to know in order to solve the problem, and coming up with strategies for solutions" (p. 43). In this way problem-based learning provides opportunities for students to draw on shared knowledge, gained through dialogue with their peers, towards the creation of viable hypotheses that they must back up and justify through credible arguments.

Overall, studies show that problem-based learning leads to many positive educational outcomes. Research has found that it can greatly improve students' problem-solving abilities in ways in which they gain skills in reasoning and the construction of flexible and transferable knowledge (Gallagher, Stepien, & Rosenthal, 1992; Hmelo-Silver, 2004; Walker & Leary, 2009). Problem-based learning has also been found to promote critical thinking more generally (Shepherd, 1998). As well as reduced anxiety and more positive attitudes towards learning within particular subject domains (Boaler, 1997; Cognition and Technology Group, 1992), research suggests that problem-based learning promotes a deeper understanding of key disciplinary concepts and processes (Barron & Darling-Hammond, 2008; Dochy, Segers, Van den Bossche, & Gijbels, 2003; Hmelo, 1998; Williams, Hemstreet, Liu, & Smith, 1998). A number of studies have also concluded that employing this approach can increase scores on standardized tests of disciplinary knowledge (Barron et al., 1998; Cognition and Technology Group, 1992).

For example, Hmelo (1998) examined the affordances of problem-based learning versus traditional forms of learning and found that students who engaged with problem-based learning were better able to transfer knowledge to new problems and had a deeper understanding of key processes, including generating more accurate hypotheses and more coherent explanations. These findings were partially supported by a meta-analysis of 43 peer-reviewed empirical studies about problem-based learning undertaken by Dochy et al. (2003). Although the research varied in terms of the effectiveness of students' understanding of key disciplinary concepts, Dochy and colleagues concluded that students who learned in problem-based learning environments gained greater problem solving skills, as well as abilities, to show interconnections among differing concepts.

Another well-researched approach to guided inquiry is project-based learning, which focuses on the creation of a presentation or a product that is usually presented to an audience outside the classroom. This could include the creation of an original play, a video, or an aquarium design judged by local architects (Barron & Darling-Hammond, 2008, p. 40). According to Thomas (2000), project-based learning specifically engages:

> complex tasks, based on challenging questions or problems, that involve students in design, problem-solving, decision making, or investigative activities; give students the opportunity to work relatively autonomously over extended periods of time; and culminate in realistic products or presentations. (p. 1)

In his review of the research on project-based learning, Thomas (2000) found students reported higher levels of engagement when learning within a project-based environment (p. 19).

A number of studies have additionally examined the impact of project-based approaches on student learning (Boaler, 1997; Krajcik & Shin, 2014; Marx et al., 2004; New American Schools Development Corporation [NASDC], 1997; Reiser & Tabak, 2014; Shepherd, 1998). Conforming to the four criteria outlined by Thomas (2000), studies have found an approach called *expeditionary learning* (EL) promoted student achievement (NASDC, 1997). As outlined in a report by the NASDC (1997), the longitudinal study conducted in 45 low-performing schools in 12 U.S. states, found that school reform oriented around EL resulted in significant increases in standardized test scores reflecting academic achievement. For example, in a school in Portland, Maine that adopted this approach, students averaged a 59-point increase in their state test scores in key curricular areas, including math and reading, "compared to a statewide average gain of only 15 points" (p. 22).

In another study examining grades 4 and 5 students working on a nine-week project to define and find solutions related to housing shortages, Shepherd (1998) found that students in a class focused on project-learning scored significantly higher on a critical-thinking test in comparison to a control group who did not take part in the inquiry project. The project-learning students also demonstrated greater confidence in their learning. Boaler's (1997) longitudinal study in the U.K. examined two schools with similar achievement and income levels and found similar gains in learning on basic mathematics procedures. However, a greater number of students from the school that employed project-based learning passed the National Exam in year three and developed more flexible mathematical knowledge than in the traditional school.

An additional approach to inquiry that has been well researched is the BSCS 5E Instructional Model (Akar, 2005; Boddy et al., 2003; Bybee et al., 2006; Coulson, 2002), which has been adapted for use in social studies (Prokes, 2009), as well as other STEM disciplines (e.g., Walters, 2004). Offering a means to promote active, inquiry-based learning, students within this model work through a series of five key stages involving engagement, exploration, explanation, elaboration, and evaluation (Bybee et al., 2006). As part of this process, learners are prompted to first engage in questions that might involve, for example, what mature plants or animals would have looked like when they were younger (Bybee et al., 2006, p. 53). With the teacher providing guidance and feedback throughout, students are subsequently invited to conduct a preliminary exploration of the question through activities that will help them draw on prior knowledge to come up with new ideas and questions. In working through the explanation phase where teachers can directly introduce particular concepts, processes, and skills, students are able to elaborate on their understandings by applying their knowledge and evaluating their responses.

Studies about the effectiveness of the 5E model show positive results relating to improved understanding of disciplinary concepts (Abdi, 2014; Coulson, 2002), scientific reasoning (Boddy et al., 2003), and a greater interest and attitude towards learning science (Akar, 2005; Tinnin, 2000). For example, Abdi (2014) analyzed the academic achievement of 40 fifth-grade students in a science course by comparing students taught with the traditional method (control group) and students taught with the 5E learning cycle (experimental group). Drawing on the results of pre- and post-tests, students scored higher with inquiry-based learning instruction. Similarly, Scott, Schroeder, Tolson, Huang, and Williams' (2014) longitudinal study of science test results in a Texas school division showed promising results for the 5E model, particularly in reducing the achievement gap for African American, Hispanic, and low-SES students. Scott and colleagues (2014) emphasized how the 5E approach may be reflective of numerous best practices in science (Schroeder, Scott, Tolson, Huang, & Lee, 2007). However, as elaborated upon in the discussion section below, various studies emphasize the need for teacher training and support in using the 5E model, along with fidelity to the 5E process, in order to obtain these results (Bybee et al., 2006; Coulson, 2002; Scott et al., 2014).

Authentic Education

Distinct from guided approaches to inquiry, authentic education came to prominence when researchers became more attentive to the complexities of human cognition, along with the ways that professionals in particular disciplines produce knowledge. According to Davis and colleagues (2015), authentic education involves approaches that "are based on reality, focused on understanding, and rich with inquiry" (p. 63). Within this way of thinking, in contrast to guided approaches to inquiry, authentic education is not a "method" of doing science, history, or math in a fixed, linear sequence (Wells, 2001), nor is it reflective of the commitments of discovery learning involving an unguided and unstructured process. Rather, it is an attempt to connect students to questions, problems, or issues that exist in the community and the world beyond the school, which promote opportunities for students to "learn their way around a discipline" (Bransford, Brown & Cocking, 2000, p. 139).

Approaches to inquiry reflecting this understanding include the Galileo Educational Network Association's (GENA) notion of discipline-based inquiry (Friesen, 2009; GENA, 2016), Newmann and associates' formulation of authentic intellectual work (King et al., 2009; Newmann, Bryk, & Nagaoka, 2001), as well as Perkins' (2009) concept of playing the whole game where students have opportunities to experience junior versions of how knowledge is created and communicated within specific disciplines (p. 25). This conceptual understanding of inquiry was apparent in a grade 5 investigation into how water could be desalinated and purified after it had been contaminated due to a tsunami (Clifford & Marinucci, 2008), as well as a grade 8 exploration that asked students to consider whether conditions that led to the Italian Renaissance were present in the city where the students resided (Scott & Abbott, 2012).

The efficacy of approaches to inquiry understood within the frame of authentic forms of education is supported by a number of large-scale empirical studies in the U.S. (Newmann, Marks, & Gamoran, 1996; Newmann et al., 2001; Smith, Lee, & Newmann, 2001), which were later replicated in Australia (Department of Education, Training and the Arts [DETA] 2004; SEUQ, 2001). Confirming findings from an earlier study (Newmann et al. 1996), Newmann and colleagues (2001) examined both "typical" and "challenging" assignments given to more than 5,000 students in grades 3, 6, and 8 in 49 schools in the Chicago area. Elaborating on the concept of authentic pedagogy from their first study, Newmann and colleagues (2001) found that students who undertook assignments reflecting high levels of "authentic intellectual work" (p. 14) achieved greater than average gains in reading and mathematics on the Iowa Test of Basic Skills. The study team defined authentic intellectual work as the:

> original application of knowledge and skills, rather than just routine use of facts and procedures. It also entails disciplined inquiry into the details of a particular problem and results in a product or presentation that has meaning or value beyond success in school. (Newmann et al., 2001, p. 14)

Of note, students in more disadvantaged neighborhoods accrued the same benefits from this approach, as compared to their counterparts in more affluent neighborhoods. These findings were later confirmed in Queensland, Australia (DETA, 2004; SEUQ, 2001). An examination of 975 classes from 24 schools over three years, found that improvements in student academic and social outcomes are strongly related to higher levels of what the report termed productive pedagogies and productive assessments, which were "derived from Newmann's construct of authentic pedagogy" (SEUQ, 2001, p. 4). Similarly, studies examining the Queensland 'New Basics' curriculum reforms found that more complex, intellectually demanding, and authentic tasks led to greater depth and rigour in student work (DETA, 2004).

These findings mirror results from the Canadian context where over the course of a three-year study, Friesen (2009) and her team examined 26 Alberta elementary and secondary schools with 12,800 students to determine the effects of discipline-based inquiry on student achievement and academic performance. Within this study, inquiry was understood to involve a number of characteristics including classroom engagements where students: a) took up questions, problems, issues that were significant to the disciplines and connected students to the world beyond the school; b) created products or work that contributed to the building of new knowledge; and c) were moreover afforded opportunities for ongoing formative assessment loops on works in progress (GENA, 2016). Results from the study demonstrated that the aggregate achievement scores on the provincial achievement tests of students in schools designated as 'high-inquiry' were higher than both the provincial average and those within the school district.

Discussion

From this vantage point, it is now possible to examine the various criticisms of inquiry-based education made by popular commentators, including the arguments that the minimally guided nature of inquiry-based learning leads to the creation of a learning environment where students fail to acquire key subject matter concepts and processes (Staples, 2014; Wente, 2013; Zwaagstra (2017). As described in the review of theory and research in the field, the argument against curricular shifts towards inquiry reflect the limitations of discovery learning. Insights from the learning sciences suggest that one of the key reasons why discovery learning is so ineffective is the underlying assumption that learner-centered pedagogies should be synonymous with learner-directed approaches where students "are expected to rediscover insights that took humanity millennia to develop" (Davis et al., 2015, p. 109). As critics of this assumption point out, students are unlikely to gain insights into particular "procedural heuristics" (Hattie & Yates, 2014, p. 77), such as the scientific method, or in the case of history, how to critique a source document, when the teacher does not teach these explicitly.

The problem with using this argument to dismiss inquiry altogether, however, parallels Hmelo-Silver and colleague's (2007) criticism of how Kirschner and collaborators' (2006) critique of inquiry "indiscriminately lumped together several distinct pedagogical approaches—constructivist, discovery, problem-based, experiential, and inquiry-based—under the category of minimally guided instruction" (p. 99). As our review of the research demonstrated, while discovery-based approaches have limited educational efficacy, both guided approaches to inquiry and approaches to inquiry growing out of the authentic education movement have been shown to possess significant educational affordances. In this regard, Sawyer (2014) argues that recent advances in the learning sciences (Furtak et al., 2012; Hmelo-Silver et al., 2007; Wilke & Straits, 2005) demonstrate that inquiry is most effective when students "repeatedly generate and articulate their knowledge, ask deep questions, self-explain, and justify their reasoning" (p. 35). Following this learner-centered approach, the teacher is able to maintain enabling parameters in ways that increase student voice and agency within an environment marked by dialogue and the co-construction of knowledge.

Seen in this light, arguments by Wente (2013) and Zwaagstra (2017), along with like-minded critics, create a false and unproductive dichotomy between direct instruction and approaches to inquiry distinct from discovery learning, which see direct instruction as one strategy among a range of pedagogical interventions within a larger learning sequence (Krajcik, Czerniak, & Berger, 1999). In this way, guided approaches to inquiry and approaches that reflect the commitments of the authentic education movement do not stand in opposition to direct instruction, but rather seek to extend traditional approaches to education in ways "that might support deeper understandings and more engaged learning" (Davis et al., 2015, p. 98).

In seeking to achieve this aim, Clifford and Marinucci (2008) highlighted the need for teachers to avoid privileging the questions and interests of students simply because they come from the students themselves, as this “can quickly degenerate into sentimental practice that shies away from thorny conversations about whether mistakes are being made or misconceptions overlooked” (p. 683). This insight can be seen within the domain of history and social studies education (Breakstone, Smith, & Wineburg, 2013; Körber and Meyer-Hamme, 2015; VanSledright, 2015). Based on extensive research, VanSledright (2015) asserted, for example, that learning how to do history in ways that achieve powerful and deep understandings requires explicit instruction in discipline-specific practices such as "resisting the temptation to judge the past by personal, present-day sociocultural standards" (p. 40). Gaining insights like this will not occur for students through a completely unstructured and unguided classroom environment. Rather, there is a need for tasks and classroom activities—which could include short lectures—that help students overcome intuitive, but unhelpful, common-sense understandings that would allow them to think about and engage in the study of the past differently than they might do on their own.

This point highlights a second false dichotomy evident within Zwaagstra's (2017) assertion that because inquiry approaches to teaching and learning focus on the process of learning and not the content, students fail to gain foundational skills and knowledge. In fact, guided approaches to inquiry, along with approaches to inquiry that have grown out of the authentic education movement, provide a way to design student assignments and assessments where students must move beyond memorizing information and algorithms, towards demonstrating deep understanding of key insights, concepts, and processes by applying them within new and unfamiliar contexts (Koh & Luke, 2009). The need for such an approach is supported by a significant body of research, which has demonstrated that students who had opportunities to engage in more intellectually challenging performances of understanding did better on standardized tests as compared to students who learned primarily through lecture-based classrooms (e.g., Friesen, 2009; King et al., 2009; Newmann et al., 2001). Summarizing this body of literature, Koh and Luke (2009) asserted that "there was a strong relationship between the quality of teacher assignments and student work; that is, teachers who assigned more intellectually demanding tasks were more likely to get authentic intellectual work from students" (p. 293).

The theory of learning that can explain these findings was well articulated by Whitehead (1929/1967), who argued that the primary purpose of education was to prevent knowledge from becoming inert, which he saw as “ideas that are merely received into the mind without being utilized, or tested, or thrown into fresh combination” (p. 5). This view of learning is supported by recent insights from the learning sciences, which contend that long-term changes in neuronal structures and brain activity can occur only when people are actively adapting and testing ideas, concepts, and processes within new contexts (Davis et al., 2008, 2015; OECD, 2007; Sawyer, 2014). Accordingly, the repetition of predictable activities or the memorization of facts without opportunities to apply this learning in new and unfamiliar situations—all hallmarks of traditional approaches to education—actually work to diminish capacities for more sophisticated, flexible, and creative action (Davis, Sumara, & Luce-Kapler, 2000, p. 75).

Given the weight of this well-established body of research, questions remain around why a number of large-scale studies cited by popular critics of inquiry (Ashman, 2017; Intellectual Mathematics, 2016; Staples, 2014) have found inquiry-based approaches to have limited educational value. Staples (2014), for instance, used the work of Hattie and Yates (2014) to support his claims. An examination of this source, however, revealed that these scholars did not actually speak directly to the efficacy of inquiry. However, Hattie (2009) has been critical of inquiry in the past, which he defined as follows:

> Inquiry based teaching is the art of developing challenging situations in which students are asked to observe and question phenomena; pose explanations of what they observe; devise and conduct experiments in which data are collected to support or contradict their theories; analyze data; draw conclusions from experimental data; design and build models; or any combination of these. (p. 208)

In a synthesis of two ‘inquiry-based teaching’ meta-analyses, Hattie (2009) found that inquiry-based teaching "was shown to produce transferable critical thinking skills as well as significant domain benefits, improved achievement, and improved attitude towards the subject" (p. 210). However, he concluded that inquiry-based teaching had a very small effect size (d=0.31) on student learning as compared to other influences. Specifically, when Hattie (2009) ranked the 138 influences related to achievement, an inquiry-based approach to teaching was ranked 86 th (p. 209). He concluded that the effects of this approach were far less significant than other influences when it came to student comprehension of content.

There are a number of shortcomings, however, in Hattie's (2009) meta-analysis. The majority of studies used in his work were conducted in the 1980s and early 1990s. This older body of research from science education did not involve the contemporary research literature engaged in this paper (e.g., Furtak et al., 2012; Sawyer, 2014). Further, the definition of inquiry, the aspects that are examined in the study, and the way in which inquiry is evaluated has important ramifications for determining its value. Notably, Hattie's (2009) definition of inquiry reflects a linear approach, in which students are rarely given an opportunity to learn from their errors due to time limitations and fears of getting the wrong answer (Hodson, 1998; Hofstein & Lunetta, 2003). In contrast, recent research related to iterative and recursive approaches to inquiry has shown that such processes produce a positive effect on student learning because students have a chance to revisit and learn from their mistakes (Furtak et al., 2012; Scott et al., 2014). A recent meta-analysis of guided inquiry-based approaches to science that examined more recent studies than that of Hattie (2009), for instance, found higher effect sizes for inquiry-based approaches that involved teacher-led activities (Furtak et al., 2012). As Furtak and colleagues noted, “engaging students in guided inquiry contexts does lead to learning gains when contrasted with comparison groups featuring traditional lessons or unstructured student-led activities” (p. 324).

Issues related to how inquiry is defined and conceptualized is an ongoing problem in the research literature. For example, Piagetian tasks, which build on developmentally-appropriate, connected challenges, and emphasize the need for students to employ higher-order thinking skills, were ranked as the second most impactful of all approaches in Hattie's (2009, p. 43) study. However, Piagetian tasks were presented as distinct from inquiry in Hattie’s (2009) study. This, despite the strong affinities between Piagetian tasks and many guided approaches to inquiry, as well as Newmann and colleague’s (2001) notion of authentic intellectual work. Issues around the way inquiry is defined was additionally apparent within Hattie’s (2009) examination of problem-based learning (pp. 210-214), which notably received a low effect size in his meta-analysis. However, as Boss (2014) noted, pedagogical processes strongly associated with robust and well-designed problem-based curricular engagements, such as ongoing formative feedback, as well as valuing error, all received rankings by Hattie (2009) in the 'desired effects' zone (para.

6).

This insight highlights a need to better appreciate the key instructional supports that need to be in place for inquiry to lead to positive educational outcomes. Along with ongoing formative feedback loops and valuing mistakes as a necessary part of the learning process, the research shows that students need opportunities to develop adequate content and procedural knowledge before beginning more open and self-directed inquiries (Alake-Tuenter, Biemans, Tobi, Wals, & Mulder, 2012; Bell, Smetana, & Binns, 2005). In this regard, research has found that introducing and explicitly teaching particular "procedural heuristics" (Hattie & Yates, 2014, p. 77) commonly used in the disciplinary fields of inquiry, enable students to more productively engage in processes of inquiry (Hmelo-Silver et al., 2007).

However, within guided approaches to inquiry, in contrast to traditional approaches to education, explicit instruction of disciplinary concepts often occur later in the inquiry process, rather than at the beginning. Within the BSCS 5E Instructional Model (Akar, 2005; Boddy et al., 2003; Bybee et al., 2006; Coulson, 2002), for instance, explicit instruction of procedural heuristics are introduced during the third explanation stage in ways that make direct connections “to experiences in the engagement and exploration phases” (Bybee et al., 2006, p. 9). Coulson’s (2002) study found that teachers who followed this sequencing in their practice, saw their students achieve greater learning gains than students whose teachers did not show the same fidelity to the 5E process. When examining the efficacy of inquiry-based approaches, such findings reinforce the need to consider not only the instructional supports in place during the inquiry process, but also when and how they are introduced.

Critics of inquiry-based approaches to education (Ashman, 2017; Intellectual Mathematics, 2016) have additionally drawn on findings from a recent PISA report (OECD, 2016b) that found "enquiry" education had limited educational value. To come to this conclusion, teachers and students were asked how frequently (i.e., “never or hardly ever”, “in some lessons”, “in most lessons” and “all lessons”) students were, for example, "given opportunities to explain their ideas … spend time in the laboratory doing practical experiments … required to argue about science questions … [and] allowed to design science experiments” (OECD, 2016b, p. 69). After accounting for differences in socio-economic profiles between schools, the study concluded that:

> greater exposure to enquiry-based instruction is negatively associated with science performance in 56 countries and economies. Perhaps surprisingly, in no education system do students who reported that they are frequently exposed to enquiry-based instruction score higher in science. (OECD, 2016b, p. 71)

Given these findings, the study also concluded that more frequent enquiry-based teaching was linked to stronger epistemic beliefs about science, as well as a greater likelihood that students would go on to work in science-related occupations.

This report contrasted with Kang and Keinonen’s (2017) examination of the 2006 PISA data, which found that while students engaging in open inquiry was "a strong negative predictor of students’ performance and insignificant effect on their interest, guided inquiry-based learning was indicated as a strong positive predictor of students’ performance, and its positive effect on interest was also statistically significant” (p. 16). The difference in findings between these examinations of different iterations of the PISA data suggests there is a need, once again, to better appreciate how inquiry is being interpreted by the students and teachers in these studies, as well as the pedagogical practices and instructional supports that may or may not have been in place within these classrooms.

In this regard, the study's definition of "enquiry" as emphasizing the need to learn in meaningful contexts, engage in scientific argumentation, and draw data-informed conclusions (OECD, 2016b, p. 69) could have been understood by the teachers and students in a variety of ways. This is true, for example, in relation to the question about the extent to which "students spend time in the laboratory doing practical experiments" (OECD 2016b, p. 152). On one hand, this could be associated with doing textbook-based laboratories where students work through a step-by-step linear process towards arriving at a single correct answer. While many teachers and students might have reported this experience as doing inquiry, researchers have argued that laboratories in classroom settings following this model only mimic inquiry-based processes in superficial ways (Hodson, 1998; Hofstein & Lunetta, 2003).

Teachers and students reporting that they are often involved in doing practical experiments could have equally understood this to mean exploring a meaningful problem within a learning environment in which students may approach and investigate the problem using many methods. Noting that research suggests that students need significant supports to better understand key scientific inquiry procedures (Hodson, 1996, p. 132), this learning environment could additionally involve scaffolding in processes such as "hypothesizing or defining dependent, independent, and confounding variables" (Kang & Keinonen, 2017, p. 16). These two interpretations about how "enquiry" can be understood demonstrates that teachers and students may self-report a high frequency of doing practical experiments, but the inquiry-based instruction that is experienced would be qualitatively different. Before the results of the PISA study (OECD, 2016b) can be used as the basis of an argument that inquiry has little educational value, there is a need to better understand and verify how teachers were engaging in inquiry with their students in the science classrooms under examination. This verification would move beyond student and teacher self-reporting, and include third-party confirmation.

Conclusion

An established body of research demonstrates that contemporary schooling contexts, which continue to reflect the principles of standardized education, have created learning environments that have not only led to pervasively low levels of intellectual engagement (Willms et al., 2009), but are also inadequate for the myriad challenges of the 21st century (Davis et al., 2015; Gardner, 2008; Sawyer, 2014). Noting the decline of traditional industries requiring limited levels of education, educational researchers have emphasized the need to better prepare young people to enter an economic landscape dominated by entrepreneurial and globally connected workplaces that will require a range of new competencies (Darling-Hammond, 2008; Wagner, 2012). This includes the ability to manage complexity, synthesize and analyze information, collaborate in teams, communicate effectively in a variety of mediums, and develop solutions to complex problems.

Seeking to develop student capacities in these areas, jurisdictions of education around the world, including in the Canadian educational context (Alberta Education, 2013; British Columbia Ministry of Education, 2013; Ontario Ministry of Education, 2013), have introduced curriculum documents emphasizing the need for teachers to engage their students in processes of inquiry. Our synthesis of the research literature has shown that ministries of education should maintain their commitment to these curricular shifts. However, it is clear that there is a greater need to help the public better understand the research basis that has informed this change in direction. In undertaking this work, it will be necessary to engage more vigorously with popular commentators that have leveled various critiques against curriculum reforms orientated around inquiry-based approaches to education.

When engaging critics, ministries of education should be explicit that they are not promoting discovery learning, where students receive limited guidance and instruction; they are adopting approaches to inquiry that have demonstrated significant educational affordances, including guided approaches to inquiry (Furtak et al., 2012; Hmelo-Silver et al., 2007), as well as approaches aligned with the authentic education movement (Galileo Educational Network Association, 2016; King et al., 2009). These conceptual frameworks, contrary to what critics of inquiry have claimed, do not stand in opposition to key elements of traditional forms of education, such as direct instruction. Rather, they seek to introduce authentic assessment practices (Koh & Luke, 2009), increase the quality of student assignments (Friesen, 2009; Newmann et al., 2001) and moreover, extend the range of instructional supports employed in the classroom. Research in the learning sciences has shown that teaching and learning sequences that possess such characteristics support deeper understanding and more intellectually engaging learning experiences for students (Davis et al., 2015; Sawyer, 2014).

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Notes

1 Over the course of this time, girls were five to nine percentage points more likely to attend school regularly compared to their male counterparts.

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