Supporting Inquiry Learning as a Practice: A Practice Perspective on the Challenges of IBL Design, Implementation and Research Methodology

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Abstract: Inquiry Based Learning (IBL) provides learners with an authentic learning challenge and valuable opportunities to improve their scientific domain knowledge, while expanding their repertoire of creative skills and attitudes. But mastering the "what", "why" and "how" of the cultural tools that science employs, and appropriating the structures and systems designed to enculturate them into communities of inquiry is no easy feat. Taking a practice perspective on IBL can illuminate some challenges that teachers, students and educational designers encounter, and may help researchers operationalize important variables, capturing the complexity of this learning practice. A new definition of IBL will be unpacked showing the added value of regarding it as a practice. This will inform the pedagogical design approach, but will also hold implications for methods of research. The feasibility of the ambition to enculturate learners into an authentic practice, providing them with transferrable skills, will be discussed.

Keywords: Inquiry Based Learning, practice, authentic, design, implementation

Introduction

Inquiry experiences can provide valuable opportunities for learners to improve their scientific domain knowledge and expand their repertoire of creative learning skills and attitudes (Saunders-Stewart, Gyles, & Shore, 2012). Mastering scientific inquiry means mastering the "what," "why," and "how" of the cultural tools that scientists employ (Lehrer and Palincsar, 2014). These tools (e.g. systematic ways of thinking, research instruments, and conventions like peer-review) are embedded within the activities through which scientists build their knowledge. When introducing Inquiry Based Learning (IBL) into the educational context, this represents considerable complexities and uncertainties for both teachers and learners. Still, IBL is increasingly valued and recognized as a powerful form of learning, fit for the 21st century (Hmelo-Silver, Duncan and Chinn, 2007).

According to Anderson's (2002) definition "Inquiry science is a hands-on constructivist approach to science education. Students address teachers' and students' questions about natural phenomena or events by conducting scientific investigations in which they collaboratively develop plans, collect and explain evidence, connect the explanations to existing scientific knowledge, and communicate and justify the explanations" (Anderson, 2002). This definition specifies some explicit activities that students and teachers engage in. Students conduct collaborative scientific investigations, that mimic to some degree the practices of actual scientists who are co-creating new knowledge. Through their collaborative activities they practice more systematic ways of thinking (applying e.g. critical thinking, analytic thinking and information literacy), learn to use instruments (computer/technical) and practice their collaboration and communication skills. Through engaging in inquiry practices, students can become aware of the process of producing, testing, and revising knowledge and the criteria of evaluating knowledge claims (Smith, Maclin, Houghton, & Hennessey, 2000).

Still, the implementation of IBL often runs into problems. The richness in social meanings, embedded in the practices of scientific communities of inquiry, may not be easily grasped in the context of schools, since activities in that context draw on implicit or explicit understandings of how learning takes place that are not in direct accordance, or are discontinuous with the epistemology underlying the practice of IBL. But in the 21st century we should be preparing students to engage in a multiplicity of communities, and help them be aware how learning can happen across contexts (e.g. Kim, Hung, Jamaludin & Lim, 2014). Consequently, both teachers and students need to learn to balance and manage the tensions that arise when 'stepping into' a different context of learning (see also Hung, Ng, Koh, & Lim, 2009).

But how do we best explain the difficulties that learners have in mastering and appropriating (Wertsch & Rozin, 1998) the cultural tools of science inquiry? How do we get learners engaged in this complex process? What kind of conceptual and technological tools can we apply? An often cited publication by Edelson, Gordin, & Pea (1999) lists several challenges of IBL and how they might be addressed through technology and curriculum design. These challenges (motivation, accessibility of investigation techniques, background knowledge & skills, and practical constraints in the learning context) are still prevalent today. The current paper problematizes the way in which these challenges are framed, and provides some thoughts towards explaining why students may not respond to pedagogical and technological IBL designs the way we anticipate. The aim is to introduce a relational epistemology of practice, and a new definition of IBL, which will help those involved (teachers, designers, researchers and learners) better understand and appropriate the structures and systems that are designed to help build their own communities of inquiry. Figure 1 provides an overview of the considerations which emanate from taking a practice perspective on IBL.

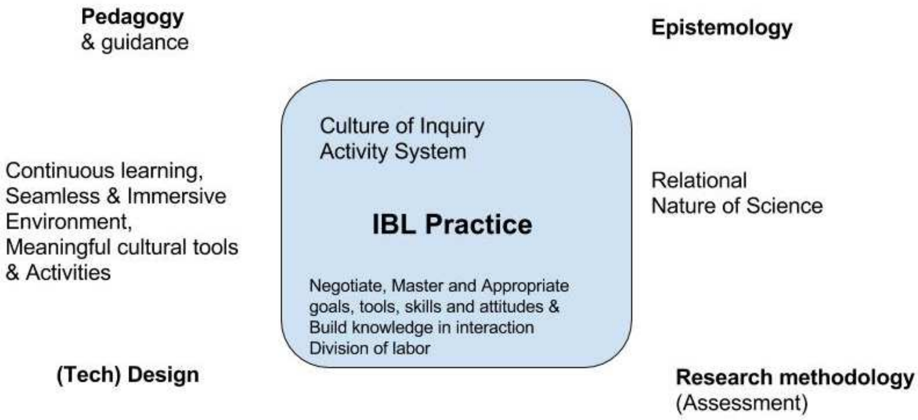

Figure 1. Epistemology, Design, Research and Pedagogy of IBL as Practice.

A relational epistemology of practice

IBL draws on several theoretical frameworks to explain how learning happens; for instance experiential learning theory (Healey, 2005), situated learning (Crawford, 2007), constructivist theories of learning (Hmelo-Silver et al., 2007), social learning theory (Bandura, 1986; West, 2009) and socio-cultural theory (Wortham, 2008; Kyza, 3012). These theories all consider aspects of epistemology. Epistemologies specify the nature of knowledge (e.g certainty/diversity), how knowledge develops (ways of knowing, e.g. the relationship between the knowers and the known), and how it is justified (quality control). Our epistemologies influence how we, as teachers (Lunenberg, Ponte & van de Ven, 2007) researchers (Fenstermacher, 1994; Allert, 2010), designers (Chee, 2011) or learners (Hogan & Maglienti, 2001; Baek, & Schwarz,2015), view the world and act in it. They influence how we see learning, how we study and support it, and how we (chose to) learn and assess.

If we want to support deep learning (involving critical thinking, analysis, and evaluation skills) and meaning making, our epistemological beliefs and those held by students matter. Said simply, if we think that all knowledge is already 'out there', that google is an authoritative source for true and certain knowledge, and that we can just look up THE answer to our questions, why would we even engage in inquiry as learners? Students' epistemologies are dependent on the contexts in which they encounter knowledge (Hammer and Elby, 2002; Sandoval and Morrison, 2003). Maybe we pay too little attention to the view of knowledge which is held in practical educational contexts, and to the implications this view has for our understanding of IBL and it's practical design. IBL activities, when not properly embedded in (or as an expansion on) the primary context (Dohn, 2013) of learning, are at risk of not being experienced as fully meaningful. They are introduced as side-projects, after which we return to what is really at stake.

IBL most often involves collaborative arrangements, and many educational IBL designs involve technological support. Suthers (2006) discussed several epistemologies applicable to collaborative learning arrangements, supported by technological designs. He lays bare a variety of assumptions we may hold of what it means to learn in collaborative settings. A common account of learning seems to position itself somewhere between purely individual epistemologies (learning remains a process within individual minds) and completely intersubjective epistemologies (learning consists of interactions), stating that learning is a group activity that results in individual changes. In IBL approaches learning is often characterised as a form of collaborative knowledge construction (Stahl, 2000), implying an interactional constructivist epistemology.

So interaction between people leads to learning, but does this provide us with a complete picture of what is going on when we introduce IBL into classrooms? An intersubjective epistemology assumes a participatory process within which beliefs are enacted, without being necessarily mutually accepted. Intersubjectivity is a process of mutual constitution (Matusov, 1996, Wegerif, 2006). When students are negotiating their understandings of how they are supposed to learn (and which beliefs to hold in the process), this represents learning at an interpersonal level. To better support learning as becoming embedded within the practice of a community, learning might additionally have to be addressed at the community level, where learning is a process of legitimate peripheral participation (Lave & Wenger, 1999). When IBL is first introduced we cannot assume that a community of scientific practice can be instantly created and that it will pursue externally driven goals; we should not ignore the critical issues of negotiated meaning, personal history and trajectories of learning (e.g. Henderson, 2015). Shared goals and expectations will have to be negotiated and cultural tools appropriated. Scientific epistemology refers to beliefs and views about how scientific knowledge is developed and justified, and involves a set of ideas and assumptions about the nature of science (Hogan and Maglienti 2001; Sandoval 2005). Even though it is difficult to attain the levels of epistemological understanding that professional scientists attain (Wu & Wu, 2011; Chuy et al., 2010), we could introduce students as legitimate peripheral participants (Lave & Wenger, 1999) in a community that develops scientific practice.

The technological tools we, as educational designers, introduce also need to be considered. These tools become similarly embedded in the practice of IBL, and they hold representations that externalise the designers' beliefs about what is important in IBL practice. The (broader) pedagogical design shapes, and to some extent may constrain the activities that students develop. Technology design can provide possibilities for certain (intersubjective) relations, but may not for others. Thus, the consequence is that an applicable epistemology includes the tools available and considers how the students relate to them. This epistemology is not only intersubjective, it is relational; a relational epistemology of practice. The epistemology of IBL is in essence that knowledge emerges, or is constructed, in relational interaction, between learners, more knowledgeable others, and the cultural resources of a community of practice (CoP). Based on the ideas presented about regarding IBL from a practice perspective, a new definition of IBL Practice is introduced:

> **Inquiry-Based Learning Practice:** Engagement in continuous, immersive and meaningful inquiry activities, organised around recognised and shared goals, applying a repertoire of skills and attitudes necessary for participation in a community of inquiry, while negotiating, mastering and appropriating its cultural tools.

This expansive definition achieves a couple of things, which will now be demonstrated by unpacking and discussing its elements. First, it explicitly includes the cultural tools of a broad community of inquiry. When doing inquiry, students enter into a tradition of knowledge creation evolving for centuries. Being aware that we, as learners, are standing on the shoulders of giants, that we can take an active role in the co-generation of knowledge, science being collective in nature (Schibeci, 1986; Fleer, 2013) both humbles and empowers us. The definition further reminds us that knowledge is continuously being (re)developed. To speak of a practice, the participants need to hold some things in common, and the definition claims a clearly recognized common goal is necessary. The activities that we design for IBL may not initially be perceived as meaningful. Students are often task-oriented and are not often invited to consider if these tasks trigger meaningful activity for them. Meaning is created and negotiated in activity, and activity is formed by the meaning it instantiates and perpetuates (Dohn, 2014). The use of the term immersive reminds us that we should help students cross the boundaries that science's cultural tools might raise for them, not only by providing appropriate designs that support seamless learning interactions, but by examining with them the relations they are forming with each other and with the cultural tools of science. The referral to the 'community of inquiry' aims to evoke the concept of 'community of practice', not simply as an aspirational state of harmonious collaboration, an instrumentalist strategy (Henderson, 2015), or a way to achieve the adoption of (mobile) IBL technology, but to ensure we acknowledge the complex relationship between technology, learners, the collective and a 'given' socio-cultural context.

Design issues

So given the complex relationship between these elements, how do we design for IBL practice? According to Wenger (1998), practice is not a result of design but a response to design. Even if a set of procedures are imposed on the learners, the practices surrounding them will be a result of negotiated meaning by the participants. The activities students engage in are emergent from the design of tasks, the affordances of the learning environment (Suthers, 2006), and the division of labor. Participants are bound by socially constructed webs of belief (essential to understanding what they do), and are not simply connected through the tasks they are given (Brown, Collins, & Duguid 1989). This means that, even though the teacher and the mediating technology can provide cues for activities, how they will emerge remains to a certain degree uncertain. The consequence of this uncertainty is that it may be wise to apply broad principles providing teachers and educational designers with useful guidance and helpful foci, without constraining creativity. Educational design generally needs to be based on a pedagogical framework (e.g. Protopsaltis, Bedek, Kopeinik, Prinsen, & Parodi, 2015), but when implementing and adapting such a design, we should consider taking the practice of IBL as a starting point. This may prevent us from designing systems that do not amply (seamlessly) support the developing practice. A learning environment, instead of being viewed as an application, might more productively be conceived of as an approach (Downes, 2005), that encourages the development of communities of inquiry. For instance, personal learning environments (PLE's) allow for a certain degree of flexibility, providing contextually appropriate toolsets that can be adjusted (e.g. by being modular) according to current needs and circumstances. Even if we cannot design learning itself, from a CoP stance we can design an environment that will either facilitate or frustrate emergent practices and identity (Wenger, 1998). The fact that practices are by nature in constant developmental flux means that IBL design will not necessarily progress toward an ideal or 'always successful' design, but that the possibility of adaptation will be key. User-driven development and formative evaluations (Bedek et al., 2015) can be adopted as part of the ongoing design process, allowing to pinpoint and help resolve arising issues in a process of collaboration between technology development and pedagogy.

IBL entails the application of a repertoire of skills and attitudes, and mastery of cultural tools. Extensive scaffolding is employed in inquiry learning approaches (Hmelo-Silver et al., 2007), reducing cognitive load through cognitive apprenticeship (Quintana et al., 2004), and allowing students to learn in complex domains. The main assumption behind such designs is that given structure and guidance, students will become increasingly accomplished problem-solvers. Scaffolding is provided through task structuring, coaching and the provision of hints. A literature review on potential types of guidance for supporting student inquiry when using for instance virtual and remote labs (Zacharia et al., 2015) identifies six types of guidance; constraining the process, using a performance dashboard, providing prompts, providing heuristics, scaffolding, and direct presentation of information. Care should be taken, though, to not forget that we are designing an environment that engages students in an ongoing social process and that their systematic ways of thinking are not just mediated by artefacts but also through dialogue about the reasons behind provided structure and guidance. Guidance thus also means that teachers provide time to pause and identify the rules and norms (conventions) governing the collective understanding in the moment, placing the perceptions and views of the members of the culture under study.

Since IBL is a social process, many current designs include feedback (e.g. dashboards) and reflection tools (e.g. digital notebooks, or reflection widgets) with which social factors and student perceptions can be examined. Additionally, the affordances of social media are increasingly integrated to support collaboration across time and space, and to provision more just in time support. The ways in which the inclusion of such media actually supports continuous, immersive and meaningful IBL activities is still under study.

Students' responses to technological designs are most often examined through usability measures, and the examination of cognitive load and student motivation. Sometimes engagement is examined through log-file data. Usability tests often does not include pedagogical criteria (Nokelainen, 2006), even though pedagogical usability should be central to any design effort. This brings us to further consider some issues relating to how the reconceptualization of IBL impacts on the ways in which we research the success of our designs.

(Research) Methodological issues

How do we research and capture inquiry learning as a practice? It is a challenge to move abstract conceptualisations into the realm of actual data. When we assert that "students' employment and understanding of provided cultural tools (elements of our designs) are embedded in, and interdependent with, complex social and cultural contexts (e.g. Rasmussen & Ludvigsen, 2010; Säljö 2010), it makes sense to follow students' activities in context and over time, to focus on students' interaction trajectories (Ludvigsen et al., 2011) and on the process of knowledge construction and meaning making. Situated learning provides us with a messy reality, but CoP (social practice theories) can have significant value as an analytical framework to understand it.

The CoP approach has been criticised as being too abstract, and consequently too difficult to operationalize (Storberg-Walker, 2008). It is clear that practice is not only the thing that members do (participate/activity), but also the ways in which they understand what they do (attributed meaning). Still, there is uncertainty as to the appropriate level of analysis (Storberg-Walker, 2008); are we analysing at the level of collective meaning (examining mutual engagement; interactions) or individual meaning (examining participation)? This is a multi-level issue, and a challenge to understand how an event at one level can shape an event at another.

By capturing interaction patterns (e.g. through network analysis, actor network analysis, and/or semantic analysis) and how they develop over time, we can focus on the relations being formed with provided (and emergent) cultural resources. This means combining quantitative ánd qualitative measures. While collecting evidence of students using the tools (e.g. through logs) and applying inquiry skills, we should also consider to what level they appropriate them; if they recognise their use and value.

Storberg-Walker (2008) provides, as one solution to the problem of capturing collective meaning making, the establishment of research to practice partnerships, in which practitioners take a leading role in identifying, assessing, critiquing, and problematizing aspects of practice. It seems that not only teachers and students should engage in the ongoing social process of inquiry, but researchers should immerse themselves in the local practices more often and co-engage in the negotiation of the tools supporting inquiry practice. After all, they are themselves practical experts.

Implications for the educational context

The aforementioned issues have clear indications for the educational context. Introducing a new practice in this case means introducing a new view of knowledge and of how learning takes place. This requires explicit attention, since learners' epistemologies influence how they see and approach learning. Making time to explore with students their views on the Nature of Science can help bring to light their current conceptions (Wu & Wu, 2011) and introduce novel conceptions, more in line with how the source, the nature and the justification of knowledge is perceived in communities of inquiry.

Working from a relational epistemology will place the focus on the group as a learning agent. The application of social learning analytics (Buckingham Shum & Ferguson, 2012) can help shift the focus towards properties of learning which come into being through social activity. They can help examine how students are interdependent of each other in the IBL process.

Since IBL practice can only be emergent, as a response to educational design, it seems design can only provide scaffolds and cues for IBL activities, but cannot determine this response. The ways in which students respond needs additional monitoring, e.g. by providing them with opportunities to reflect on their experience. In this way they can explore how their personal viewpoints, feelings and values fit with the practices of science.

It is clear that especially the 'why' of the cultural tools needs explicit negotiation (discovering the reasoning behind the practice). It may help to provide students with exemplary cases and to discuss with them the role of activity structures, supporting systems and artefacts. Learning technologies form only one component of the IBL 'orchestration', that is, "the process of productively coordinating supportive interventions across multiple learning activities, occurring at multiple social levels" (Dillenbourg et al. 2009, 12).

Conclusion and discussion

The exposition above attempts to make the cases that all the uncertainty, discomfort and hard work that go into supporting IBL as a practice is worth it too make IBL a meaningful and productive experience for students. Of course the perspective laid out in this article will be disputed, and there are many remaining questions, for instance relating to the level of authenticity we can provide in and outside the classroom. Knight et al. (2014) endorse that students should be given the opportunities to engage in authentic learning challenges, wrestling with problems and engaging in practices increasingly close to the complexity they will confront when they move on from school. According to Knight et al. (2014) the focus on practice reflects this growing recognition in educational thinking. But it might be that there is no such thing as real authenticity in the context of our classrooms; are they by their nature artificial? In a draft version of a paper on 'Defining authenticity', Brown and Menasche (2006) argue for degrees of authenticity, rather than positing it as a binary concept (authentic or not authentic). They define three types of task authenticity: 'genuine', 'simulated' and 'pedagogical' and state that genuine authenticity "exists when learners engage in tasks in ways and for reasons they would in the real world" (Brown & Menasche, 2006, p.3).

But if IBL practice is considered as being in constant developmental flux, and can only approach authenticity, then what do we mean by taking 'IBL practice' as a starting point when implementing and adapting IBL designs in practice? We should realise that mimicking the actual practices of professionals is an unobtainable ideal in the context of e.g. primary and secondary schools. As Wu & Wu (2011) rightfully point out, when we aim to examine whether students apply the epistemological beliefs of professional scientists (i.e., formal epistemology), rather than the views and ideas they generated during inquiry practices in school (i.e., practical epistemology; Sandoval 2005), we will find that students still hold naïve epistemological views. Clearly we should take into account their proximal knowledge of the nature of science (Hogan 2000; Sandoval 2005). Their practical epistemology (involving ideas of the nature of knowledge, the approach of producing knowledge, and the criteria of evaluating knowledge) will more accurately reflect their decisions while constructing scientific knowledge and the criteria they apply in the evaluation of the knowledge which they are developing. Studies of how professionals learn in practice (Cheetham & Chivers, 2001) show that the point of becoming a fully competent professional is often not reached until long after professional training has ended, and reaching it involved a range of experiences in the authentic CoP context.

An additional concern that touches on learner participation in the practice of IBL is a concern over equity. Learners should be provided with learning opportunities that are equitable in access and quality. The social and cultural dynamics of the collaborative practices within learning communities may have differential effects on learner participation and outcomes (e.g. Prinsen, Terwel, Zijlstra, & Volman, 2013). For instance, not all learners develop similar interests in science (Prinsen, 2012). According to Schreiner & Sjøberg (2007), interest in science can be conceptualized as a process of identification that develops within personally relevant social practices. The development of interest is a process that is mediated in various social contexts (Costa, 1995) and with various cultural artefacts, through participation in practices in which particular values are enacted (e.g., Bøe, Henriksen, Lyons & Schreiner, 2011). Those who, through practice, identify successfully with science persevere and re-engage with it over time. Hung and Chen (2007) develop a similar argument when they propose approaches, which emphasize the identity enculturation aspect in diverse communities.

Finally, design should take into account the developmental stages at which the IBL practice currently manifests itself. Schools, at any one point, have their own form of authentic practice which will have to be fit into a continuum of approaches that move towards the practices of actual professional scientific communities. Authentic learning challenges, according to Knight et al. (2014), provide the opportunity for developing transferable skills and competencies, and the qualities needed to thrive in complexity and uncertainty. An often heard question from teachers is "Should or should we not decrease the complexity of the IBL process?" Even though there are many challenges presented in this paper, we may have to accept the complexity of IBL and progressively support students in grappling with this complexity, without expecting them to 'get it right' too soon. The newly proposed definition would suggest that it is a continuous process, and if we want learning to become a life-long endeavour, we owe it to our students to let them work through the struggles they will inevitably encounter when they continue to inquire the phenomena of life.

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