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Keywords

Constructivism; Student-centered pedagogy; Problem solving; Adidactic; Scientific debate; Modeling; Experimental practice; Teachers' practice; Pre-service and in-service training

Related Terms (and Acronyms)

Inquiry-based education (IBE), Inquiry-based learning (IBL), Inquiry-based science education (IBSE), and Inquiry-based teaching (IBT)

Definition

Inquiry-based mathematics education (IBME) refers to a student-centered paradigm of teaching mathematics and science, in which students are invited to work in ways similar to how mathematicians and scientists work. This means they have to observe phenomena, ask questions, look for mathematical and scientific ways of how to answer these questions (like carrying out experiments, systematically controlling variables, drawing diagrams, calculating, looking for patterns and relationships, making conjectures and generalizations), interpret and evaluate their solutions and communicate and discuss their solutions effectively.

The role of the teacher in such a setting is different to traditional teaching approaches: pedagogies make a shift away from a 'transmission' orientation, in which teacher explanations, illustrative examples and exercises dominate, towards a more collaborative orientation, in which students work together on 'interconnected', 'challenging' tasks. Here, the teacher's role includes making constructive use of students' prior knowledge, challenging students through effective, probing questions; managing small group and whole class discussions; encouraging the discussion of alternative viewpoints and helping students to make connections between their ideas.

Related terms (and acronyms) are: Inquiry-based education (IBE) inquiry-based learning (IBL), inquiry-based science education (IBSE), and inquiry-based teaching (IBT).

Socio-political background

In recent years, IBME, and generally IBE, have met a real success especially in educational policy and curriculum documents, but also in developmental in-service and pre-service professional development courses and projects. The reasons for this wide popularity of IBE may be found in the alarming decline in young people's interest for sciences and mathematics studies, attested in most countries in the world, especially in Europe and North America, as well as the poor results of many countries in mathematics and science in international evaluations like PISA. In Europe, for instance, this led to political reactions at various levels. A famous report known as Rocard's report (Rocard et al. 2007) incriminated (among other causes) the "deductive approach", in which "the teacher present the concepts, their logical – deductive – implications and gives example of applications" resulting in students lacking interest, considering science and mathematics to be extremely difficult, being not able to apply their knowledge in bigger and maybe unfamiliar contexts. Instead of this traditional education, the experts advocate the promotion of IBE, and refer to Linn, David and Bell (2004) to promote IBE: "By definition, inquiry is the intentional process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments". This led the EU to invest a lot of money to support research projects to promote widespread dissemination of these pedagogies in order to improve Europe's capacity for innovation. For more details on the different European projects on the implementation of IBE see www.proconet-education.eu.

Historical background

Historically the importance of inquiry in education is generally attributed to the American philosopher and educator John Dewey (1859–1952). In his book published in 1910, he acknowledged the importance of inquiry in child's attitude towards science: "This scientific attitude of mind might, conceivably, be quite irrelevant to teaching children and youth. But this book also represents the conviction that such is not the case; that the native and unspoiled attitude of childhood, marked by ardent curiosity, fertile imagination, and love of experimental inquiry, is near, very near, to the attitude of the scientific mind." (Dewey 1910, p iii).

Moreover Dewey insists on the process through which inquiry develops: "There is continuity in inquiry. The conclusions reached in one inquiry become means, material and procedural, of carrying on further inquiries." (Dewey 1938, p 140). He also puts forward the importance of action on objects, rather than language in scientific thinking: "The authors of the classic logic did not recognize that tools constitute a kind of language which is in more compelling connection with things of nature than are words […] Genuine scientific knowledge revived when inquiry adopted as part of its own procedure and for its own purpose the previously disregarded instrumentalities and procedures of productive workers." (Dewey 1938, p 94).

Dewey's perspective on education implies a practice of teaching based on projects closely linked to students' life and interests, and to the development of inquiry habits of mind considered as generic. However, the details of Dewey's work are usually diluted in more general approaches, despite the relevance of his work for contemporary reflection in education (Hickman and Spadafora 2009). Historically, IBE at first concerned sciences rather than mathematics. In this sense, one major event was the publication of the *National Science Education Standards* in the US in 1996 (National Research Council 1996). From there a wide spectrum of IBSE approaches and practices emerged and developed (Barrow 2006), with various definitions that the 2000's revised NSRS tried to summarize in 5 points (National Research Council 2000, p 27):

- students create their own scientifically oriented questions;
- students give priority to evidence in responding to questions;
- students formulate explanations from evidence;
- students connect explanations to scientific knowledge;
- students communicate and justify explanations.

In the PRIMAS project (www.primas.eu 2011) these are embedded in broader picture capturing what could be meant by an inquiry-based teaching practice in science and mathematics, see figure 1.

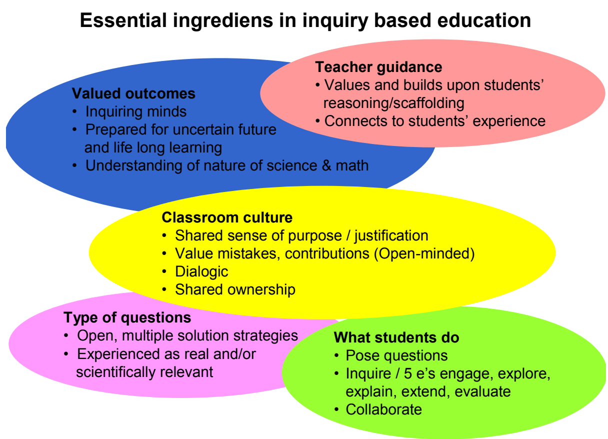

Figure 1: The working definition of IBE in the PRIMAS project

IBME and mathematics education research

The focus on inquiry in mathematics education is more recent than in science. It is based on the increasingly shared view that mathematics and sciences education are closely connected, that mathematics is not purely deductive and that mathematical concepts may be grasped through some experimental practice. However, the migration in mathematics led to some specificities, especially a particular connection with problem solving, a learning environment where problems drive the learning, a long tradition in mathematics education (see e.g. Rocard et al., pp 9–10).

Although the term IBME has not been traditionally used, several research works and theories in mathematics education can be linked to it. Artigue and Blomhoej (in press) have made an overview of these links offering a well documented and illustrated analysis. Even if they do not claim of course to be exhaustive, they reviewed several different trends and theories, namely: Problem Solving tradition, Theory of Didactic Situations, Realistic Mathematic Education, Modeling perspectives, Anthropological Theory of Didactics, and *Dialogical and Critical* approaches.

These authors conclude this review by a reflection on the possible conceptualization of IBE in mathematics education. Such a theoretical concern has been missing so far, due to the fairly recent migration from science.

Evidences from research of IBME benefits

Considering the socio-political background, as depicted above, the success of IBME as a remedy to all problems is barely questioned. However, this issue is more complex when approached from a research perspective. One of the most extensive surveys was published recently in the context of science (Minner, Levy and Century 2010), but it is also relevant for mathematics. It took into account 138 studies (mostly in the US) published between 1984 and 2002, and tried to evaluate the impact of IBL on students' competencies in sciences. One of their first duties was to develop a framework in order to measure the level of IBL in the instructional intervention at stake in each study. "In this framework, inquiry science instruction can be characterized as having three aspects: (1) the presence of science content, (2) student engagement with science content, (3) student responsibility for learning, student active thinking or student motivation within at least one component of instruction – question, design data, conclusion or communication." (p 478). Based on this framework, their overall conclusion is that "the evidence of effects of inquiry-based instruction from this synthesis is not overwhelmingly positive, but there is a clear and consistent trend indicating that […] having students actively think about and participate in the investigation process increases their science conceptual learning." (p 493).

Concerning mathematics, there are also several studies, which point some various positive effects of IBME of students' achievements, motivation, autonomy, flexibility, etc. There has also been a concern on the type of students for whom IBME could be more beneficial, but these studies lead to a mosaic of evidences from which it is not always easy to draw some general conclusions. Yet, an overview of these results with references to several studies can be found in (Bruder and Prescott 2013). Furthermore, the political pressure due to the supposedly radically positive effects of IBME on students' achievements in and motivation for mathematics is an opportunity for the implementation of IBL in day-to-day teaching but may also elude some research necessity. Still large-scale studies on the implementation of IBL and its effects in mathematics education are missing.

Research on teachers' practices regarding IBME

In spite of research evidences and political pressure, IBME remains quite marginal in day-to-day mathematics teaching, and often limited to softer versions compared to more ambitious experiments. This raises the issue of the role of IBME in teachers' training and professional development courses, based on research works on teachers' practices (see for instance the ICMI study (Even and Ball 2009) or (Grangeat 2011) and the results of the European project S-team http://www.s-teamproject.eu/). In this sense, one important results from research show that one essential, yet not sufficient issue is that teachers have experienced this type of teaching personally in their own mathematical or professional training, in other words, the paradigm of inquiry could serve as a model for designing activities with trainees. This issue is specifically stressed in research works on communities of inquiry (see e.g. Jaworski et al. 2007) or the model of lesson studies in Japan (see e.g. Inoue 2010).
Another concern is that professional development courses need to start off from teachers' needs, to be relevant to day-to-day teaching and should engage teachers in reflecting on their teaching practice and on their beliefs on what they consider as good mathematics education. Also, since IBME places more responsibility on teacher concerning design of appropriate learning situations and guiding of students' learning, teachers have to be aware and convinced by all good reasons for promoting IBE. This is also important in relation to the teachers' need for legitimacy in relation to students, parents and colleagues.
In order to be effective professional development courses need to develop on a long-term perspective, allowing teachers to learn about inquiry-based education, try out inquiry-based pedagogies in their teaching and to reflect on it in the next meeting. However, including IBME in pre- and in-service teacher education is not sufficient to establish a sustainable teaching practice in mathematics in which IBL plays a substantial role. Systemic support from school policy is of course crucial. In particular, curricula and external assessment need to include some inquiry dimension (See Maass and Doorman 2013).

Cross-References

- ► Anthropological Approaches in MathematicsEducation, French Perspectives
- ► Argumentation in Mathematics
- ► Argumentation in Mathematics Education
- ► Collaborative Learning in Mathematics Education
- ► Communities of Inquiry in Mathematics Teacher Education
- ► Constructivism in Mathematics Education
- ► Critical Thinking in Mathematics Education

- ▶ Dialogic Teaching and Learning in Mathematics Education
- ▶ Didactic Situations in Mathematics Education
- ▶ Interdisciplinary Approaches in Mathematics Education
- ▶ Learner-Centered Teaching in Mathematics Education
- ▶ Lesson Study in Mathematics Education
- ▶ Mathematical Modelling and Applications in Education
- ▶ Mathematics Teacher Identity
- ▶ Models of In-service Mathematics Teacher Education Professional Development
- ▶ Models of Preservice Mathematics Teacher Education
- ▶ Motivation in Mathematics Learning
- ▶ Realistic Mathematics Education
- ▶ Teacher Beliefs, Attitudes, and Self-Efficacy in Mathematics Education
- ▶ Theories of Learning Mathematics

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