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Title : Inquiry learning… what is relevant evidence ?

Inquiry Based Learning (IBL) aims to produce “in-depth” understanding. However, large-scale assessment studies (e.g. PISA) suggest that most students do not attain very good scientific literacy, highlighting the need for both better descriptions of learning designs and more relevant measure of student scientific knowledge that might inform design and learning supervision.

Relevance depends on the conceptual framework in which the variables exist. We consider student learning results from socio-cognitive interactions with resources and others – the *milieu* (Brousseau, 1998). Cognitive conflict is therefore encouraged but epistemic resolution favored (Buchs, Darnon, Quiamzade, Mugny, & Butera, 2008). We consider student scientific understanding as resulting from an individual process of justification that builds on experiments, puts them in perspective and discusses the links between data and assertions (Toulmin, 1958). Science knowledge is also a social process, where ideas exposed to discussion by peers finally strengthens justification of individual understanding (Osborne, 2010). This implies that justification by teacher authority might prevent student scientific understanding and that developing student autonomous justification is a prerequisite. Pedagogic authority and scientific authority (by which it is decided what is justified) should be clearly separated. Teacher’s interventions should therefore not *correct* – preventing student’s justification process – but reveal incoherencies within in the productions of students and with authentic resources. Here we define authenticity in reference to the scientific paradigm (Kuhn, 1972) and conceptual proximity to experiments: for example, *Nature* articles are more authentic than academic textbooks and teacher produced documents are less.

We argue that relevance of student’s understanding should be judged within the epistemology of the current paradigm: explanations of the underlying mechanisms for biology (Morange, 2003). We propose epistemic complexity (EC) (Hintikka, 1992) as a content-independent measure of evidence for in-depth understanding of biology concepts.

Attempting to steer inquiry by teacher adjusting the milieu to conceptual development of students(Altet, 1993), while more difficult, focuses on the learning process rather than a rigidly planned set of activities supposed to produce learning. We developed an IBL framework that scaffolds student learning while preserving their ownership of questions. The design was conceptualized as a *milieu* and described in terms of design features that the students are confronted to. A list of 27 design rules were synthesized into three design principles linked to theoretical foundations: i) students are responsible for producing a share of knowledge (cooperative structure (Buchs, et al., 2008)), ii) students and teacher share a common goal of knowledge building (knowledge-building community of learners (Scardamalia & Bereiter, 2006)) and iii) confrontation to resources of high authenticity guide towards the structuring concepts of the field (we believe the latter to be an original contribution).

Methods

The study was conducted between 2006 and 2010 in advanced high school classes, totaling 52 students. Each intervention lasted most of the year. The curriculum covered molecular biology, genetics, and immunology. We adopted a design-based research approach (Brown, 1992; Collins, 1992) : formative research by testing and refining educational designs based on principles derived from prior research.

Student knowledge building was scaffolded by a Wiki writing space. Progressive understanding could be traced by comparing revisions of student text recorded in the wiki server for word and question count, question refinement, and EC using a four-point scale: unelaborated facts, elaborated facts, unelaborated explanations, and elaborated explanations. We rated texts at investigation start middle and end: These moments were chosen as representative of inquiry phases. Additional data that we will not present here include classroom observations, survey data and grades. In addition to our own analysis, an independent expert judged student productions.

IBL learning is structured and focused by questions. The design can be summarized as follows: i) student questions are raised from observation, experimenting or reading, they are assigned to groups by sub-theme (humoral immunology, cellular immunology, etc.), ii) students search-select-synthesize using resources such as experiments, observations, books, online resources, iii) students present their current understanding to peers, leading to confrontation of understanding and question redefinition; the process iterates until the texts are printed into a brochure decisive for student's preparation of important exams. Two such inquiry cycles last about 4 weeks, then the class addresses a new chapter.

Selected results

Design features of the *milieu* include a simple but powerful rule (conceptual coherence of questions and answers) that insured steering of the inquiry process by the questions and prevented dilution by easily accessible resources. As student text became more complex, it was split into separate questions that were discussed and sorted (Figure 1). This produced conceptual refinement, while allowing supervision of curriculum coverage by negotiation of questions.

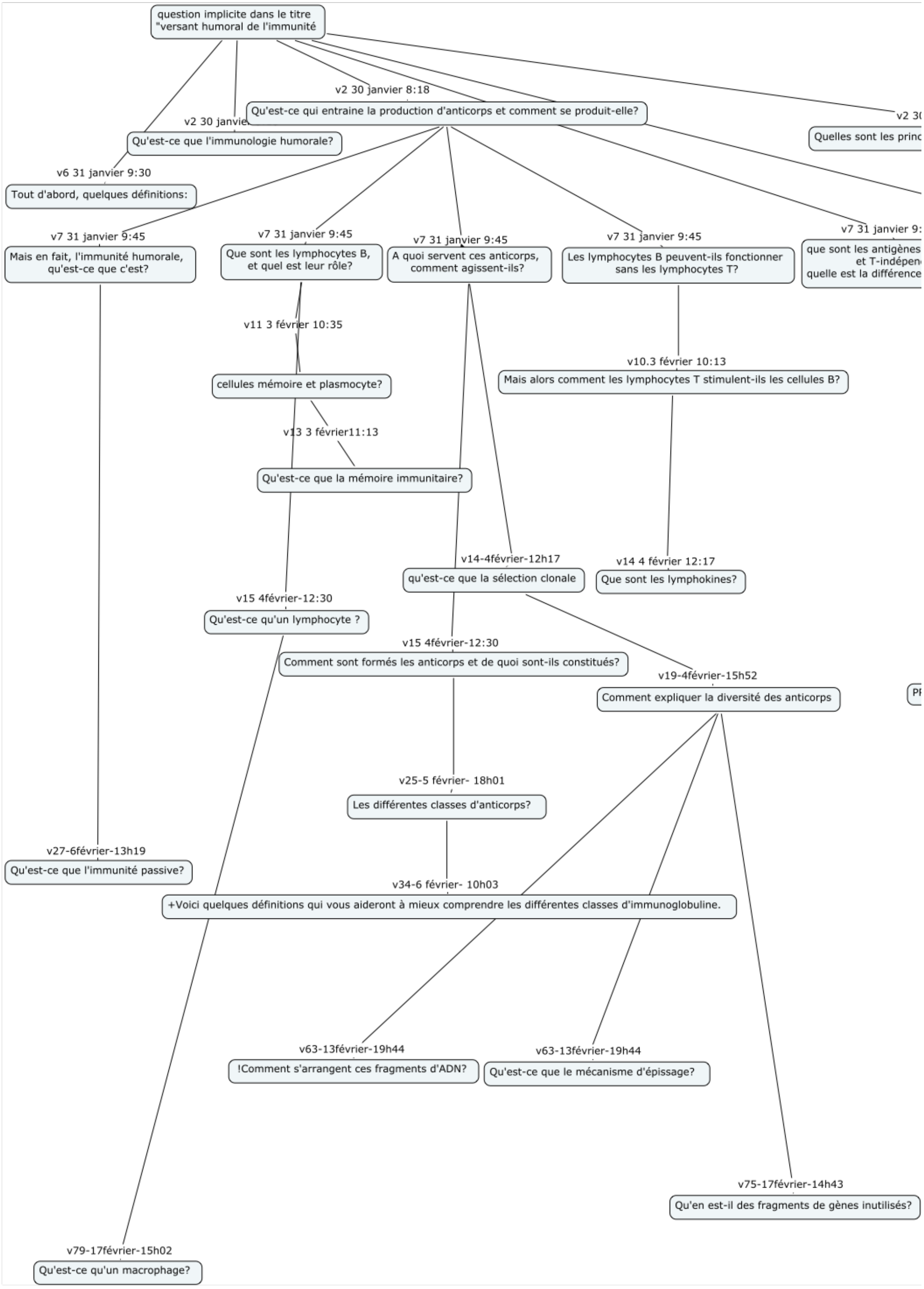

Figure 1: A sample of question elaboration (in French).

Epistemic complexity increased during inquiry progression, (Figure 2) with an initial phase characterized by a burst of questions, word count increase and low EC (mostly descriptive), followed by a phase characterized by few new questions, slight increase in word count and moderate EC (mostly unelaborated explanations). A third phase saw word count increase continue and reach an average of 3171 words per group, a median number of 27 questions (Figure 2), and was characterized by a strong increase in EC where the number of elaborate explanations grew relative to simple descriptive answers. EC increases (example 2006) from 5 Elaborated Explanation items (15.6 %) at the beginning, to 50 out of 247 items (20.2%) at the end, suggesting that students produced in-depth knowledge about explanations of the mechanisms of immunology. The EC increase followed teacher intervention (deadlines, assessments, brochure finalized).

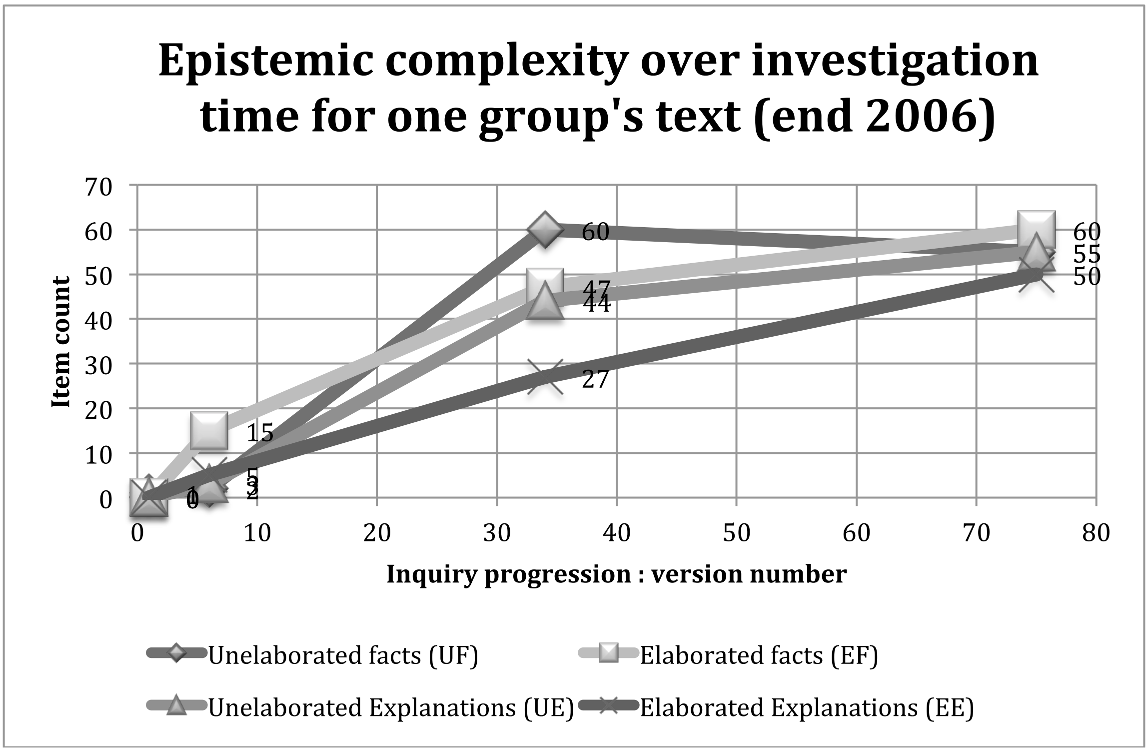

Figure 2: An example of epistemic complexity increase. Note that very few elaborate explanations are found until late into the investigation.

Discussion

These results – and more we will show – suggest that robust and effective learning was achieved by designing the *milieu* learners are confronted to. This might be more relevant than describing learning tasks with scripts. Our results show how separation of scientific and pedagogic authority allows teacher control of inquiry via *milieu* variables such as student responsibility, knowledge-building goal, and authentic resource confrontation. Our data argue for a comprehensive approach optimizing multiple design rules rather than maximizing one single variable. They also confirm that measuring EC provides a relevant way of informing student progression of understanding so as to guide and design development of student understanding in biology.

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