Epistemic complexity as a measure of inquiry progress in science education

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Abstract
Inquiry-based learning (IBL) is highly promoted in science education to foster students' understanding of concepts and of the paradigms in which the concepts were developped and assessed in the scientific community. Though generally highly motivating for students, IBL could fail reaching deep knowledge if students are not sufficiently guided in the inquiry process. The difficulty for teachers is to know when these guiding interventions are needed without lowering students autonomy in the investigation. In this study, we proposed to use epistemic complexity of the texts produced by the groups of students over time as an indicator of their progress in the inquiry process and understanding. The results showed that epistemic complexity increases both in absolute and relative value in students' production. Moreover, the level of epitemic complexity in the final productions of the inquiry cycle is higher at the end compared to the beginning of the year. This findings suggest that epistemic complexity is an helpful indicator to assess the progress in students' understanding over time and investigate the effect of instructional intervention in inquiry-based learning design.

Introduction

Inquiry-Based Learning (IBL) in Science Education is promoted in many countries. However, concerns about guidance towards learning objectives and in-depth scientific knowledge are common and underline the need for indicators of students' cognitive progression. During the iterative process of question elaboration and experimenting, reading, synthezing, argumenting, which constitutes IBL, teachers need to apply a subtle mix of student guidance and autonomy. Information found during inquiry might overwhelm students. So both students and teachers need indicators that inquiry is indeed moving towards objectives.
Explanations of the underlying mechanisms are central questions in the current paradigm of biology. Leading student's understanding past simple descriptive knowledge to elaborate explanations is considered difficult in all cases. Though valuable in practice, teachers' representations cannot be considered a sufficiently reliable indicator of student cognitive progress or other educational variables. Consequently indicators that inquiry is indeed developing deep knowledge (centered on elaborate explanations) are greatly needed. One possible candidate is epistemic complexity (EC) (Hakkarainen, 2003) which distinguishes descriptions and explanations and their elaborateness. In a field study, we have explored its use as indicator of inquiry progression in texts produced by students in an inquiry design .
The objective of the research was first to develop and test an Inquiry Based Learning design scaffolded by a wiki writing space for full-year high school biology, then to analyze the wiki records under the perspective of EC and guidance of inquiry. Our research question is whether epistemic complexity can be used as a measure of inquiry progress in science education.

Methods

This research presents a set of field studies of an IBL design repeated during 4 years (2006-

2010), with 19-year-old students majoring in biology, totaling 61 students. This study was conducted within a larger research, for which we chose Design-Based-Research (DBR) as our research paradigm. The intervention lasted most of the year. The curriculum covered molecular biology, genetics and immunology.
The learning design was inspired by a knowledge-building community of learners, was structured for cooperative learning and was scaffolded by a shared wiki in which students wrote their current understanding. They investigated answers to inquiry questions by experimenting and reading authentic resources. Early in the investigation process and close to the end, students presented their understanding to peers, leading to confrontation of knowledge, question redefinition. The student's efforts resulted in a brochure critical for student's preparation of important exams, making it a very important document to them. An inquiry cycle lasted 3 to 4 weeks, after which the class addressed a new chapter.
Data was collected from the wiki automatic history recordings. We analyzed a sample of four documents over the years (same subtopic, same group size (3-4), same period of the year (end)), for word number and question number in each revision of the document. Texts were rated for EC using a four-point scale adapted from Zhang, Scardamalia &al. (2007): unelaborated facts, elaborated facts, unelaborated explanations, and elaborated explanations. We measured texts at the beginning and end of the year, and in each EC was measured at investigation start middle and end: These moments were chosen as representative of inquiry phases.

Main results

We first analyzed the global quality of the wiki productions as indicators of student's understanding . As there are no standardized exams in Switzerland, an expert was called and reported that the design produced adequate knowledge of biological mechanisms. Moreover, a questionnaire administered to students one year later at university indicated that 89% considered this course prepared them well for university.
We then analyzed the process of knowledge elaboration in the wikis. We observed (Figure 1) 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). This suggests inquiry requires 3-4 weeks to develop deep scientific understanding, and is tied to teacher's intervention.
Moreover, yearlong comparison of EC between the first investigation (September 2008) and at end of year (March 2009) (Figure 3) showed that students reached a higher level of EC (respectively 15 % and 28.7 elaborate explanations) suggesting inquiry skills develop over the year and EC can capture such progress.

Discussion

These results are reasonable evidence that the IBL allowed students to acquire in-depth understanding of biological mechanisms and validate the design in which the research questions are discussed. Our results also suggest that EC gives relevant insight into the understanding progress of students, helping reveal conceptual phases in the inquiry progress, effectiveness of IBL developing with time, guiding design and teacher intervention.

For education, EC could be a measure of understanding progress (at least in biology). Simplified versions of EC could be used to guide inquiry learning as an indicator that students are indeed developing deep scientific knowledge about biology. For research, EC could be used to compare different science education interventions, or to discuss the influence of different design features.

Fig 1 : Epistemic complexity over investigation time for one group's text (end 2006)

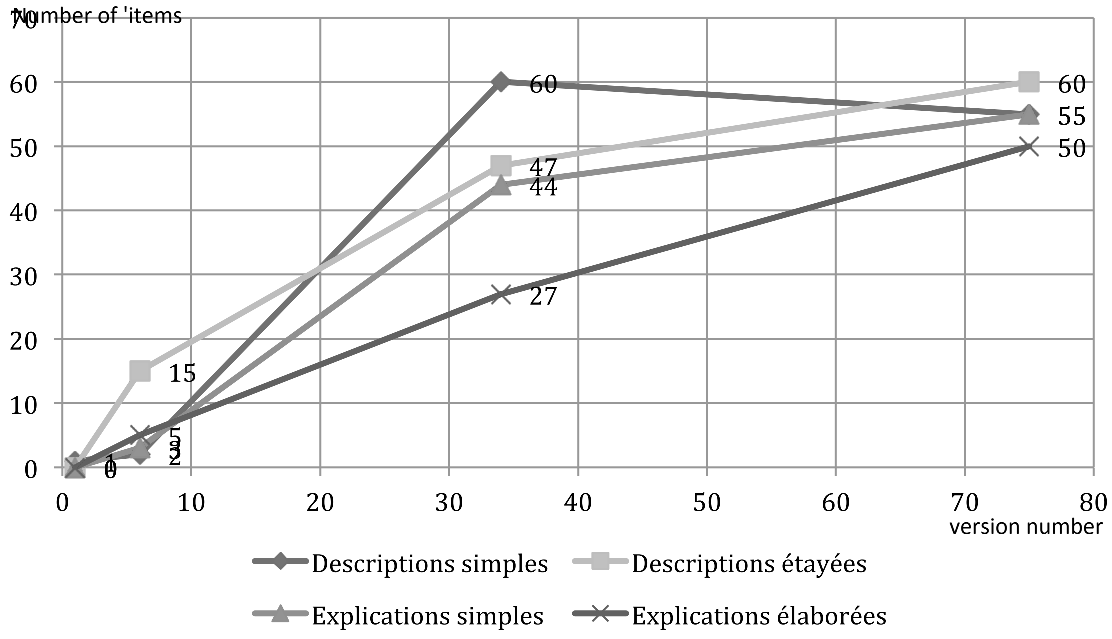


Fig. 2 : Question count over inquiry time for one group's text (end 2007)

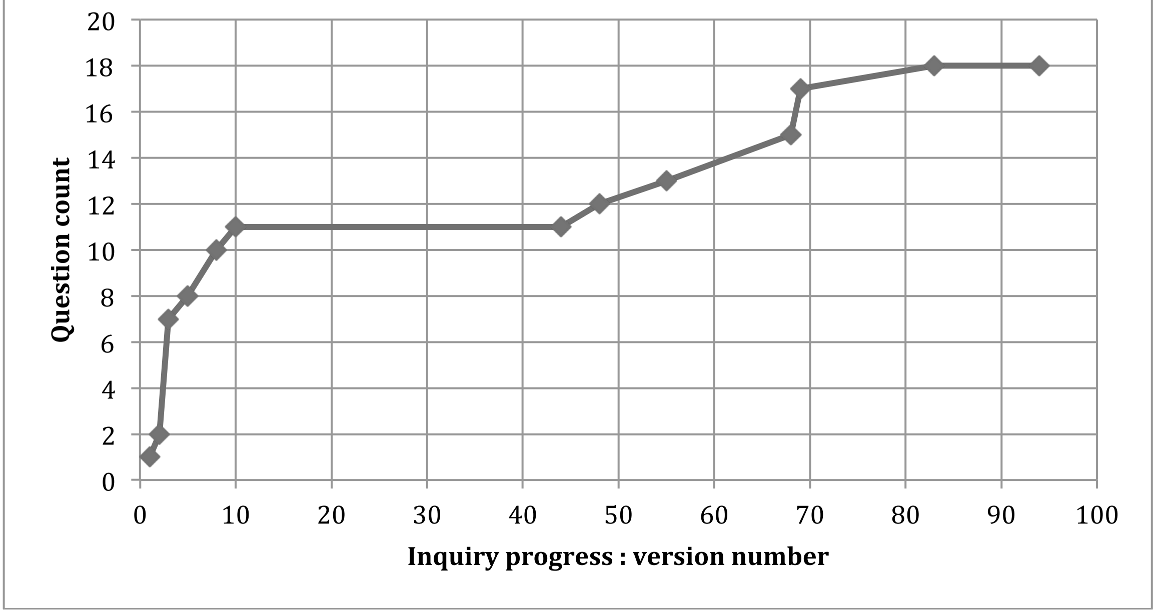
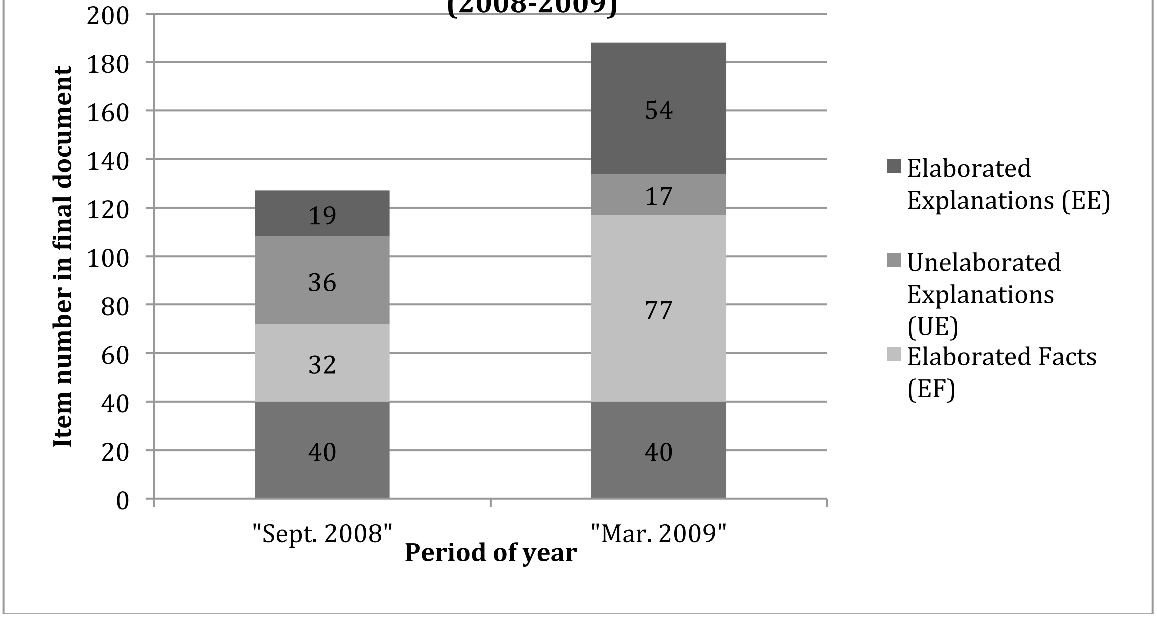


Fig. 3 : Epistemic complexity begin end year for one group (2008-2009)



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