Empowering next generation learners : Wiki supported Inquiry Based Learning ?

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Abstract

In this article we discuss an Inquiry Based Learning (IBL) design for high school science teaching. IBL is defined as iterative cycles of *Ask, Investigate, Create, Discuss, Reflect*. We developed over 5 years a teaching design involving students in collaborative writing supported by collaborative writing spaces (Wikis). The general goals were to develop in-depth biological knowledge, scientific argumentation and high-level knowledge-building in information-dense environments, and evolution of student's Notion Of Science (NOS). Each course lasted one year and covered different chapters of biology at different points in the curriculum. Students produced a collection of collective documents framed as help to prepare their exams, rather than a public showcase of their knowledge or that of the teacher.
We adopted a Design Based Research framework, geared towards refining the design and to create design rules for wikis in IBL.
We used data from the Wiki server histories, student surveys, marks, and other sources.
The design in its current form and a few major design rules derived during the process will be discussed.
Preliminary findings suggest that adequate computer technologies such as wikis can be effective cognitive tools in an IBL design, by supporting collaborative writing activities and epistemic confrontation geared towards knowledge building. They also support the idea that effective learning strategies to empower students in a technological info-dense world should include active focused collaborative productions and encourage the use of complex rather than popularized literature.

Introduction

First let's define biology as a method for building knowledge about life processes by experimental investigation.Above all, the bioscience disciplines are experimental sciences and their defining characteristics are:

(1) A**ll knowledge is related to observation or experiment**;

(2) Biosciences are a family of methods and disciplines grouped around the investigation of life processes and the interrelationships of living organisms;

(3) they **exist in an environment of current hypotheses rather than certainty;**

(4) they include disciplines in which rapid change is happening;

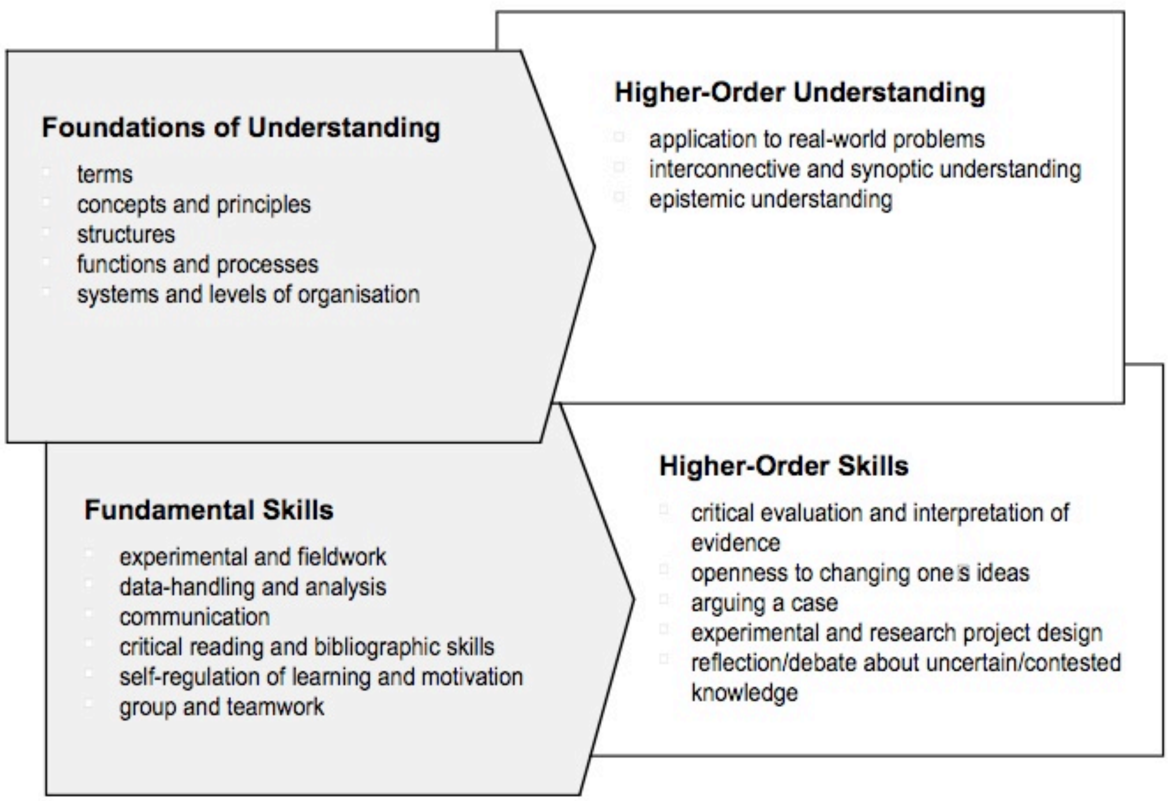
(5) and they are essentially practical and experimental subjects (Sears & Wood, 2005).

It is particularly relevant here that all biological knowledge is "related to observation or experiment" and that they "exist in an environment of current hypotheses rather than certainty". Both of these characteristics are in fact very difficult to achieve in science teaching (William A. Sandoval, 2003)

Learning Goals

What has to be learnt in biology has been greatly debated and too often focuses only on one aspect (e.g. general models : *systems and levels of organization* (Modell, 2000), or *self regulation of learning and motivation* : "Lived curriculum" (Wright & Klymkowsky, 2005), and numerous others). Many of these seem to focus on presenting *the* problem and suggesting *the* solution. Of course learning Biology seen as a manner of building knowledge implies a vast array of knowledge and skills that have been nicely summarized by (Hounsell & McCune, 2002).

Figure 3: Aspects of Ways of Thinking and Practising in Biology



Aspects of Ways of Thinking and Practising in Biology after (Hounsell, D, McCune V.,, 2002; QAA, 2002)

No single design could seriously pretend to address all these objectives. We will try and focus on a few major objectives that in our opinion need special attention in modern biology teaching.

Biology IT-induced change vs. didactic use of IT for teaching biology

Biology is undergoing a major change from a physico-chemically-based reductionist paradigm (*in vitro*) towards an information science-based (IT-Rich biology, *in silico*) paradigm (NRC Committee on Undergraduate Biology Education to Prepare Research Scientists for the 21st Century, 2003). This change probably represents a paradigm shift (Kuhn, 1972) and has lead me to isolate 4 major aspects of IT-induced change in biology practice (F. Lombard, 2007) which accounts for 30 to 70% of most biologist's time.
(1) Bioinformatics, nucleotide or protein sequence databases and management.
(2) Other databases : GIS, Systematics etc
(3) Systems Biology & simulations
(4) Information management
Clearly new ways of experimenting, data processing, building knowledge, publishing have emerged from within biology. They do not replace previous forms of, but enhance current biology.
If this new IT-Rich Biology is of importance to understand this design's context, it is not the focus of this article. Also it should not be confused with the *didactic use of IT* for teaching (François Lombard, 2007; Schneider et al., 2003). However we do believe that IT-supported pedagogical designs are more efficient than others as we shall argue later.

Research objectives

Amongst all the general goals of this design, many are specific to IT-biology education, so I shall discuss here the more generally relevant design goals. Our aim is to foster :
- Better in-depth understanding of science processes (rather than rote learning).
- Better capability for knowledge building in an environment of current hypotheses rather than certainty.
- Evolution of student's epistemic understanding (Notion Of Science (NOS)).
- Empowering students for high-level knowledge-building in information-dense environments.

How a design embodying these objectives could be created, and how to tune it in a way that enhances these outcomes are the research questions. So far we have already chosen a design called Inquiry Based Learning and are now researching how this design can be adapted to embody the conjectures. First results reveal this implies striking a delicate balance among many trade-offs we will discuss in this article.

Inquiry Based Learning

Refined over five years, this design can be classified as a form of Inquiry Based Learning. "Inquiry" has been officially promoted as a pedagogy for improving science learning in many countries (Hounsell & McCune, 2002; NRC National Research Council, 2000; Rocard et al., 2006). Inquiry can be defined as "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"(Linn, Davis, & Bell, 2004). It is often touted as a way to implement in schools the scientific method: "The crucial difference between current formulations of inquiry and the traditional "scientific method" is the explicit recognition that inquiry is cyclic and nonlinear." (W. A. Sandoval & Bell, 2004) p. 216. However, we use *Inquiry Based Learning* in a more specific manner, referring to a specific teaching model : an iterative process of (1) question eliciting activities, (2) active investigation by students, (3) creation (in this case Wiki documents), these are (4) discussed already at early stages of the process, leading to (5) reflection about knowledge and the learning process, which in turn leads to new and refined questions (1) and the process goes on for another cycle.

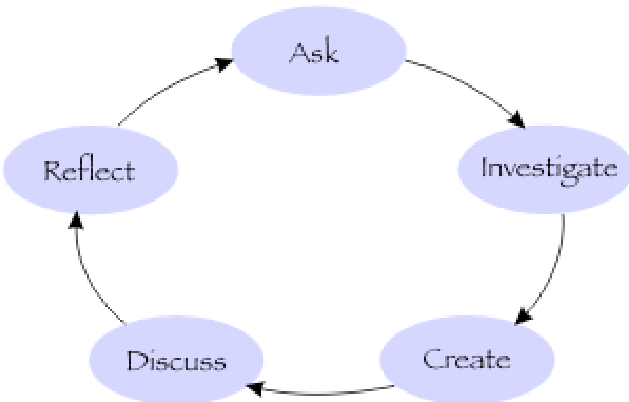


Fig 1 : The canonical Inquiry Based Learning cycle
Source : The Inquiry Page http://inquiry.uiuc.edu/

We will describe the design in terms of the individuals that participate, the activities that they engage in, the roles they assume, the resources that they make use of and the groups they form (Kobbe, 2006).

The design

The students were high school biology students of various levels, but mostly final year (18-19 year old) students in a biology major course in Geneva. The curriculum is divided in chapters, and for each chapter, students worked in groups of 4 on a subtopic, chosen to be slightly overlapping. Each group was responsible for one document: a Wiki page in which questions were collected and answers were recorded as they were found. The pages were progressively structured according to a template. The whole class produced a collection of Wiki pages that were printed at the end of each chapter as a brochure of 20-30 pages. This brochure was framed as help for the students themselves to prepare exams. During lessons, students spent a large share of their time searching in books, experimenting, observing, etc to answer assigned questions. Once the student have searched for a few hours, they present to the whole class the state of their current knowledge, stating the questions they pursue, how they found answers, what they know, what they don't know yet and how they plan to learn that. This leads to refining the questions, re-defining the sub-topics each group tackles and new emerging questions. The groups then deepen investigation and the cycle is repeated. Most often, 2 cycles could be achieved and the last cycle ends with a final presentation, (which was more geared on final understanding of knowledge than the first). Resources include a general biology textbook, specialized academic books, experimental equipment, field observations, selected Internet on-line-books or resources and Internet access to many resources such as Wikipedia.

A few methodological points

We adopted a Design Based Research (DBR) framework (Design Based Research Collective, 2003), for both ethical reasons and adequacy to our research objectives. Indeed, DBR, in which the design itself is the object of research allows the classroom to benefit form the best available design research can provide (Brown, 1992) while gaining valuable insight into research questions.

> Central to the enterprise is that the classroom must function smoothly as a learning environment before we can study anything other than the myriad possible ways that things can go wrong. Classroom life is synergistic: Aspects of it that are often treated independently, such as teacher training, curriculum selection, testing, and so forth actually form part of a systemic whole. Just as it is impossible to change one aspect of the system without creating perturbations in others, so too it is difficult to study any one aspect independently from the whole operating system. Thus, we are responsible for simultaneous changes in the system, concerning the role of students and teachers, the type of curriculum, the place of technology, and so forth. These are all seen as inputs into the working whole. Similarly, we are concerned with outputs from the system, a concern that -leads us to look at new forms of assessment. It is essential that we assess the aspects that our learning environment was set up to foster, such as problem solving, critical thinking, and reflective learning. Assessment also allows us to be accountable for the results of our work to the children themselves, to parents, to teachers, to local authorities, and, last but not least, to fellow scientists. Another critical tension in our goals is that between contributing to a theory of learning, a theoretical aim that has always been a keystone of our work, and contributing to practice. This is intervention research designed to inform practice.(Brown, 1992)

Its worth noting that the since the design itself is the focus of the research, it acknowledges fully the fact that the teacher's behaviour is also changed by the design as it evolves. Rather than being a problem (dependant variables should be limited) as in classical research, this is seen as a feature of the design and - when favourable - such effects are sought.
The aim is both to gather scientific findings for research (as this is part of my doctoral research) and refining the design while identifying design rules for biology education, especially IT-rich biology.

Since in DBR the design itself is the object of research, the data collected and analyzed relates to the effects of design features, i.e. *conjectures* as described by (W. A. Sandoval, 2004). Based on my objectives and the literature on science education, I have identified a dozen conjectures and will shortly discuss here a few.
(1) Helping the students build their knowledge in an activity geared towards a meaningful goal should allow them to develop better in-depth understanding of science processes (rather than rote learning) (De Vecchi, 2006; Giordan, 1998).
(2) Iteratively building a meaningful, clearly focused and significant document as writing-to-learn (Scardamalia, 2004) theories suggest, should help empowering students for high-level knowledge-building in information-dense environments.
(3) Cooperative writing activities, in an appropriate shared writing space (wiki), should help them build in-depth knowledge, by allowing idea confrontation (Socio-cognitive conflict (Astolfi & Develay, 2002; David Hammer, 1996; Joshua & Dupin, 1993; W. A. Sandoval, 2003))
(4) Presenting the state of their current knowledge at early stages should help students learn to work with knowledge "in an environment of current hypotheses rather than certainty".

(5) Assigning the teacher a tutor role, and finding the scientific authority to validate knowledge in experiments or high level resources (books, scientific articles, etc.) should develop scientific knowledge building, i.e."that all knowledge is related to observation or experiment". (William A. Sandoval & Daniszewski, 2004)

Data collection and analysis

One major source of data is Wiki *history* data : the Wiki server automatically records practically all versions of the text, and which allows retrieving previous states of the pages.
These records are called "history" and can be used for research purposes as well as for pedagogy, such as comparing versions to help students become aware of progress.
Students answered questionnaires, during their learning process, and later on, at the university. These questionnaires gave information on the perceptions of students about their knowledge, the learning methods and the design.
In a few cases, in-training teachers attended the course and kept journals or other records. These gave a different point of view on the events in the classroom, and were discussed. They helped formulate and to adjust some of the conjectures. They also gave opportunities to view the teacher as a variable of the system rather than as the main cause of what happens in class.

Time frame of analysis

The history of each Wiki document could be analyzed for changes of the same group working on the same document across a few weeks : we call this *stratigraphic* analysis.
As each class –and the teacher - works through the whole year, the successive Wiki documents recorded could be compared : we call this *yearlong* analysis.
Over the years, data accumulated of successive iterations of Wiki documents about the same curriculum gave information about the evolution of the design : we call this *longitudinal* analysis.
The uses of various resources along stratigraphic, yearlong, and longitudinal axis were partly recorded, and the use of specialized academic books, internet resources, etc. can be retrieved from the bibliographic references in the Wiki pages.

Preliminary findings

(1) Sharing a collaborative writing space helped to bridge discontinuous student investment, consolidating student's learning efforts around a collective production. Student productions' quality increased clearly in terms of the type of questions addressed (from mostly descriptive to explanations of biological processes), and in terms of focus and clarity.
(2)Wiki's informal structure and simple learning curve helped students focus on building their knowledge rather than summarizing definitive knowledge produced by others. The students became aware of the potential of writing –collaboratively- to structure and scaffold the development of knowledge in very information-rich environments. Wikis were found to encourage student homework by providing awareness feedback about other student's work. Wiki's informal structure, simple learning curve fits in well with the iterative "bricolage " approach of science.
(3) The collaborative writing space provided a ground for epistemic confrontation of students working on the same text, and presenting to others. The shared understanding of the goal of the document being created and it's destination appeared as crucial. They became aware of the assessing power of their own knowledge that presentations reveal.

(4) Collaborative writing and presentation helped students choose a more scientific way of validating knowledge (ideas are accepted through their ability to explain data or stand up to criticism, rather than because they are authoritatively ratified) and seeing science as dynamic.
(5) Goal oriented, question-driven iterative text composing favored building complex knowledge in info-dense environments; high school students were found capable of sifting through massive information sources and extracting specific information from high-level academic books, in addition to web, low-level textbooks and popularized science. Students became aware of the critical role of questions and having a meaningful writing goal to enable selection of information and building of knowledge.

What are the trade-offs of these design rules ?

We will present the most interesting design rules that structure the current design for discussion with the audience. The main trade-offs identified – clearly inspired by (William A. Sandoval & Daniszewski, 2004) – include:

- **Formal mastery of domain vs. developing student's ideas**.

Since curricula, school authorities and parents focus primarily on students acquiring knowledge, teachers are hard-pressed to ensure that they give students adequate and correct information. This leads to a *science of conclusions* and is stark contrast with science as a way of building knowledge where we "communicate to his students that their ideas are valuable scientific ideas and that ideas are accepted through their ability to stand up to or respond to criticism, rather than because they are authoritatively ratified" (William A. Sandoval & Daniszewski, 2004).

Valuing student thinking is often considered a loss of precious time leading to unsure results. There is a very difficult trade-off between giving time for the students to process data and attain conclusions and ensuring that the content of the curriculum has been "covered" (AAAS, 1993; Wooley & Lin, 2005) " …in teaching through inquiry teachers must manage trade-offs between their goals for students' formal domain mastery and students' inquiry goals. " (William A. Sandoval & Daniszewski, 2004)

- **Focus on document quality vs. on quality of the learning supported by this document**.

For various reasons including the large visibility of internet documents, and teacher professional image, (Horman, 2005; Martel, 2005) many teachers using internet-based writing tools are afraid that errors in student-created pages might be seen as a sign of inadequacy of the teacher. This often leads the teacher to take great care that the published document is of high quality. But this takes the focus away from the great educational potential of the process by which learning is produced : the way the students progressively and collectively author pages and how that leads to learning. It can also lead to a teacher revising them so much that the students relinquish control on them and lose motivation (Ryan & Deci, 2000).

- **Accessible, easy to understand resources vs. authentic resources**.

Most teachers seem to consider it their role to simplify complex scientific knowledge into a simple accessible form.

> "The greatest intellectual sin that we educators commit is to oversimplify most ideas that we teach in order t make them more easily transmissible to learners. In addition to removing ideas from their natural contexts for teaching, we also strip ideas of their contextual cues and information and distill the idea to their "simplest" form so that students will more readily learn them. But what are they learning? That knowledge is divorced from reality, and that the world is a reliable and simple place. But the world is not a reliable and simple place, and ideas rely on the contexts they occur in for meaning " p.8 (Jonassen, 2003)

On the other hand access to *authentic* data and tools, through the web or otherwise (authenticity is increasingly relevant to IT-rich science anyway (F. Lombard, 2007)), is generally acknowledged to increase learning (D. Hammer, 1997). Of course these are generally more complex, in different formats or degrees of complexity and generally more complex to handle.
- **Popularizing science vs. empowering students to face complex information**. High quality textbooks or web sites now including great pictures, easy to read text, and brilliant, synthetic diagrams certainly help reluctant students get involved into documents. Furthermore, media or scientific magazines often encourage a vision of science teaching as popularizing. On the other hand, giving access to authentic original but complex resources allows students to build their own synthesis and that probably is what allows proper knowledge building.

> [...] the individuals learning the most in this classroom are the professors. They have reserved for themselves the very conditions that promote learning: actively seeking new information, organizing it in a meaningful way, and having the chance to explain it to others (Huba & Freed, 2000)

Of course, using authentic data and tools is often more risky, it is more difficult to get these into classrooms (although IT has changed some of that), and it puts great demands on the skills that have to be developed by students (F. Lombard, 2007). These skills often were not even part of teachers training.
- **Teacher authority vs. student empowerment.** As we move the focus from teaching and resources to students and activities, the role of the teacher changes from a scientific authority, a knowledge-giving *professor* to a guide amongst a rich world of resources. Of course this role is less authoritative and less center-stage ! Although probably all teachers would agree to the need for empowering students and giving them autonomy, few really accept relinquishing control, a sometimes captive audience and aura of classical teaching.

Conclusion

Our findings suggest that Wikis can be used as effective cognitive tools in an IBL design geared towards knowledge building, contributing importantly to develop scientific thinking.
If we want students to build knowledge in a scientific way, we should teach them how to formulate and express their ideas. And create opportunities to confront them to experimental data, literature and argument so as to decide of their validity.
By supporting collaborative writing activities and encouraging epistemic confrontation such designs can offer opportunities to develop true scientific knowledge building in students, favor in-depth understanding of science processes, and evolve student's epistemic understanding of science (Notion Of Science (NOS)).
This design affords a crucial role to student-owned questions for focusing the inquiry, epistemic confrontation and wading the info-dense environment. Teaching students a knowledge-building strategy empowers them in a world in which knowledge creators are favored over passive information consumers.
Because we are moving towards an information society (Bindé & UNESCO, 2005), an inescapable change is happening to information access, and that has implications for education: the web, media and other IT sources constantly bathe students in a flow of information: therein lies both an opportunity to learn and to confront what school traditionally teaches. This is a problem in a rigid view of education, but a fantastic opportunity if we find ways to help ourselves and our students to build knowledge out of this indiscriminate shower of information.

If IT is clearly one of the causes of the information overload problem, certainly some of the solutions are to be found in using some of these same IT tools to enhance learning rather than dissolve it. "No longer is information itself power; rather, power is gained from the ability to access the right information quickly. " (NSF, 2006)

Isn't it the school's responsibility to teach our students how to face the information overload and build their knowledge in a technological world rather than complain about the shortcomings of the way they use these technologies.

After (Duchâteau, 1992) compared e-documents given to students with bottles and learning as the absorption of their contents, I would like to defend the idea that the documents created by the students (e.g. in the Wiki) is of no value by themselves, it is the writing process that can – under appropriate conditions - lead to knowledge building : the wiki document, like an empty bottle, can be disposed of once it's contents have been assimilated.

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Sources :

AAAS. (1993). *Project 2061, Benchmarks for Science*. Washington: American Association for the Advancement of Scienceo. Document Number)

Astolfi, J.-P., & Develay, M. (2002). *La didactique des sciences* (6e éd. mise à jour ed.). Paris: Presses universitaires de France.

Bindé, J., & UNESCO. (2005). *Towards knowledge societies : UNESCO world report* (No. 923204000X). Paris: UNESCO. (P. UNESCO o. Document Number)

Brown, A. L. (1992). Design Experiments: Theoretical and Methodological Challenges in Creating Complex Interventions in Classroom Settings. *The Journal of the Learning Sciences, 2*(2), 141-178.

De Vecchi, G. (2006). *Enseigner l'expérimental en classe : pour une véritable éducation scientifique* Paris: Hachette éducation.

Design Based Research Collective. (2003). Design-Based Research: An Emerging Paradigm for Educational Inquiry. *Educational Researcher, 32*(1), 5-8.

Duchâteau, C. (1992). L'ordinateur et l'école ! Un mariage difficile ? *Publications du CeFIS, 5*(28).

Giordan, A. (1998). *Une didactique pour les sciences expérimentales*. Paris: Belin.

Hammer, D. (1996). More than misconceptions: Multiple perspectives on student knowledge and reasoning, and an appropriate role for. Education research *American Journal of Physics, 64*(10), 1316-1325.

Hammer, D. (1997). Discovery learning and discovery teaching. *Cognition and Instruction 15*(4), 485-529.

Horman, J. (2005). *Une exploration de l'interaction sociale en ligne lors de la réalisation d'activités d'apprentissage collaboratif dans deux espaces interactifs: un site internet et des wikis.*, Université Laval.

Hounsell, D., & McCune, V. (2002). *Teaching-Learning Environments in Undergraduate Biology: Initial Perspectives and Findings* Edinburgh: Economic & Social Research Council, Department of Higher and Community Educationo. Document Number)

Huba, M. E., & Freed, J. E. (2000). *Learner-Centered Assessment on College Campuses: Shifting the Focus from Teaching to Learning*. Needham Heights, MA Allyn & Bacon.

Jonassen, D. H. (2003). *Learning to Solve Problems with Technology: A Constructivist Perspective*. Upper Saddle River NJ USA: Merrill Prentice Hall.

Joshua, S., & Dupin, J. J. (1993). *Introduction à la didactique des sciences et des mathématiques*. Paris: Presses Universitaires de France.

Kobbe, L. (2006). *Framework on multiple goal dimensions for computer-supported scripts*: Knowledge Media Research Center (KRMC)o. Document Number)

Kuhn, T., S. (1972). *La structure des révolutions scientifiques*. Paris: Flammarion.

Linn, M. C., Davis, E. A., & Bell, P. (2004). Internet Environments for Science Education.

Lombard, F. (2007). Du triangle de Houssaye au Tétraèdre des TIC : Comment l'analyse des productions TIC permet d'approcher une compréhension des interactions entre les savoirs d'expérience et de recherche(Contribution au REF03). In B. Charlier & D. Peraya (Eds.), *Les technologies éducatives : une opportunité d'articuler les savoirs d'expérience et ceux issus de la recherche ?* . Bruxelles: De Boeck.

Lombard, F. (2007, 24-28 Avril 2007). *L'actualité de la biologie : vulgariser ou autonomiser ?* Paper presented at the JIES : XVIIIes Journées internationales sur la communication, l'éducation , la culture scientifiques techniques, et industrielles, Chamonix.

Martel, V. (2005). *Émergence d'une communauté d'apprentissage en réseau à l'ordre primaire [ressource électronique]: l'activité de transformation d'un environnement d'apprentissage par la direction, les enseignants et les élèves (étude de cas).* Université Laval, Laval.

Modell, H. I. (2000). How To Help Students Understand Physiology? Emphasize General Models. *Advan. Physiol. Edu., 23*(1), 101-107.

NRC Committee on Undergraduate Biology Education to Prepare Research Scientists for the 21st Century. (2003). *BIO2010: Transforming Undergraduate Education for Future Research Biologists* (No. ISBN: 0-309-08535-7): National Research Council o. Document Number)

NRC National Research Council. (2000). *Inquiry and the National Science Education Standards. A Guide for Teaching and Learning*: National Acadmies Press.

NSF. (2006, May 24-26, 2006). *Reconsidering the "Textbook".* Paper presented at the Reconsidering the "Textbook", Washington.

Rocard, M., Csermely, P., Jorde, D., Lenzen, D., Walberg-Henriksson, H., & Hemmo, V. (2006). *Science education Now : a renewed pedagoy for the future of Europe*. Bruxelles: OECD EUROPEAN COMMISSION o. Document Number)

Ryan, R. M., & Deci, E. L. (2000). Self-Determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-Being *American Psychologist 55*(1), 68-78.

Sandoval, W. A. (2003). Conceptual and Epistemic Aspects of Students' Scientific Explanations. *Journal of the Learning Sciences, 12*(1), 5-51.

Sandoval, W. A. (2003, June 2004). *The inquiry paradox: why doing science doesn't necessarily change ideas about science.* Paper presented at the Sixth Intl. Computer-Based Learning in Science Conference 2003 Nicosia, Cyprus.

Sandoval, W. A. (2004). Developing Learning Theory by Refining Conjectures Embodied in Educational Designs. *Educational Psychologist, 39*(4), 213-223.

Sandoval, W. A., & Bell, P. (2004). Design-Based Research Methods for Studying Learning in Context: Introduction. *Educational Psychologist, 39*(4), 199-201.

Sandoval, W. A., & Daniszewski, K. (2004). Mapping Trade-Offs in Teachers' Integration of Technology-Supported Inquiry in high School Science Classes. *Journal of Science Education and Technology, 13*(2).

Scardamalia, M. (2004). CSILE/Knowledge Forum®. *Education and technology: An encyclopedia*, 183-192.

Schneider, D., Class, B., Catherine, F., Girardin, F., Lombard, F., Morand, S., et al. (2003, Juin 2003). *Conception et implémentation de scénarios pédagogiques riches avec des portails communautaires Les communautés virtuelles éducatives.* Paper presented at the second colloque de Guéret.

Sears, H., & Wood, E. (2005). Linking Teaching and Research in the Biosciences. *Bioscience Education e-journal (BEE-j), 5*.

Wooley, J. C., & Lin, H. S. (2005). *Catalyzing Inquiry at the Interface of Computing and Biology. Committee on Frontiers at the Interface of Computing and Biology, National Research Council*: National Academies Presso. Document Number)

Wright, R. L., & Klymkowsky, M. W. (2005). Points of View: Content versus Process: Is This a Fair Choice? *Cell Biology Education, 4*, 189-198.