The Tension Between HyperText Environments and Science Learning

by

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Introduction

Subversive Software Design and Constructivism

In science education there is no dearth of research around the benefits of constructivist teaching and learning (Brooks & Brooks, 1993). In addition, within the realm of educational technology much work continues to focus on constructivism (Perkins, 1991; Jonassen, 1994; Greening, 1998). It would seem that there may be potential to marry science education with computer technology under the umbrella of constructivist learning experiences.

Software can be designed for science education, however in preparing the software the author is likely to have a particular curriculum agenda which include objectives and sequence of learning. Does this not defeat the purpose of creating constructivist-learning environments? How can the designer possibly account for prior learning or allow students to build their own understandings in meaningful ways?

Inherent in structuring software the author inadvertently may be destroying any notion of constructivist learning.

There may be hope. Squires (1999) has suggested that instructors often subvert the focused software intents and utilize the software in original capacities that meet their own objectives. He further recommends that software can be prepared which presumes that the instructor will subvert the intended use. He coins this approach "volatile design."

The Influence of Constructivism on the Design of Software

For this action research project, software was designed (MacKinnon & Forsythe, 1999) for the purposes of teaching a grade 12 chemistry unit on acids and bases. The software was prepared around a group of foundational constructivist ideas noted in the literature (Dick, 1991; Duffy & Jonassen, 1991; Greening, 1998; Merrill, 1991; Osborne, 1996; Perkins, 1991; Willis & Wright, 2000).

The issue of designing constructivist instructional environments has prompted Savery & Duffy (1995) to offer the following guidelines:

1. Anchor all learning activities to a larger task or problem.
2. Support the learner in developing ownership for the overall problem or task.
3. Design an authentic task.
4. Design the task and the learning environment to reflect the complexity of the environment they should be able to function in at the end of learning.
5. Give the learner ownership of the process used to develop a solution.
6. Design the learning environment to support and challenge the learner's thinking.

Table 1 demonstrates how we have attempted to address these guidelines.

Table 1

Design Features of the Software

Guideline	**Response as manifested in the IIT model**
1	A unit challenge acid-base problem serves as an umbrella task.
2	The teacher assists the learner by applying closure to topics.
3	The unit challenge as well as problems embedded in the unit are based on real data from authentic chemistry settings.
4	The unit challenge is a multicomponent-multidimensional task which can only be successfully completed by careful consideration of the entire unit of study
5	Through use of a hypertext environment students have the flexibility to address topics both sequentially and in a non-linear fashion. The pace and order of study is only confined by pre-set curricular deadlines
6	Because the role of teacher has been shifted away from presenter of knowledge, there is greater opportunity to challenge/assist individual students at their level of conceptual understanding.

More recently Greening (1998) has been critical of the purely academic and theoretical discussions of the constructivist movement and joins Osborne (1996) in recommending we turn our attention to pragmatic issues and realist approaches based on the constructivist notion. Greening (1998) develops an argument for sound pedagogical application of constructivism to instruction based on the learning principles forwarded by Koschmann, Myers, Feltovich & Barrows (1994). These include the following:

1. The concept of “multiplicity” that suggests that learning should reflect the complex nature of knowledge by using multiple approaches in perspective.

2. The concept of "activeness" that suggests that learning should evoke a desire or need to know and thus promote an aggressive and active process of self-direction, goal setting, problem-finding and solving.
3. The concept of "accommodation" where students are challenged to accommodate new experiences in light of existing cognitive structures (Posner, Strike, Hewson & Gertzog, 1982).
4. The concept of "articulation" relates to settings that encourage presentation of knowledge at a level of abstraction which promotes articulation of ideas by learners and subsequent critical analysis by peers in a positive non-competitive environment. This results in negotiated shared understandings.
5. The concept of "termlessness" highlights the importance of appropriate use of technologies to develop instruction which puts emphasis on the learning of processes rather than a product-oriented approach. In a practical sense technology doesn't always communicate the ideas better; we should be discerning our applications.

Table 2 demonstrates how these concepts have influenced the design of this IIT model.

Table 2

Design Features of the Software

Concepts	**Response as manifested in the IIT model**
1	Students are engaged in a diverse series of activities. The computer serves to direct and organise the learning setting.
2	Because students control the learning environment, there is flexibility to explore topics of special interest outside the realm of the provincial curriculum.
3	Within the content presented students existing schema are challenged. The unit challenge provides an opportunity for restructuring of knowledge on a regular basis as students build their concepts.
4	Students are working in groups of three where they continually negotiate meaning and articulate understandings to each other.
5	In past research the computer has been used to deliver entire tutorial-based learning packages. This work represents a marked departure from that model in that the computer suitably organises the learning space and directs students to partake in a diverse range of activities including laboratories, library research, etc.

The Integrated Interactive Technology Model (IIT): An Action Research Project

A study was undertaken over 16 weeks with two classes of 15 students each. The classroom was fitted with six computers (IBM 486 DX 66, 48 MB RAM).

While the value of co-operative learning settings has long been recognised (Kagan, 1992), more recent research (Johnson & Johnson, 1996) has linked innumerable benefits to co-operative learning and the use of technology. Coupled with the growing trend to maximize the use of limited computer resources (Dockterman, 1997), a choice was made that the students in the IIT model engage the acid-base chemistry unit in groups of three.

Often the terminologies “interactive software” or “software integrated into the curriculum” have various implications (Reidl, 1995; Rose, 1999). In the context of this research, the unit of study followed a model where the computer served as an introducer of topics, a prompter of activities and generally an organisational tool. It should be noted that the model is not necessarily sequential nor cyclical as presented. Students have the flexibility to enter and leave the software environment at chosen junctures through a hypermedia interface. This ensures students can be working on different curriculum simultaneously and in turn promotes more efficient use of minimal computer resources. Figure 1 clearly indicates that the software in fact is not intended for standalone use. Students are actively engaged in a variety of activities away from the computer.

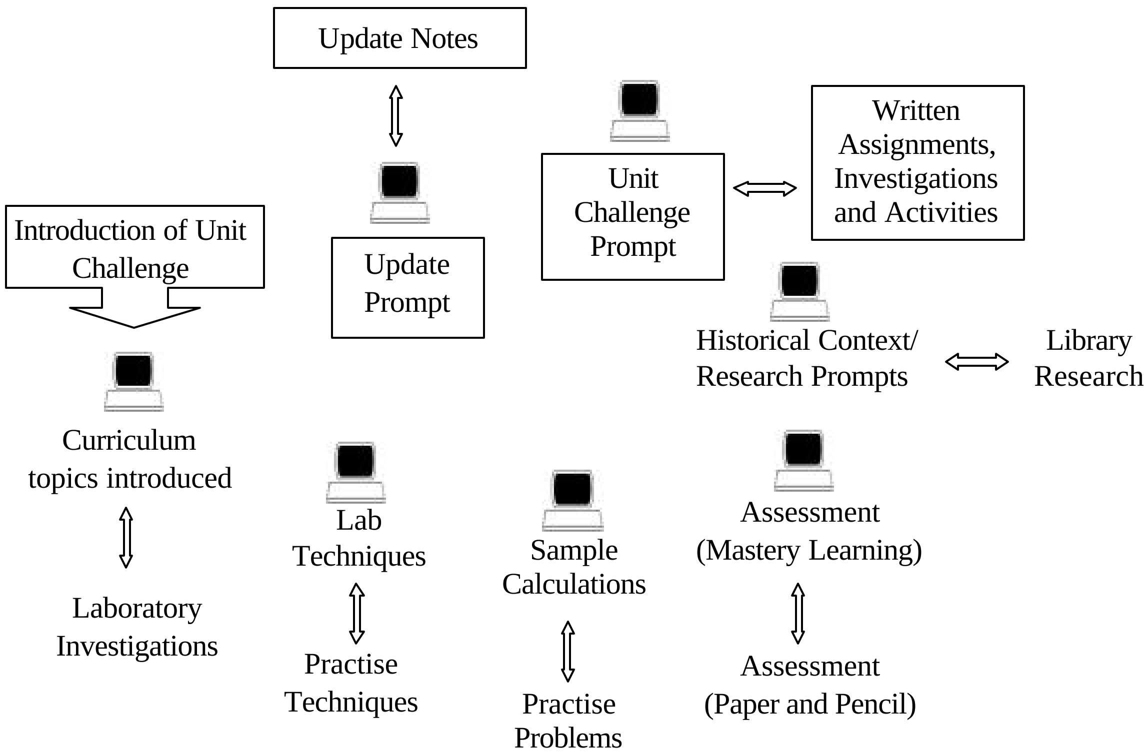

Figure 1. The integrated interactive technology model.

A crucial component of this instructional system taps into the established benefits of problem-based learning. Savery & Duffy (1995) contend that "The more the problem-solving learning situation represents the real world, the more likely the student will transfer skills to other problem solving situations. . . . This can be done by anchoring learning in meaningful contexts which simulate apprenticeship learning." (p. 41) Building on situated cognition (Carr, Jonassen, Litzinger & Marra, 1998), encourages the creation of fruitful generative learning environments (Cognition & Technology Group at Vanderbilt, 1991; Grabowski, 1996) where reasoning and sustained exploration are the foci.

At the onset of the instruction, students were supplied with an authentic and relevant acid-base problem (pH of a local lake). This is referred to as “the unit challenge.” Students at the computer, (see Figure 1) were introduced to: (1) new theoretical topics, (2) lab techniques through video clips and pictures, (3) sample calculations, (4) assessment in the form of mastery learning exercises, (5) historical context for the topics. Away from the computer, (see Figure 1) students engaged in: (1) laboratory investigations, (2) practising lab techniques, (3) practise problems, (4) paper and pencil assessment, (5) library research, and (6) assignments, investigations and activities. As students progressed through theory and practise, both at and away from the computer, they periodically revisited the problem and constructed new understandings about how to solve the problem. This was accomplished by computer prompts that sent students away to consider the application of learned theory and to update their "unit challenge" notes.

The Hypertext Environment

The entry interface screen is shown in Figure 2. From this hypertext screen, students could access any individual component of the unit’s content. You will note that the user interface is a timeline. This further serves to provide context for students as they study the history of acid-base chemistry. Research has shown that a well-organised interface and adequate preliminary instruction allows students to become very comfortable with the software. This promotes a “transparent technology” in terms of their learning (Adrianson & Hjelmquist, 1993). Advanced organisers have been linked to better retention and comprehension of instructional content (Ausubel, 1960; Mayer, 1979). Hypertext menuing systems have the additional advantages of (1) promoting open-ended environments for learning (Hannifin, Hall, Land & Hill, 1994), and (2) promoting self-regulating learning behaviours in students (Shin, 1998).

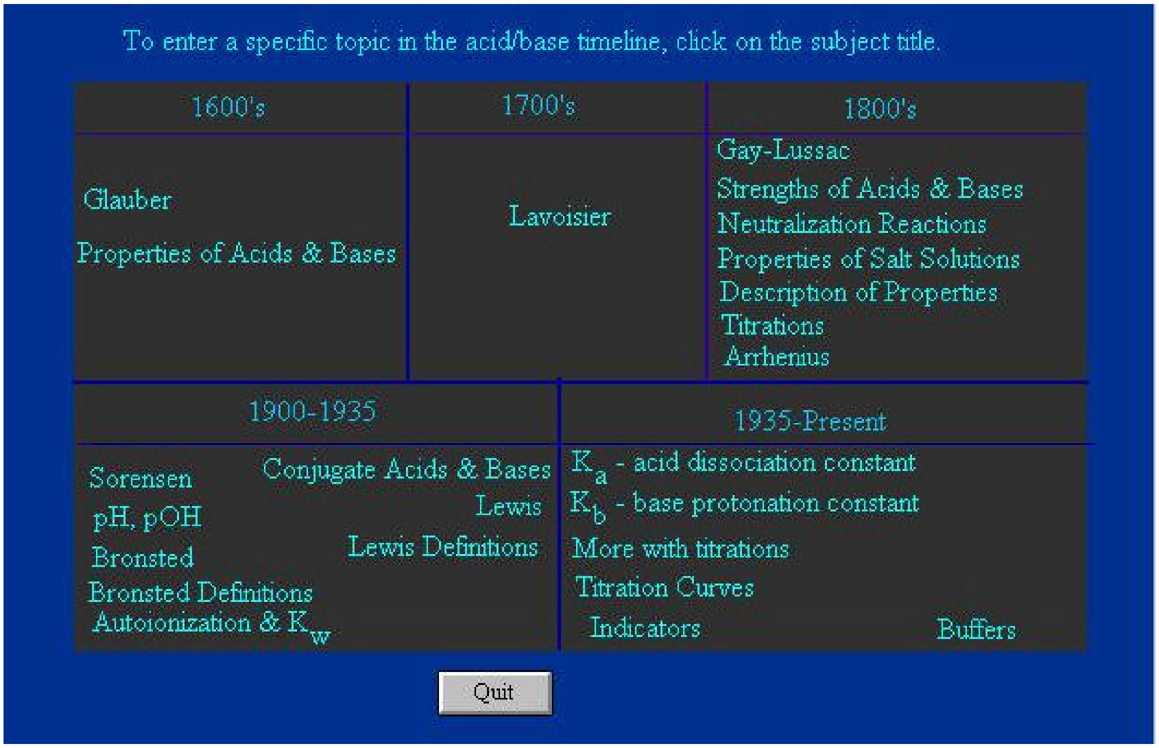

Figure 2. Timeline user interface.

The Value of Hypertext Environments?

There are continued warnings to educators of the “excessive optimism” (Selwyn, 1997) that accompanies computer usage in public schools. Meanwhile there remains considerable encouragement in the literature that we are moving beyond what Beynon and Mackay (1989) term a “techno-romantic” period in the study of computer impacts on education. Means (1994) has suggested that computers have the potential to encourage both higher order learning and act as a vehicle for educational reform. One rapidly growing application is that of hypertext environments (Kearsley, 1988). These settings offer students considerable flexibility to access a variety of media as they organise their ideas in novel ways. Friedlander (1989) is supportive in his assertion that "by encountering the same materials in a variety of modalities, students grasp the richness and depth of the material. They also extend and refine their own capabilities, becoming better viewers, creators and critics." (p. 38) In speaking specifically of hypermedia, Berger, Lu, Belzer, and Voss (1994) claim, "by giving students a tool that allows them immediately to gratify their intellectual curiosity through exploration, hypermedia turns students into active learners rather than passive receivers of knowledge." (p. 479) Moreover, Marsh and Kumar (1992) have specifically identified the following benefits of hypermedia:

1. Knowledge construction, active learning and learner control of learning.
2. Non-linear knowledge exploration in an all-inclusive medium. A wide variety of resources can be included in the hypermedia environment.
3. Facile integration of science and technology concepts and issues.
4. The overview of an omni–directional knowledge system can be presented.

And says Kearsley (1988) "hypertext matches human cognition . . . hypertext should improve learning because it focuses attention on the relationships between ideas rather than isolated facts." (p. 23)

The preponderance of claimed positive attributes of ready information access are balanced with comments of caution. While Roselli (1991) would concur that "this kind of environment obliges the learner to make decisions continually and to assess constantly his state of progress, forcing him to apply higher-order intellectual powers," (p. 42) she has concurrently recognised a problem of "user disorientation" which accompanies hypertext systems. Not only do learners find themselves confused in a quagmire of information but may have a tendency to experience "conceptual disorientation" in which they lose their initial conceptual focus as they explore the information network (Marchionini, 1989; Roselli, 1991). Friedlander (1989) warns software developers that, "the temptation is to make the system so free and interactive that users have complete control at every moment. While this is a praiseworthy goal, users can often feel bewildered and overwhelmed by choices and uncertainty." (p. 36)

What Happened in the IIT Model?

A plethora of data (both qualitative and quantitative) were collected on the IIT setting the sequence of which is shown in Table 3a and 3b. From these sources it was easily possible to triangulate the findings of the study.

Table 3a

Data Collection Sequence

Week 1

- Survey 1 “Experiences with Computers”
- Interview 1 with students “unpacking the experiences and preliminary attitudes”
- Interview 1 with teacher “unpacking the experiences and preliminary attitudes”
- Field Notes: 5 days x 3 hours per day observing students working in IIT system
- Discussion of Teacher Notes and Member Check (corroborating interview transcripts and survey findings)
- Daily Progress Reports from students (hardcopy)

Week 2

- Survey 2 “Learning Styles”(preferred modes of learning, work ethic, course expectations, expectations of education in general)
- Field Notes: 5 days x 3 hours per day observing students working in IIT system
- 15 hours of audio/video taped group work
- Discussion of Teacher Notes and Member Check (corroborating interview transcripts and survey findings)
- Peer Debriefing with a professional colleague
- Daily Progress Reports from students (hardcopy)

Week 3

- Survey 3 “Student Attitude Towards Project and IIT Approach”
- Interview 2 with students “interim attitudes” a follow up on survey
- Field Notes: 5 days x 3 hours per day observing students working in IIT system
- 15 hours of audio/video taped group work
- Discussion of Teacher Notes and Member Check (corroborating interview transcripts and survey findings)
- Daily Progress Reports from students (hardcopy)

Week 4

- Interview 2 with teacher “Interim Report of Progress”
- Field Notes: 5 days x 3 hours per day observing students working in IIT system
- 15 hours of audio/video taped group work
- Discussion of Teacher Notes and Member Check (corroborating interview transcripts)
- Peer Debriefing with a professional colleague
- Daily Progress Reports from students (hardcopy)

Table 3b

Data Collection Sequence Week 5-8

Week 5

- Teacher asked to identify observed "higher–order thinking skills
- Field Notes: 5 days x 3 hours per day observing students working in IIT system
- 15 hours of audio/video taped group work
- Discussion of Teacher Notes
- Daily Progress Reports from students (hardcopy)

Week 6

- Concept Map Activity (students asked to map the curriculum to date)
- Students asked to identifying aspects of "higher–order thinking skills" in their work.
- Students asked to identify routes to solving problems.
- Field Notes: 5 days x 3 hours per day observing students working in IIT system
- 15 hours of audio/video taped group work
- Discussion of Teacher Notes
- Daily Progress Reports from students (hardcopy)
- Member Check with students with regard to a) concept mapping, b) identifying thinking skills and c) identifying problem-solving strategies

Week 7

- Survey 4 "Satisfaction With the Unit Approach"
- Interview 3 with students (as above) "Satisfaction With Unit Approach"
- Interview 3 with teacher "Satisfaction With Unit Approach"
- Field Notes: 5 days x 3 hours per day observing students working in IIT system
- 15 hours of audio/video taped group work
- Discussion of Teacher Notes and Member Check (corroborating transcripts of interviews and survey findings)
- Daily Progress Reports from students (hardcopy)

Week 8

- Project Matrix: students asked to identify knowledge, attitude, feelings, skills and interpersonal growth (Before, During After) project
- Field Notes: 5 days x 3 hours per day observing students working in IIT system
- 15 hours of audio/video taped group work
- Discussion of Teacher Notes
- Peer Debriefing: final meeting with professional colleague to discuss findings
- Final Member Check With Students re: the global findings of the study

From the aforementioned data, it was abundantly clear that, as students approached the software, they did so in a linear sequential fashion. Three questions emerge: (1) is this because of poor software design, (2) is this because of poor choice of unit content or (3) is it simply human nature to follow reading from beginning to end? These questions all relate to an assumption that hypertext environment would improve learning when in fact it may have little impact.

The acid-base software was accessed via a timeline. Though we were confident of the benefits of situating the science in real contexts through a historical timeline as well as vignettes (see Figure 3), recent literature (Allchin, 2000) suggests that this may be short-sighted in that students can't really appreciate the social dynamics of science "as it happened." The lessons in the software were constructed such that they were not necessarily dependent on each other as would be the case in teaching atomic structure followed by bonding for example. Despite this flexibility our students chose to follow without exception, the lessons in the order they appeared. It would seem that the hypertext environment was not useful to them in terms of the order in which topics were addressed. However in qualitative interviews certain attributes did emerge. Said one student "what I like about the software is that I can go back to the place I left off, say … when I miss a class." While another remarked "not only can I jump in where I left off but I can go back to ideas that I found difficult to understand… sometimes a new concept jogs me to think a different way about something I had seen earlier."

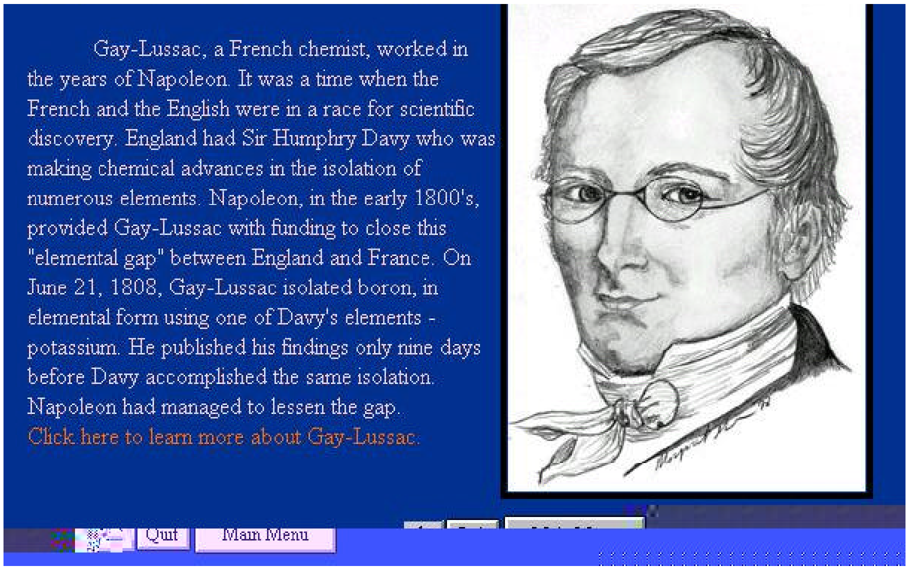

Figure 3. Historical vignettes.

Conclusions

Though it isn't clear that hypertext environments are particularly helpful to the students in this case study, in retrospect there may be aspects of this mode of learning that have gone untapped and could be consciously built into future IIT projects. Further work may address:

(1) It may not be crucial to avoid science units that conceptually build upon topics sequentially since students seem to default to following the historical time line in order anyway. In fact in focus group interviews students indicated that the learning "made more sense" while following the historical development in calendar-order.

(2) In that we face a wide range of learners, a hypertext environment has the potential to provide a variety of contextual problems that better match the variation in "reasons to learn."

(3) Hypertext learning environments could potentially offer students the opportunity to study a topic at different levels of sophistication thus better matching their prior learning, their experiences and time constraints associated with the unit.

(4) Hyperlinking within the software could address the topic at:

   a. The macro level including things that can easily be processed through the senses or,

   b. The micro level where structure and connections cannot easily be seen. An example of this might be the study of the cell. The software might present:

      I. The whole organization of the cell.

      II. The cell at the molecular level.

      III. The chemical and physical interactions of the cell

(5) The flexible nature of this software allows the teacher to use it as a framework for learning, an independent mastery learning exercise or simply as a classroom resource. We believe this is possible because of the intentional "volatile design" approach we used, which affords the teacher the opportunity to subvert any implied use.

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