Learners not Lurkers:

Connecting Conceptual and Social Networks in Science Education

Dr. Silvia d'Apollonia[1]

Dr. Suzanne Kunicki[1]

Professor Murray Bronet[2]

Dawson College[1], John Abbott College[2]

July, 23, 2015

La présente recherche a été subventionnée par le ministère de l'Enseignement supérieur, de la Recherche et de la Science dans le cadre du Programme d'aide à la recherche sur l'enseignement et l'apprentissage (PAREA).

PAREA Project Title: **Learners, not Lurkers: Connecting Conceptual and Social Networks in Science Education**

PAREA funding from August 2010 to July 2015

Report submitted July 28th, 2015

Principal Institution:

Dawson College

3040 Sherbrooke West

Montreal, QC, H3Z 1A4

Researchers:

Dr. Silvia d'Apollonia (principal researcher), Dawson College

Dr. Suzanne Kunicki (co-researcher, Dawson College

Professor Murray Bronet (co-researcher) John Abbott College

To contact researchers:

Silvia d'Apollonia sdapollonia@dawsoncollege.qc.ca

Suzanne Kunicki skunicki@dawsoncollege.qc.ca

Murray Bronet murray.bronet@johnabbott.qc.ca

Research project coordinator : Mme. Kaila Folinsbee, Coordinator of Research, Office of Instructional Development, Dawson College

Dépôt légal — Bibliothèque et Archives nationales du Québec, 2015
Dépôt légal — Bibliothèque et Archives Canada, 2015

ISBN 978-1-5501699-7-3

RÉSUMÉ

L'utilisabilité   Technologies du Web 2.0   Les médias sociaux   Les croyances des professeurs

Nos étudiants vivent dans un monde à la carte où ils sont branchés en permanence sur leurs pairs, leurs technologies, le contenu Web qui les intéresse. On les invite à partager, à collaborer, à créer. Cependant, quand ils entrent dans les cours de sciences, ils se retrouvent souvent dans un univers où ils ne sont plus branchés sur leurs pairs, sur les outils dont ils se servent habituellement et sur leurs ressources d'apprentissage (exception faite du conférencier). On exige d'eux qu'ils consomment, rivalisent et reproduisent « la connaissance donnée ». Pourtant, les technologies du Web 2.0 sont maintenant disponibles pour changer « l'enseignement des sciences » en « coconstruction des sciences » et transformer les observateurs en apprenants.

Dans ce projet, nous avons intégré la connaissance conceptuelle traditionnelle des cours d'initiation à la biologie et à la chimie dans l'environnement d'apprentissage du Web 2.0, ce que nous avons respectivement appelé *Biologie branchée* et *Chimie branchée.* Les questions que nous nous sommes posées étaient les suivantes :

1. Quel est le degré d'utilisabilité de *Biologie branchée* et de *Chimie branchée*? Ces applications sont-elles assimilables, mémorisables, efficaces, fiables et satisfaisantes?
2. Les étudiants qui utilisent les applications *Biologie branchée* et *Chimie branchée* développent-ils des réseaux conceptuels étendus sur les sujets à l'étude?
3. L'utilisation de *Biologie branchée* et de *Chimie branchée* améliore-t-elle le rendement scolaire des étudiants?

Nous avons élaboré un questionnaire comportant 20 questions sur l'utilisabilité afin de vérifier si l'application *Biologie branchée* était assimilable, efficace, mémorisable, fiable et satisfaisante. Trois des cinq composantes présentent une cohérence interne avec le coefficient alpha de Cronbach (assimilable, mémorisable et efficace) avec, respectivement, des résultats de 0,65, 0,67, et 0,56.

L'utilisabilité des applications Biologie branchée et Chimie branchée

Selon les étudiants, *Biologie branchée* s'est avérée nettement moins utile avec la division cellulaire qu'avec la structure cellulaire et l'évolution. Bien qu'ils aient été tout aussi satisfaits des trois sujets, ils ont trouvé dans ce cas l'application *Biologie branchée* moins assimilable, efficace, mémorisable et fiable. Cela pourrait refléter la difficulté inhérente à l'utilisation des ressources électroniques pour acquérir une compréhension de la division cellulaire, car il y a une forte composante de *réalisation* dans la compréhension de la division cellulaire.

Nous avons recueilli des Web analytiques de *Biologie branchée* à l'aide du service de suivi commercial Crazy Egg pendant toute l'intervention. Les étudiants ont visité *Biologie branchée* lorsque les sujets étaient étudiés en classe pour la première fois et pour réviser la matière avant les examens. Il semble qu'il y a eu un effet de nouveauté, les étudiants ayant visité *Biologie branchée* en grand nombre au commencement de l'intervention, puis moins souvent à mesure que le semestre avançait. Crazy Egg a fourni plusieurs visualisations sur la façon dont les étudiants ont utilisé l'application. Ces visualisations peuvent donner aux institutions des

indications sur la conception optimale d'un environnement d'apprentissage pour maximiser l'utilisation qu'en font les étudiants. Elles peuvent aussi renseigner les professeurs qui utilisent le Web 2.0, ainsi que les concepteurs, sur l'emplacement (en haut de la page) et le moment (en soirée) qui sont les plus favorables à l'acquisition des informations par les étudiants.

Biologie branchée couvre l'ensemble du cours d'introduction à la biologie, incluant des liens de navigation vers des exercices préparatoires, des cours (donnés dans des classes d'apprentissage actif), des exercices de renforcement, des liens vers des tutoriels externes et une activité comprenant des objectifs pour chaque sujet lié à un glossaire. Chaque élément correspondait à plusieurs outils du Web 2.0 : tests en ligne, réponses immédiates aux questions, images, vidéos et animations, activités Web internes et externes, mots croisés en ligne, activités de schématisation conceptuelle en ligne, etc. Nous avons recueilli des données sur trois sujets : la structure cellulaire, la division cellulaire et l'évolution. Les indices d'interactivité (nombre de clics/nombre de visites) pour la structure cellulaire, la division cellulaire et l'évolution étaient respectivement de 0,96, 0,84 et 1,37. Cela nous indique que les étudiants passaient d'abord par la page d'accueil pour suivre le lien vers les sujets. Une fois sur la page des sujets, ils se dirigeaient vers les éléments souhaités. Les étudiants étaient étonnamment méthodiques dans leur visite des éléments liés aux sujets. Ils visitaient rarement les liens de tutoriels (1,1 %) présentés dans ces pages et n'utilisaient pas non plus les boutons de navigation, préférant garder les pages ouvertes et naviguer en utilisant les onglets.

Les éléments ci-dessous contiennent plusieurs outils du Web 2.0. Nous nous sommes intéressés à la façon dont les étudiants ont utilisé ces derniers dans chaque élément.

- Dans l'élément **Objectifs et glossaire**, les indices d'interactivité (nombre de clics/nombre de visites) pour la structure cellulaire, la division cellulaire et l'évolution étaient respectivement de 0,1, 0,3 et 0,2. Les étudiants visitaient cet élément essentiellement pour lire les objectifs d'apprentissage, cliquant rarement sur les termes du glossaire (18 %).

- Dans l'élément **Exercices préparatoires**, les indices d'interactivité (nombre de clics/nombre de visites) pour la structure cellulaire, la division cellulaire et l'évolution étaient respectivement de 4,9, 7,7 et 12,2. Les étudiants utilisaient donc cet élément pour interagir avec le matériel. Ils ont également été plus interactifs si l'on considère la durée de l'intervention. Ils ont été méthodiques dans leur utilisation des outils du Web 2.0, utilisant principalement les exercices préparatoires pour cliquer sur les questions donnant accès à une réponse immédiate (60,3 %) et sur le résumé des sujets (32,7 %). Ils allaient rarement vers les images, les animations et les vidéos (5,1 %) et pratiquement jamais vers les activités proposées (1,2 %).

- Dans l'élément **Cours**, les indices d'interactivité (nombre de clics/nombre de visites) pour la structure cellulaire, la division cellulaire et l'évolution étaient respectivement de 0,55, 1,8 et 0,43. Les étudiants ont donc utilisé cet élément principalement pour lire la page et probablement réviser la matière étudiée en classe.

- Dans l'élément **Exercices de renforcement**, les indices d'interactivité (nombre de clics/nombre de visites) pour la structure cellulaire, la division cellulaire et l'évolution étaient respectivement de 0,90, 0,80 et 0,65. Les étudiants n'ont pas interagi avec cet élément. Autrement dit, ils se sont rendus sur la page, l'ont lue et l'ont quittée. Les étudiants ont donc principalement utilisé cet élément pour participer aux jeux-questionnaires sur les sujets. Ils allaient rarement vers les tutoriels et pratiquement jamais vers les mots croisés en ligne ou les outils de schématisation conceptuelle.

En fait, les étudiants ont utilisé *Biologie branchée* comme un guide d'étude électronique. Ils ne s'en sont pas servi pour partager, collaborer ou créer. Ils l'ont plutôt utilisé pour étudier la matière et réussir leurs examens. Cela peut refléter la façon dont *Biologie branchée* a été conçue, l'absence de récompenses pour l'utilisation du site comme une plateforme collaborative, ou leur modèle d'apprentissage associatif, dans lequel l'acquisition des connaissances se fait en associant la bonne réponse à un stimulus.

Les étudiants ont visité Chimie branchée 40 fois et ont cliqué sur les liens proposés seulement 28 fois. Ils ne se servent donc pas de cette activité facultative.

L'utilité de Biologie branchée

Nous avons relevé une corrélation significative entre les notes obtenues dans le test de contrôle des étudiants sur la division cellulaire et ce qu'ils ont déclaré à propos de leur utilisation de *Biologie branchée*. Ainsi, bien que les étudiants aient répondu que *Biologie branchée* s'était avérée moins assimilable, fiable, mémorisable et efficace pour la division cellulaire, leurs résultats ont pu être positivement associés à l'utilisation du site. Cette corrélation pourrait être le résultat du contexte dans lequel l'enseignement a été donné (la classe d'apprentissage actif) et non celui de leur utilisation réelle du site.

Les modèles mentaux sur la structure cellulaire et la division cellulaire de l'ensemble des étudiants étaient notablement similaires aux modèles mentaux de l'ensemble des professeurs. En revanche, le modèle mental de l'ensemble des étudiants sur l'évolution différait de celui des professeurs. En d'autres mots, *Biologie branchée* a aidé la classe à développer une compréhension approfondie de la structure et de la division cellulaire, mais pas de l'évolution. Encore une fois, l'absence d'une véritable expérience avec des contrôles adéquats nous empêche de conclure que *Biologie branchée*, par opposition à l'apprentissage dans une salle de classe active, est à l'origine de la compréhension approfondie que la classe a acquise de la structure cellulaire et de la division cellulaire.

Lorsque nous avons examiné les modèles mentaux des étudiants sur la structure cellulaire, la division cellulaire et l'évolution, respectivement 26 sur 31, 29 sur 36 et seulement 16 sur 36 avaient acquis les modèles mentaux des spécialistes.

Quelles sont les croyances des professeurs sur la facilité d'utilisation des outils numériques en classe?

Nous avons décidé d'interviewer les deux enseignants ayant accepté de participer de même que les trois enseignants qui avaient refusé. Les interviews des enseignants ont été transcrits et codés dans des catégories préexistantes sur les sujets de la recherche : *les outils numériques utilisés en classe, les outils numériques souhaités, les avantages des outils numériques, les obstacles à l'utilisation des outils numériques* et *les croyances relatives à l'enseignement et à l'apprentissage.*

Tous les professeurs ont mentionné qu'ils utilisaient la ressource numérique fournie avec le manuel scolaire qui comprenait deux courts vidéos (2), deux jeux-questionnaires (2) et un tutoriel (1). Trois professeurs ont déclaré avoir utilisé des vidéos sur YouTube. Deux ont déclaré avoir utilisé des télécommandes, des tableaux blancs interactifs, des sites Web externes et des sites Web créés par des enseignants (les deux professeurs participants), et des simulations (les deux professeurs participants). De plus, un des enseignants participants a déclaré utiliser les applications Google Docs et Google Spreadsheets. Il est à noter qu'aucun professeur n'a mentionné utiliser une plateforme de gestion de cours bien que tous l'aient fait. En outre, aucun des enseignants qui utilisent First Class, une plateforme de collaboration, n'en a fait mention. Cela nous suggère que l'utilisation de cette plateforme est à ce point passée dans les usages que les professeurs la considèrent comme faisant partie de leurs pratiques pédagogiques.

Il y a eu très peu de réponses à la question portant sur l'intérêt pour de nouveaux outils numériques. La plupart des réponses concernaient l'amélioration d'outils numériques déjà utilisés. Les professeurs reconnaissaient tous que les outils numériques présentent plusieurs avantages. Les réponses les plus courantes avaient trait à l'augmentation des interactions avec l'étudiant et au renforcement de son engagement ainsi qu'à leur utilité comme moyen de suivre les progrès de l'étudiant, de lui fournir une rétroaction immédiate et d'améliorer sa compréhension et son intérêt pour la matière enseignée.

Nous avons obtenu très peu de réponses à la question portant sur ce qui fait obstacle à l'utilisation des outils numériques. Les professeurs utilisent volontiers la technologie et tous consacrent du temps à préparer leurs cours. Trois professeurs ont répondu que l'accès des étudiants aux outils numériques peut être un obstacle. Deux professeurs ont mentionné qu'ils aimeraient avoir un soutien en cas de problèmes techniques pendant le cours. Deux professeurs estimaient que l'obstacle consistait d'abord à trouver et à évaluer les outils. Enfin, un professeur voyait l'obstacle dans le manque de collaboration du département pour développer et évaluer des outils de cours adaptés aux besoins.

Les interviews ont aussi révélé une pédagogie centrée sur l'enseignant dans laquelle celui-ci reste tributaire du manuel et du matériel connexe. Par exemple, un plan de cours commun précise les pages du manuel pour lesquelles les étudiants sont responsables. Tous les professeurs, et cela vaut également pour ceux qui utilisent les outils du Web 2.0, ont un enseignement normatif. Cela peut venir à la fois de la nature de la science (telle qu'elle est enseignée dans les cours d'introduction) et des pratiques d'évaluation (un examen final commun composé principalement de questions à choix multiple).

Plusieurs questions découlent de cette recherche :

- Puisque le contexte ne risque pas de changer, *y a-t-il une place pour un apprentissage faisant appel aux médias sociaux*[1] *(rendu possible grâce aux outils du Web 2.0) dans les cours d'introduction à la science*? Si oui, quel serait l'équilibre parfait entre ce type d'apprentissage et l'apprentissage collaboratif?

[1] Aussi appelé apprentissage émergent par opposition à l'apprentissage normatif ou connexe.

- *Certains sujets se prêtent-ils mieux à un apprentissage qui fait appel aux médias sociaux et, si oui, lesquels?*
- *Comment pouvons-nous assouplir les pratiques d'évaluation pour encourager un apprentissage qui fait appel aux médias sociaux?*
- *Comment concevoir des environnements d'apprentissage qui font appel aux médias sociaux qui soient aussi efficaces pour les professeurs que pour leurs étudiants?*

Il faudra répondre à plusieurs de ces questions avant que ce que les outils du Web 2.0[2] ont à offrir puisse être pris en compte dans les cours d'introduction à la science. Un des résultats les plus importants de ce projet pourrait bien être les discussions que susciteront les questions abordées ici au sein de la Faculté des sciences.

[2] Une base de données interactive annotée des outils du Web 2.0 sera maintenue sur le site SALTISE (http://www.saltise.ca/)

SUMMARY

Our students are immersed in an “on-demand” world where they are connected full-time to their peers, to their technologies, and to the web-content that interests them. They are encouraged to contribute, collaborate, and create. However, when they enter science classrooms, they often enter a world in which they are disconnected from their peers, from the tools they regularly employ, and from their learning resources (other than the lecturer). They are required to consume, to compete, and to replicate “given knowledge”. Yet Web 2.0 technologies are now readily available to transform “science instruction” to “science co-construction”- to transform lurkers to learners.

In this project, we incorporated traditional conceptual knowledge in introductory Biology and Chemistry courses into a Web2.0 learning environment called *Connected Biology* and *Connected Chemistry*, respectively. Our research questions were:

1. What is the usability of *Connected Biology* and *Connected Chemistry*? That is are *Connected Biology* and *Connected Chemistry* learnable, memorable, efficient, error-free, and satisfying?
2. Do students who use *Connected Biology and Connected Chemistry* develop deep conceptual networks of the topics under investigation?
3. Does the use of *Connected Biology* and *Connected Chemistry* enhance students’ performance in the course?

We developed a 20-item Usability Questionnaire which measured whether *Connected Biology* was learnable, efficient, memorable, error-free, and satisfying. Three of the five components were internally consistent (Learnable, Memorable, and Efficient) with Cronbach’s alphas of 0.65, 0.67, and 0.56, respectively.

Usability of Connected Biology and Connected Chemistry

Students thought that *Connected Biology* was significantly less useful for Cell Division than for Cell Structure and Evolution. Although they were equally satisfied across the three topics, they thought that Connected Biology was less learnable, efficient, memorable, and error-free. This may reflect the inherent difficulty in using electronic resources to acquire an understanding of cell division as there is a strong component of *embodiment* in understanding cell division.

We collected web analytics of *Connected Biology* using a commercial product Crazy Egg over the entire course. Students visited *Connected Biology* when the topic was initially covered and to review for exams. There appears to be a novelty effect, in that students visited *Connected Biology* in large numbers at the beginning of the intervention; but less so as the semester progressed. Crazy Egg provided multiple visualizations of how students accessed *Connected Biology*. These can inform the institutions on the optimal design to maximize student use. The visualizations can also inform Web 2.0 designers/teachers where (at the top of the page) and when to post information (in the evening) to maximize student acquisition.

Connected Biology covered the entire introductory Biology course and included navigation links to preclass exercise, the classes (held in an Active Learning Classroom), consolidation exercises, links to external tutorials, and activity frames with the objectives for each topic linked to a glossary. Each element had several Web 2.0 tools (e.g., on-line practice tests, immediate

feedback questions, images/videos/animations, internal and external web activities, on-line crossword puzzles, on-line concept mapping activities, etc.). We collected data on three topics: Cell Structure, Cell Division, and Evolution. The interactivity index (number of clicks/number of visits) for the Cell Structure, Cell Division, and Evolution units were 0.96, 0.84, and 1.37, respectively. This indicates that students were using the home page primarily to link to each topic. Once on the topics page they linked to the elements. The students were surprisingly consistent in their visits to the elements across topics. They primarily visited the pre-class and consolidation exercises and the objective/glossary. They rarely visited the linked tutorials (1.1%) which were featured on these pages. They also did not use the navigation buttons; but rather kept the pages opened and navigated by the tabs.

Each of the above elements contained several Web 2.0 tools. We subsequently analyzed how students used the Web 2.0 tools within each element.

- The interactivity indices (number of clicks/number of visits) for the **Objectives and Glossary Element** for Cell Structure, Cell Division, and Evolution were 0.1, 0.3, and 0.2, respectively. Students visited this element primarily to read the learning objectives; rarely clicking on the glossary terms (18%).
- The interactivity indices (number of clicks/number of visits) for the **Pre Class Exercises Element** for the Cell Structure, Cell Division, and Evolution units were 4.9, 7.7, and 12.2 respectively. Thus, students used this element to interact with the material. They also increased their interactivity over the span of the intervention. They were consistent in their use of the Web 2.0 tools, primarily using the Pre Class Exercises element to click on the immediate feedback questions (60.3%) and the summary of the topics (32.7%). They accessed the images, animations, and videos rarely (5.1%), and almost never accessed the suggested activities (1.2%).
- The interactivity indices (number of clicks/number of visits) for the **Class Element** for the Cell Structure, Cell Division, and Evolution units were 0.55, 1.8, and 0.43 respectively. Thus, students used this element primarily to read the page, perhaps to review what was done in class.
- The interactivity indices (number of clicks/number of visits) for the **Consolidation Exercises** for the Cell Structure, Cell Division, and Evolution units were 0.90, 0.80, and 0.65 respectively. Thus, students did not interact with this element. That is, they went to the page, read it, and left. Students used this element primarily to do practice quizzes on the topics. They rarely accessed the tutorials, and almost never accessed the on-line crossword or on-line concept mapping tools.

Thus, students were using *Connected Biology* primarily as an electronic study guide. That is, they did not use it to contribute, collaborate, or create. Rather, they used it to learn the required content and do well on the exams. This may reflect the design of *Connected Biology*, the absence of rewards for the use of the site as a collaborative platform, or their model of learning, i.e., *associative*, in which learning happens by associating the correct answer to a stimulus.

Students visited *Connected Chemistry* 40 times and clicked on linked items only 28 times. Thus, they did not make use of this “optional” activity.

Utility of Connected Biology

There was a significant correlation between students' reported grades on their Cell Division post-test and their reported use of *Connected Biology*. Thus although students reported that Connected Biology was less learnable, error-free, memorable, and efficient for Cell Division, their achievement was positively associated with their reported use of the site. This may reflect the effect of the context of instruction (the Active Learning Classroom) and not their actual use of the site.

The aggregated students' mental models of Cell Structure and Cell Division were significantly similar to the aggregated experts' (teachers') mental models. On the other hand, the aggregated students' model of Evolution was not similar to the aggregated experts' (teachers') mental model. That is, *Connected Biology* helped the class develop a deep understanding of Cell Structure and Cell Division, but not Evolution. Again, the absence of a true experiment with adequate controls prevents us from concluding that *Connected Biology*, as opposed to teaching in the Active Classroom caused the class to acquire a deep understanding of Cell Structure and Cell Division.

When we examined individual student's mental models, 26 out of 31, 29 out of 36, and only 16 out of 36 had acquired the experts' models for Cell Structure, Cell Division, and Evolution, respectively.

What Are Teachers' Beliefs About the Usability of Digital Tools in the Classroom?

We interviewed the two teachers that participated in the study as well as the three teachers that decided to not participate. Interviews with teachers were transcribed and coded into pre-existing categories that reflected the research interest: *digital tools used in course, desired digital tools, benefits of digital tools, barriers to the use of digital tools,* and *beliefs about teaching and learning.*

All teachers stated that they used the digital resource packaged with the text book. These included short videos (2), quizzes (2), and tutorials (1). Three teachers reported that they used you-tube videos. Two teachers reported that they used clickers, Smart Boards, external web-sites, teacher-created web-sites (the two participating teachers), and simulations (the two participating teachers). In addition one of the participating teachers reported using Google Docs and Google Spreadsheets. It is noteworthy that none of the teachers stated that they used a course management platform although all did. In addition none of the teachers that use First Class, a collaboration platform, mentioned it. This suggests that their use has become so internalized that teachers consider their use as part of their normal teaching practice.

There were very few responses to the question on what additional digital tools would they desire. Most responses had to do with improving the digital tools that they were already using.

All teachers saw many benefits to the use of digital tools. The most frequent responses were increases students' engagement and interactions, allows you to monitor students' progress, allows you to provide immediate feedback, increased student understanding and increases students' interest in content.

There were very few responses to the question on what were the barriers to the use of digital tools. The teachers were quite comfortable using technology and they all spend time preparing their courses. Three teachers responded that student access to the digital tools can be a barrier. Two teachers stated that they would like to have technical support when IT breaks down in the classroom. Two teachers responded that finding and evaluating the tools in the first place is a barrier. One teacher responded that the lack of collaboration within the department in developing and evaluating course specific tools was a barrier.

Teacher interviews also reveal a teacher-centered pedagogy in which most teachers "stuck" closely to the textbook and associated materials. For example, the common course outline specifies the pages in the text book for which students are responsible. All teachers, even those teachers that made use of Web 2.0 tools held an *associative* learning model. This may reflect both the nature of science (as taught at the introductory level) and the assessment practices (a common final consisting mostly of multiple choice questions).

There are several questions that arise from this research:

- G*iven that this context is not likely to change, is there a place for socially mediated*[3] *learning (promoted by Web 2.0 tools) in introductory science courses*? If so, what is the optimal balance of socially-mediated learning and associative learning?
- *Are there certain topics that are more suited to socially-mediated learning and what are they?*
- *How do we "open up" assessment practices so that socially*-*mediated learning is encouraged?*
- *How do we design socially-mediated learning environments that are time-efficient for both faculty and students?*

Many of these questions will have to be answered before the affordances of Web 2.0 tools[4] can be realized in introductory science courses. One of the most important outcomes of this project may well be the discussions among science faculty of the above questions.

[3] Also called emergent learning as opposed to prescriptive or associated learning
[4] An annotated interactive data base of Web 2.0 tools will be maintained on the SALTISE site (http://www.saltise.ca/)

ACKNOWLEDGEMENTS

The research team thanks the *Programme d'aide à la recherche sur l'enseignement et l'apprentissage* (PAREA), a MELS program, for its support.

We would also like to thank the following people for their support towards the completion of this project:

Office of Professional Development and Research at Dawson College

- Maeve Muldowney
- Kaila Folinsbee
- Suzanne Prevost

Finance Office at Dawson College

- Diane Wong

Dawson College Administration

- Robert Kavanagh, Academoic Dean (former)
- Raymond Bourgeois, Dean of Science, Medical Studies, and Engineering
- Barbara Freedman, Dean of Instructional Development

Technical Support

This technologically rich project could not have completed without the support and expertise of many individuals associated with Information Systems and Technology; only a few of which can can be mentioned here

- François Paradis, Director of Information Services and Technology
- Darcy Bottaro
- Natalie Kurylo-Paiva
- Kirk Fontaine
- Jason Roberts

Research Assistants

- Megann Ayotte
- Chao Zhang
- Marc Poissant

Translator

- Ann Lamontagne

The team also thanks Dr. Elizabeth Charles for conduucting the teacher interviews and for her generous support throughout the project.

Lastly, we thank our colleagues in the Biology Department and the students who participated in the study.

TABLE OF CONTENTS

LIST of FIGURES

LIST of TABLES

Chapter 1

INTRODUCTION

Our students are immersed in an "on-demand" world where they are connected full-time to their peers, to their technologies, and to the web-content that interests them. They are encouraged to contribute, collaborate, and create. However, when they enter science classrooms, they often enter a world in which they are disconnected from their peers, from the tools they regularly employ, and from their learning resources (other than the lecturer). They are required to consume, to compete, and to replicate "given knowledge". Yet technologies (Web2.0) are now readily available to transform "science instruction" to "science co-construction"- to transform lurkers to learners.

The term, **Web 2.0** tools describes tools embedded in web sites that facilitate interactions among students, teachers, resources, and the world in an on-line environment. The term was first coined by Darcy DiNucci in 1999 but popularized by Tim O'Reilly and Dale Dougherty in late 2004. Over the last decade there has been an exponential increase in the use of these tools (blogs, wiki's, twitters, YouTube, etc.) from 0 to the billions. Alternative terms include social media, the read-write web, social networking sites, technology-enhanced learning (TEL), interactive web, etc. Essential features of these tools are that they signal a shift of the user (in this case student and teacher) from consumer to creator and that from resources restricted to approved users to resources opened to everyone. This is in contrast to Web 1.0 tools which supported a "broadcast" model of teaching in which the teacher controlled the content and access, and in which discussion was limited to those in the cohort.

In this project, we incorporated traditional conceptual knowledge in an introductory Biology course into a Web2.0 learning environment, which we called *Connected Biology*. We investigated whether students using *Connected Biology* found it learnable, efficient, memorable, satisfying, and error-free. Subsequently, we investigated the utility of *Connected Biology*. That is, did students who used *Connected Biology* develop deep conceptual networks of the topics under investigation. In addition we incorporated conceptual knowledge of chemistry into two chemistry courses and piloted these interventions.

Research Questions

1. What is the usability of *Connected Biology* and *Connected Chemistry*? That is are *Connected Biology* and *Connected Chemistry* learnable, memorable, efficient, error-free, and satisfying?
2. Do students who use *Connected Biology and Connected Chemistry* develop deep conceptual networks of the topics under investigation.
3. Does the use of *Connected Biology* and *Connected Chemistry* enhance students' performance in the course?
4. What are teachers' beliefs about using digital tools in the classroom?

Chapter 2

LITERATURE REVIEW

International and National Agencies, such as the National Science Foundation (Hill, Rapoport, Lehming, & Bell, 2007), the National Academy of Science (Augustine, 2007), the National Postsecondary Education Cooperative (NPEC, 2007) and the Nuffield Foundation (Osborne & Dillon, 2008) have pointed out that we are failing to meet the global challenges of the 21st century especially in STEM (science, technology, engineering and math). In Quebec (Baillargeon, G. et al, (2001), despite the interest and ability that students have in science, there continues to be a large drop-off of students continuing science after secondary school. These, and other studies (see Pellegrino, 2006; Rosenfield, S., Dedic, H., Dickie, L. O., Rosenfield, E., Aulls, M. & Koestner, R., 2005), identify the primary cause of this failure as an outmoded method of teaching that emphasizes a magisterial model of teaching and emphasizes delivery at the expense of active participation in the co-construction of knowledge. As the National Center on Education and the Economy (2007, page 8.) states: *The core problem is that our education and training systems were built for another era. We can get where we must go only by changing the system itself.*

The Commission d'Evaluation has identified similar issues in the teaching of Sciences de la Nature in Quebec colleges: *"Sur les méthodes pédagogiques, la Commission a noté que quinze collèges devraient adapter leurs méthodes pédagogiques à l'approche par compétences et veiller à adopter des méthodes plus dynamiques. Les avis que la Commission a émis à ce sujet sur un programme de sciences représentent 79 % de ceux qu'elle a formulés sur l'adaptation des méthodes, pour l'ensemble des programmes, ce qui amène la Commission à penser qu'en Sciences de la nature, depuis la révision du programme en objectifs et standards, les méthodes pédagogiques évoluent plus lentement que dans les autres programmes et inégalement vers une adaptation à l'approche par compétences."* (Commission d'évaluation (2009, p 40).

There are at least two broad reasons for the grip that traditional methods of instruction hold in university and college Science Programs. Firstly, many, if not most, science faculty lack familiarity with educational research and thus have “outmoded” models of how students learn. Many believe that any departure from the traditional approach to the teaching of Science is not warranted. Secondly, the rapid pace of technological change discourages many science faculty from keeping up systematically with the new technologies. Furthermore, the lack of a clearly articulated vision of how the triad of cognition, technology, and assessment must be integrated to best meet the needs of students and teachers hampers the adoption of any one change (Pellegrino, 2006).

Change in Prevalent Models of Learning

We have moved from a model of learning in which the learning is situated within individual students’ minds to one that views learning as being socially mediated. For example, until the early 1990’s, most research (even that on cooperative learning, collaborative learning, and social psychology) investigated group interactions as factors promoting learning; but, measured the outcome of such learning, as individual achievement (Stahl, 2006). Thus, there was a very-strong assumption that learning is essentially situated *within single minds*, resulting in the individual being the focus of interest and the unit of analysis. However, beginning in the 1990's, many researchers rejected this individualistic approach for socially constructivist approaches. For example, researchers (Vygotsky, 1978; Suchman, 1987; Rogoff, 1990; Lave & Wenger, 1991, Chan, Burtis & Bereiter, 1997) began arguing that learning is a culturally mediated social activity, in which learners negotiate the meaning of concepts on the basis of participating in "communities of practice".

Proponents of Distributed or Situated Cognition (Hutchins, 1996; Greeno, 2007; Dror & Harnad, 2008) argue that such cognitive activities as reasoning, remembering and learning take place within the activity-system that includes not only interacting learners but also the informational systems they are accessing. Therefore, learning takes place not only in individual brains but also over the information system being used. A well accepted model of this phenomenon exists in ant colonies which grow in knowledge over several decades, despite the annual death of all ants, except the queen ant (Pacala, Gordon & Godfray, 1996; Gordon, 1996).

With the ubiquitous role of technology in education, George Siemens and Stephen Downes developed *Connectivism* to explain the role of technology in learning (Siemens, 2004, 2005, 2006). They critique Social Constructivism as implying that although learning occurs in a social context, learning is still situated within the physical constraints of a brain (single or collective). Connectivism integrates principles from complex systems, networks, and self-organization theories to situate learning within loosely connected networks that incorporate shifting, merging, and mutually supporting neural, conceptual, and social networks, not all of which reside within one individual. They also extend over the databases and other information stores manipulated by technology. As Siemens and Tittenberger (2009, p 14) conclude: *Knowledge is distributed across a network that includes people and objects. To navigate, make sense, and come to understand (even grow and advance) knowledge, the process of cognition is also distributed across networks, and includes "interactions between people and with resources and materials in the environment".*

Williams, Karousou, and Mackness (2011) proposed a systems model or framework for emergent learning and learning ecologies (see Figure 1). Their model takes into account the knowledge domain and thus takes into consideration the appropriateness of Web 2.0 technologies for specific classes. In most science classes the domain is predictable and complicated, the organization of knowledge is hierarchal, verification and correction is provided by the experts and not negotiable.

Figure 1. Framework for emergent learning and learning ecologies

Role of Computer-mediated Technology in Education

Several researchers (Strawbridge, 2010; Conole & Alevizou, 2010) have described how pedagogical perspectives and approaches influence the appropriateness of technology use. For example the *Associative Perspective* (behaviorism, instructional design, didactic, intelligent tutoring) is prescriptive (transmissive) and focuses on controlled and adaptive responses and observable outcomes. The *Cognitive Perspective* (problem-based learning, inquiry-learning, discovery-learning) is task oriented and focuses on self-directed activities in which language is a tool for the co-construction of knowledge. The *Situative Perspective* (cognitive apprenticeship, collaborative learning, social constructivism) is socio-culturally contextual and focuses on participation within a community. Clearly, Web 2.0 tools can greatly enhance classroom practices based on the *Cognitive* and *Situative Perspectives*. However, some researchers have argued that Web 2.0 tools are inappropriate in classroom practices which focus on teacher-directed systematic guidance towards prescribed goals. Conole and Alevizou (2010) argue that Web 2.0 tools can support associative pedagogies by providing modeling, timely feedback etc. Moreover, Williams, Karousou, and Mackness (2011) argue that both prescriptive and emergent learning are necessary in a learning ecology. The problem is how to balance the two somewhat contradictory approaches.

Steve Hargadon (2009) summarizes the belief held by many educators that the expectation that computers would revolutionize education has not happened. In most schools, they have replaced chalkboards, overhead projectors, typewriters, etc. They have made the delivery and assessment of learning easier; but if they were suddenly to disappear from our classrooms, teaching would not change by much. One reason for this, somewhat surprising conclusion, is that until recently, the technology, Web 1.0, used a traditional one-way information flow, with content flowing from the source (educational media and teacher) to the students. In other words, it used a "push" technology with information being "dumped" on the student according to the goals and scheduling constraints determined by the educator. However, this has radically changed with the development of Web 2.0 (Brown, 2006). Web 2.0 technologies facilitate conversations around academic concepts, artifacts (images and videos), and data collections (databases and spreadsheets) in which the "Three R's have been supplanted by the "Three C's: Contributing, Collaborating, Creating" (Hargadon (2009, p8) through tools such as Facebook, Twitter, Wiki's, Voicethreads, etc.

Over the last decade there has been an exponential increase in the use of Web 2.0 tools (blogs, wiki's, twitters, YouTube, etc.) from 0 to the billions. Moreover, blended learning environments in which on-line resources (especially open educational resources) support traditional lecture classes are now becoming the norm in many post-secondary institutions around the world (Zawacki-Richter, 2015; Gideon, Capretz, Mead, and Grosch, 2014). Thus, not only have technologists published extensive lists of the "best" Web 2.0 tools in education, researchers have begun to investigate the use of Web 2.0 technologies in post-secondary institutions, the effectiveness of Web 2.0 tools, and barriers to the use of Web 2.0 tools.

Web 2.0 tools in education.

During the last decade, annotated lists of web 2.0 tools have been published encouraging teachers to make use of these tools. Since 2007 Larry Ferlazzo has published the best web 2.0

tools of the year. In addition, Bower (2015) published a typology of 212 web 2.0 tools suitable for educational purposes. He identified 37 types of Web 2.0 tools forming 14 clusters.

See the following web sites for annotated lists of tools:

- http://larryferlazzo.edublogs.org/),
- http://edtechtoolbox.blogspot.ca/p/web-20-tools_04.html,
- http://edjudo.com/web-2-0-teaching-tools-links,
- http://web2014.discoveryeducation.com/web20tools.cfm,
- http://www.edudemic.com/best-web-tools/, and
- http://oedb.org/ilibrarian/101-web-20-teaching-tools/ to name only a few.

Use of Web 2.0 tools in post-secondary education

Gideon, Capretz, Meadows, and Grosch (2014) administered a 150 item questionnaire to 985 students and 210 instructors at Western University in 2013. Students reported that they attended lectures and then studied at home using computers but they did this alone, not by collaborating with other students on-line. They also frequently searched the internet for learning materials. On the other hand, instructors frequently used the internet to search for teaching and learning materials. They also collaborated more frequently than did students. Students and instructors used such e-learning applications as video sharing, recording software (for lectures), and on-line self-tests moderately. They primarily used traditional media in lecture-based courses, rarely using Web 2.0 applications (other than Google). Thus, although Web 2.0 tools are readily available, instructors at universities have been slow to adopt them for their courses (Tess, 2013).

Campión, Nalda, and Rivilla (2012) developed a tool to investigate the Web 2.0 use by 402 instructors at the National University of Distance Education in Spain. They reported that although instructors understand that Web 2.0 applications can be effective in fostering learning, few actually use them. Those that do so use them as a means of consuming knowledge not creating knowledge.

Facebook is the most used social-media for both students and faculty in both North America and Europe (Ellison, Steinfield, & Lampe, 2007). Junco (2012a, b) reported that college students spend an average of over one hour and forty minutes on Facebook. It is not surprising then that the use of Facebook has been the most researched platform in education. Manca and Ranieri (2013), in a review of 23 studies, found that Facebook has been used to promote class discussion and collaborative learning, co-production of content, sharing educational resources, delivering “extra-curricular” resources, and to support self-directed learning.

The effectiveness of Web 2.0 tools

Hew (2013) reviewed 16 studies conducted in post-secondary classes which provided empirical evidence on the influence of podcasts, blogs, wiki’s, twitter, and 3-D virtual worlds on student achievement. He reported that the evidence is still very weak that these technologies, *per se*, increased student achievement. In many cases, the students who used the Web 2.0 tools were given extra content, instructor support, and time on task. Nevertheless, none of the studies reported negative effects. It is worth noting that 50% of the studies used a transmissive pedagogy.

Three reviews, one of the dissertation literature (Piotrowski, 2015) and two of published articles (Tess, 2013; Davis, Deil-Amen, Rios-Aguilar, & Canché, 2014) came to the same conclusions. The majority of the studies were qualitative and collected data on affective outcomes. Results were mixed with generally positive effects on student engagement, effective communication, student satisfaction, and sense of community. Both reported that there were very few empirical studies on student achievement and in general these had methodological flaws.

A large study carried out with 9044 students enrolled in two Catalan universities (Castaño Muñoz, Duart, Sanch0-Vinuesa, 2014) concluded that the introduction of on-line activities to lecture classes significantly increases student achievement only if the on-line activities are interactive rather than transmissive.

There have been many studies on the educational effectiveness of Facebook. Most studies that have looked at the relationship between use of Facebook and academic performance have reported negative effects (Junco, 2015). However, in many cases this negative effect is mediated by multitasking (Karpinski et al., 2013). Positive results have been shown between Facebook use and students' ability to build and maintain relationships which are important for student success.

Barriers to the use of Web 2.0 tools

Given that despite the availability of Web 2.0 tools, few post-secondary instructors incorporate them in their courses several researchers have investigated the barriers to their introduction. Canole and Alevizou (2010, p 20) state that "only a minority of enthusiastic teachers and those with a research interest in the learning science, educational technology or new media, have undertaken …exploration of the use of new technologies". They review several studies that investigated the barriers to the adoption of Web 2.0 technologies. These reports conclude that the three most salient barriers are the lack of appropriate incentives, the dominant culture of the teaching profession that does not value evidence-based educational research, and the lack of pedagogical imagination and training by most post-secondary faculty.

This has not changed much since 2010(Campión, Nalda, and Rivilla, 2012; Gideon, Capretz, Mead, and Grosch, 2014; Rogers-Estable, 2014). Several researchers have identified barriers to their adoption by post-secondary faculty. Rogers-Estable (2014) identified lack of training, lack of institutional support and lack of time as the three most common barriers. Additional reasons, provided by the faculty were "not structured into the curriculum, material, and syllabus ","not appropriate to the context of the class", "would not improve learning". These later reasons provided by the instructors, emphasize that it may not be lack of technological expertise and motivation that is hindering the adoption of Web 2.0 tools; but, rather a conflict between the affordances of WEB 2.0 technologies and the deeply held beliefs of post-secondary faculty of what constitutes good teaching in their discipline (i.e., Associative Pedagogies).

Many teachers, realizing the importance of incorporating active-learning participatory technologies into their teaching practices, do make the attempt; however, many, if not most, ultimately fail to sustain their efforts (Messina, Reeve & Scardamalia, 2003). This has often been interpreted as a failure in their knowledge, effort, or available resources. However, an alternative interpretation is that features of the attempted implementation, *per se*, are at fault. That is, although the utility of the implementation is usually investigated, the usability of the implementation is not systematically tested. Usability in this context is the degree to which an implementation meets the needs of the users (both teachers and students) by being learnable, efficient, memorable, satisfying, and error-free (Usability Professionals Association, 2009). The goal of this paper is to investigate the usability of implementations, called *Connected Biology* and *Connected Chemistry*, incorporating Web 2.0 features, in College Biology and Cnemistry courses.

Chapter 3

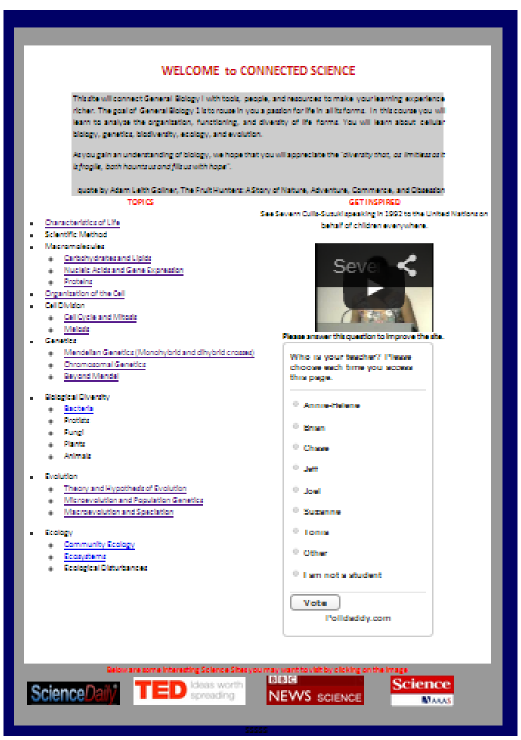
METHODOLOGY

Intervention

We used a *design-based* (Brown, 1992; Collins, Joseph, & Bielaczyc, 2004; Amiel & Reeves, 2008) methodology to design the interventions that were used to collect data. That is we went through several iterations, consulting with both teachers and students, before deciding on the final design. Dawson College has several platforms: Lea, Moodle, and First Class. Brian Seiverwright made a systematic review of the three platforms (see Appendix 1).

George Siemens makes several interesting points in his Connectivism blog. First, Moodle is a content-centric learning management system and prioritizes the organization of content. On the other hand Google and Facebook are network-centric systems which prioritize the sharing of resources. George Siemens contents that content-centric models are the wrong model for today's educational systems. With this view in mind we opted to use First Class as our platform for the intervention.

The intervention, *Connected Biology*, consists of a web site which is accessed via a home page which includes a video, links to Science sites and an outline of the topics covered by the course. Figure 2 is an image of the home page, accessed at (http://place.dawsoncollege.qc.ca/~bionya).



Each of the topics is linked to a topics page which includes the following elements: *Pre-class Exercises* (designed to prepare the students for the subsequent classes), *Classes* (designed to outline the activities done in class), *Consolidation Exercises* (designed to help students secure their learning), and the *Learning Objectives* (designed to guide students in their studying). The Web 2.0 tools associated with these elements are links to external sites, simulations, videos, images, a hot-linked glossary, on-line crossword puzzles, on-line concept mapping exercises, practice questions providing immediate feedback, links to on-line quizzes, and summaries of the topics. Classes were held in an Active Learning Classroom, containing 6 tables, each with a Smart board. There were 6 -7 students per table. In addition, students used a class conference on First Class (a collaboration platform) to access their teacher's materials and communicate with each other and their teacher.

Figure 2. Image of Web 2.0 intervention *Connected Biology*.

We collected data on 3 topics: Cell Structure, Cell Division, and Evolution.

The goal of the web-site was to guide the students in preparing and review the course content so that they could engage productively in class. Work was assigned but not graded. For a full description and map of the web-site contact Silvia d'Apollonia at sdapollonia@dawsoncollege.qc.ca

Brian Seiverwright, the original co-investigator, developed a Web 2.0 site on kinetics for an Organic Chemistry course using Moodle. The web site included an online course outline, online quizzes, a discussion board, video-lectures, an online-collaborative module for students to work on problems, and an online whiteboard and chat session. Students and teachers used the later typically the night before tests. Figure 3 is an image of the home page.

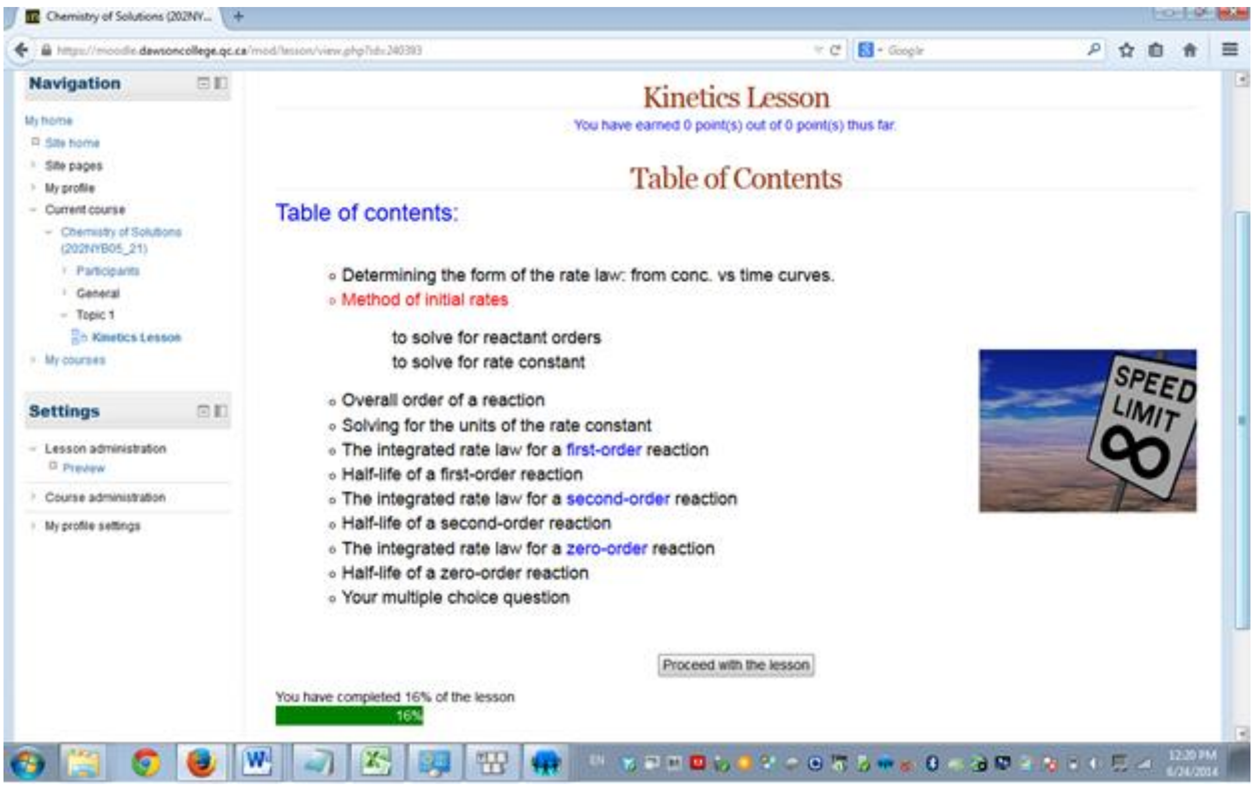


Figure 3. Image of Web 2.0 site on kinetics.

The students were asked for their experiences using this site. They reported that they especially liked the on-line quizzes, the online whiteboard and chat session, and the tool that informs them on how much of the unit they have completed.

However, Brian Severwright had to leave the project. Although we looked for chemistry faculty that would implement the intervention in their courses, we could not get any volunteers. One reason for this reluctance is the difficulty of sharing resources among faculty within Moodle (at least the Dawson implementation). Users must be registered in the class to have access.

We subsequently recruited Murray Bronet as co-investigator from John Abbott College. He designed the intervention, *Connected Chemistry* on First Class to complement the Chemistry of Solutions (202-NYB-05) course. It contained the following units:

- A Review of prior concepts which included text and activities on Significant Figures,
- Dimensional Analysis,
- Scientific Notation,
- Chemical Reactions,
- Chemical Kinetics, and
- Chemical Equilibrium

It contained the following Web 2.0 tools: YouTube videos, a blogging/forum where students could ask questions to their classmates or post comments, links to external sites/activities and a self-test with immediate feedback. For a full description and map of the web-site contact Murray Bronet at murray.bronet@johnabbott.qc.ca. Figure 4 is an image of the home page, accessed at (http://place.dawsoncollege.qc.ca/~mbronet).

Welcome to the Online Learning, Reviewing, and Self-Assessment Chemistry Website

This website is designed to complement the Chemistry of Solutions (202-NYB-05) course by providing:

- Some basic theory of the topic chosen;
- Some additional resources such as YouTube videos, interesting instructional websites, etc.;
- Some worked out examples;
- A blogging/forum site where you can ask questions to your classmates or post comments;
- A self-test to see if you have grasped or mastered the concepts presented

To see the 202-NYB Course Objectives click here

Review

- Significant Figures
- Dimensional Analysis
- Scientific Notation

Unit I - Chemical Reactions

- Nomenclature
- Net Ionic Equations (NIE)
- Stoichiometry
- Oxidation-Reduction(REDOX)
- Colligative Properties

Unit II - Chemical Kinetics

- Collision Theory
- General Rate Law
- Integrated Rate Law
- Half-life
- Arrhenius Equation
- Reaction Mechanisms

Unit III - Chemical Equilibrium

- Law of Mass Action & the Equilibrium Constant
- Le Chatelier's Principle
- Equilibrium Stoichiometry
- Acid/base Equilibrium
  - Acid/base Introduction
  - pH, pOH
  - Ka, Kb, Kw
  - Buffers
  - Indicators
  - Titration Curves

Figure 4. Image of Web 2.0 intervention *Connected Chemistry*.

Participants

The participants for *Connected Biology* were faculty and their students taking an introductory Biology course at Dawson College. The students were in the science program and taking their first college level biology course. Teachers were invited to participate in modifying and using *Connected Biology* in their courses. However, only one teacher agreed to implement Connected Biology in her classroom. Four other teachers agreed to be interviewed on their pedagogy and use of technology.

The participants for *Connected Chemistry* were one teacher and his students taking an introductory Chemistry course at John Abbott College. The students were in the science program and taking their second college level chemistry course.

Instruments (Questionnaires) and Achievement Measures

Usability is the degree to which an implementation meets the needs of the users (both teachers and students) by being learnable, efficient, memorable, satisfying, and error-free (Usability Professionals Association, 2009). A questionnaire, adapted from Lund (2001) was developed to survey students' perceptions of the usability of *Connected Biology*. The survey consisted of 20 questions (5-point scale), assessing 5 components of usability:

- Learnable: *Is it difficult to learn*?
- Error Free: *Do you make many errors using it*?
- Memorable: *Do you remember how to use it?*
- Efficient: *Does it help you get the job done"?*
- Satisfying: *Do you find it enjoyable and would you recommend it?*

The instrument is presented in Appendix 2. We conducted a reliability analysis on students' responses (n = 122). The five scales had the following values for Cronbach's alpha which measures the internal consistency of the scale:

- Learnable: 0.65
- Error Free: 0.25
- Memorable: 0.67
- Efficient: 0.56
- Satisfying: 0.42

Factor analysis indicated that the scales are correlated with none of them unidimensional. Given that there are only 4 items per factor, we consider that the three scales (Learnable, Memorable, and Efficient) are internally consistent.

Teacher-made class tests were used to assess students' understanding of the topics.

Tracking Student Use of Web-sites

We collected web analytics using a commercial product Crazy Egg (see http://www.crazyegg.com) over the entire course. Crazy Egg provides multiple views of how the user accesses the web-site. It illustrates exactly where users click on a page, including clicking on an item that appears linked but is not. This can help teachers/designers redesign web pages so that they are less frustrating to students. It also illustrates the percentage of students scrolling to the bottom of the page (almost none). This allows the teacher/designer to redesign web page so that more students view important information and resources. This is especially important when more students are accessing web resources on mobile devices with smaller screens. Crazy Egg also allows for the collection of demographic data (where users are from, what devices and operating systems they are using, what day and time they are accessing your site, etc.). This is useful information not only for the teacher; but also institutional IT departments. See the Results section for examples.

Collecting and Analyzing Students' and Teachers' Conceptual Structures

We collected students' conceptual structures of a give topic, by requesting them to rate the degree of relatedness among pairs of terms. We designed software that would generate a triangular matrix of the terms (selected by teacher experts) on-line (see Figure 5) and http://a77.ca/target/table.php?evolution). The triangular matrices completed by students and teachers were analyzed using the pathfinder software, PCKnot (Interlinks)[5]. This software

	adaptive (natural) selection	chance	change in allelic frequency	differential survival	environmental pressure	genetic drift	genetic variation	genotype	individual	mutation	non-adaptive selection	population
adaptive (natural) selection												
chance	0											
change in allelic frequency	0	0										
differential survival	0	0	0									
environmental pressure	0	0	0	0								
genetic drift	0	0	0	0	0							
genetic variation	0	0	0	0	0	0						
genotype	0	0	0	0	0	0	0					
individual	0	0	0	0	0	0	0	0				
mutation	0	0	0	0	0	0	0	0	0			
non-adaptive selection	0	0	0	0	0	0	0	0	0	0		
population	0	0	0	0	0	0	0	0	0	0	0	
	adaptive (natural) selection	chance	change in allelic frequency	differential survival	environmental pressure	genetic drift	genetic variation	genotype	individual	mutation	non-adaptive selection	population

OK

Figure 5. On-line matrix used to collect students' and teachers' proximity ratings for evolution.

generates Pfnets[6] (graphs depicted the strength of the relationships among the terms). The software also generates composite Pfnets (a graph depicting the average strength of the relationships among the terms) for the group of students. We used PCKnot to compute the coherence index, the similarity between two Pfnets, and the probability that the similarities arise by chance. Acton, Johnson, and Goldsmith (1994) have shown that the coherence index differentiates between expert and novice performance, is a good predictor of performance, and measures the accuracy of a subject's mental model.

[5] Interlinks has now published a web-based application. See http://interlinkinc.net/

[6] Pfnets are graphs consisting of labeled nodes and the links between the nodes.

Chapter 4

RESULTS AND DISCUSSION

Students' Perceptions of the Usability of *Connected Biology*

Students' perceptions of the usability of *Connected Biology* were measured at the end of each unit. The average usability scores for the Cell Structure, Cell Division, and Evolution topics were 18.1, 16, and 18.8 respectively. Students thought that *Connected Biology* was significantly less useful for Cell Division than for Cell Structure and Evolution (F = 7.635, df = 92, 2, p = 0.001. The distribution of their responses is presented in Figure 6. It indicates students were very consistent in their perceptions of the usability of *Connected Biology* for the Cell Division unit.

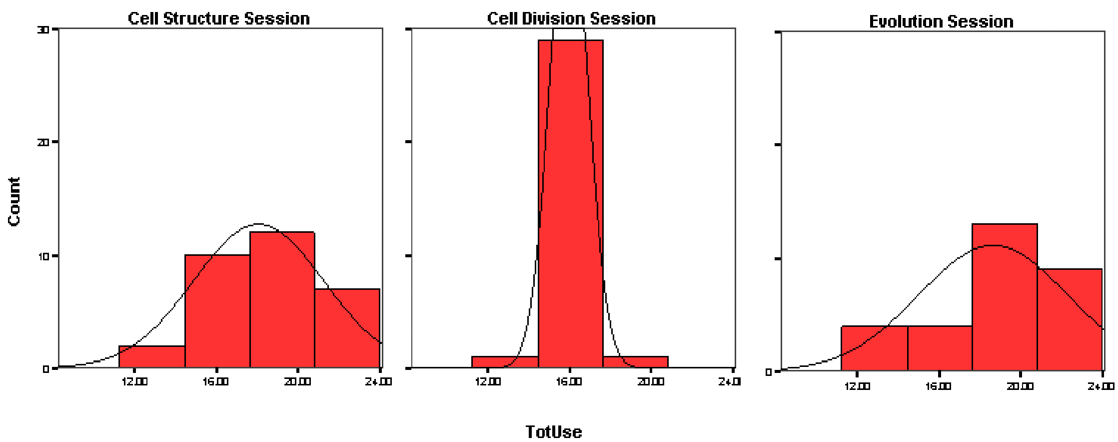


Figure 6. Frequency of student responses on the usability of *Connected Biology* on the three topics.

There was a significant correlation (t = .50, df = 30, p = .005) between students' reported grades on their Cell Division post-test and their reported use of *Connected Biology*. Thus although students reported that Connected Biology was less useful for Cell Division, their achievement was positively associated with using the site.

On the other hand, students were equally satisfied with *Connected Biology* over the three topics: Cell Structure, Cell Division, and Evolution. However, they perceived that *Connected Biology* was significantly less learnable, error-free, memorable, and efficient for Cell Division than for the other two topics. (see Table 1). This may reflect the inherent difficulty in using electronic resources to acquire an understanding of cell division. There is a strong component of *embodiment* in learning cell division. For this reason, there are many physical exercises including manipulating noodles, cut-outs, and pipe-cleaners and dances used by teachers in teaching cell division.

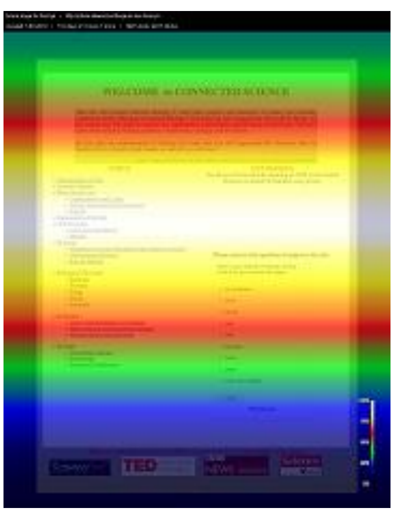
Table 1: Descriptive statistics (means and standard deviation) for students' perceptions of components of usability.

Usability Scale	Cell Structure (N=32)		Cell Division (N=31)		Evolution (N=32)	
	mean	Sd	mean	sd	mean	sd
Efficient	3.6	0.82	2.9	0.43	3.3	0.93
Error Free	3.4	0.64	3.1	0.49	3.7	0.68
Learnable	3.9	0.81	3.3	0.35	4.0	0.85
Memorable	3.9	0.84	3.1	0.28	4.1	0.94
Satisfying	3.3	0.75	3.6	0.34	3.6	0.87

There was a significant correlation ($t = .50$, $df = 30$, $p = .005$) between students' reported grades on their Cell Division post-test and their reported use of *Connected Biology*. Thus although students reported that Connected Biology was less learnable, error-free, memorable, and efficient for Cell Division, their achievement was positively associated with their reported use of the site. This may reflect the effect of the context of instruction (the Active Learning Classroom) and not their actual use of the site. As students begin to become familiar with *Connected Biology*, they may begin to conflate the preparation for classes with their classes.

How Did Students Actually Use *Connected Biology*

We used Crazy Egg (https://www.crazyegg.com), a commercial tracking service similar to Google Analytics to track the number of visits made by students as well as where they clicked and scrolled on the web pages. Crazy Egg provides several visualizations of how students used the website.



For example the heat map (Figure 7) indicates that students almost never scrolled to the resources at the bottom of the page: Science Daily, Ted Talks, BBC Science News, or Science Journal. On the other hand they scrolled to the middle of the page and accessed the topics. One reason for this behaviour may be that students were not given encouragement or grades by the teacher to visit these sites. We had expected that, as science students, they would be intrinsically motivated to explore the recommended science news links. However, students were focused on learning the content as quickly and efficiently as possible. Another reason may be their position on the page (at the bottom). More research is needed on this topic. As more and more students use mobile devices with smaller screens) teachers may have to redesign the web resources they use.

Figure 7. Crazy Egg heat map for home page of *Connected Biology*.

The confetti visualizations provided both the IT department and the teacher with valuable information. These are presented in Figures 8 to 16 along with interpretations of the data.

The *new (white) vs returning (red)* students confetti visualization shows that

- new students click randomly on the page
- returning students appear to click on topics

This may indicate that returning students have learned how to navigate the site; but, new users have not.

Figure 8. Crazy Egg Confetti visualization (new versus returning) for *Connected Biology* home page.

The *referrer* confetti visualization shows that

- 88% of visits come from a link from the first class server
- 11.5 % come directly from a saved link
- less than 1% come from a link from Facebook

This suggests that students do not use their Facebook pages for school work, confirming the conclusions made by other researchers that students do not like to use the social media they use with their friends for school.

Figure 9. Crazy Egg Confetti visualization (referrer) for *Connected Biology* home page.

The *country* confetti visualization shows that

- 92% of visits were from computers in Canada (red)
- 5% of visits were from the United States green
- 3% were from Europe (violet).

These results may reflect visitors from other countries who came across the site by accident, or from students that were vacationing abroad during the spring break. The former explanation is more likely since the Canadian visitors appeared to be clicking on the topics and the other visitors appeared to be clicking more randomly.

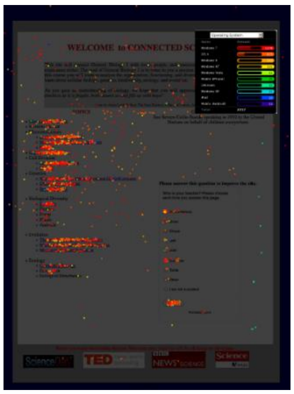
Figure 10. Crazy Egg Confetti visualization (country) for *Connected Biology* home page.

The *device* confetti visualization shows that

- 97% of visits were from users on computers
- 1.5 % each from smart phones and tablets.

This may reflect the fact that the website was designed for computer screens and is really not suitable for smaller devices.

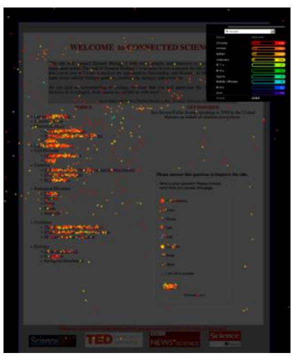
Figure 11. Crazy Egg Confetti visualization (device) for *Connected Biology* home page.



The *operating system* confetti visualization shows that

- 68% of visits were from users using the Windows operating system (53% Windows 7, 7% Windows 8, 5% NT, 2%Vista, and1% XP)
- 28% of visits were from users using the OS X operating system
- 2% of visits were from users using the i-phone and i-tablet and
- 1% were from users using the android mobile OS

Figure 12. Crazy Egg Confetti visualization (operating system) for *Connected Biology* home page.



The *browser* confetti visualization shows that

- The top three browsers used by students are Chrome (35%), Firefox (24%) and Safari (20%)
- 4% of users used Apple mobile browsers
- 12% used unknown browsers

Figure 13. Crazy Egg Confetti visualization (browser) for *Connected Biology* home page.

Classes were held Wednesday and Friday. The *day of week* confetti visualization shows that students visited the site

- 24% on Friday
- 20% on Thursday
- 16% on Wednesday
- 13% on Tuesday
- 10% on Sunday
- 10% on Monday
- 7% on Saturday

Thus students primarily visited the site on the days in which the class was held and on the day between the two lectures.

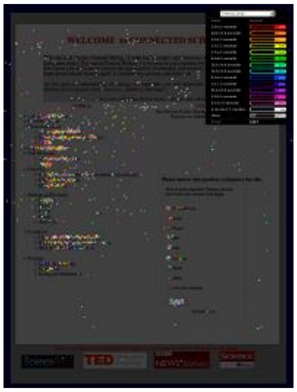
Figure 14. Crazy Egg Confetti visualization (day of the week) for *Connected Biology* home page.

The *time of day* confetti visualization shows that students visited the site

- 40% between midnight and 4:00 AM
- 16% between 3:00 PM and 6:00 PM
- 15% between 7:00 PM and 11:30 PM
- the rest in small numbers at other times

Thus, most students access the web-site in the evening, mostly after midnight.

Figure 15. Crazy Egg Confetti visualization (time of day) for *Connected Biology* home page.



The *time to click* confetti visualization shows that students took the following time to click on a link

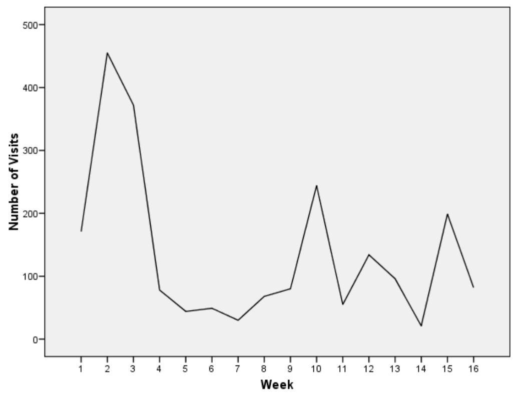
- 5% took less than 1 second
- 34 % took between 1 second and 15 seconds
- 15% took between 15 seconds and 30 seconds
- 7% took between 30 seconds and 45 seconds
- 5% took between 45 seconds and 1 minute
- 3% took 1 minute or more

This indicates only 5% of users (probably accidental visitors) were “gaming the system”.

Figure 16. Crazy Egg Confetti visualization (time to click) for *Connected Biology* home page.

The above visualizations can inform IT Departments which devices, operating systems, and browsers students use to access institutional resources. Thus, they can inform the institutions on the optimal design to maximize student use. The visualizations can also inform Web 2.0 teachers/designers where and when to post information to maximize student acquisition.

You can also download the data for specific time periods in an excel spreadsheet and carry out statistical analyses. We collected students' visits, clicks, and scrolls during the entire intervention of 16 weeks. Figure 17 illustrates the number of visits to the home page of *Connected Biology* during the intervention.



- Cell Structure was covered in weeks 1 and 2
- The first class test was given in week 3
- Cell Division was covered in weeks 4 and 5
- The second class test was given in week 10
- Evolution was covered in weeks 11 and 12
- The final exam was given in week 16

Figure 17. Number of visits to *Connected Biology* by week.

Students visited *Connected Biology* between weeks 2 and 3, on week 12, and on week 15. There appears to be a novelty effect, in that students visited *Connected Biology* in large numbers at the beginning of the intervention; but less so as the semester progressed. The data suggests that students began to visit *Connected Biology* to prepare for the final exam on week 12 but stopped visiting it on weeks 13 and 14 while they were preparing for their lab test and presentation of their research project (neither of which was covered by *Connected Biology).*

Figure 18 shows the number of visits to each topic. Students visited Cell when the topic was covered in class and the week prior to the final exam. On the other hand, students visited Cell Division when the topic was covered in class and the week of the second class test. They also visited this topic on week 12, perhaps when they received the results of their second test after the Easter break (week 11). They did not visit this page to review prior to the final exam. Students visited Evolution when the topic was covered in class and to review it for the final exam.

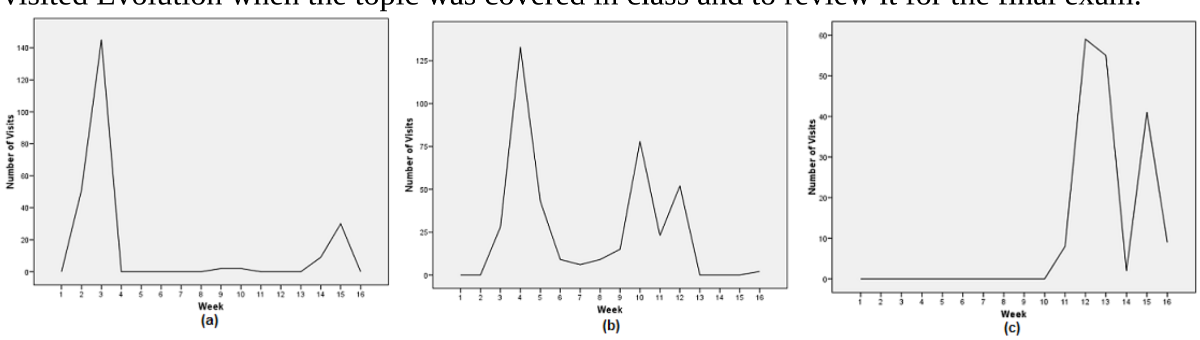


Figure 18. Number of visits to Cell Structure (a), Cell Division (b) and Evolution (c) by week.

Students' accessed *Connected Biology* via a home page which listed each topic and linked to the topic pages for each unit. These topic pages included navigation links to preclass exercises, the classes, consolidation exercises, links to external tutorials, and activity frames with the objectives for each topic linked to an on-line glossary. Each element had several Web 2.0 tools (e.g., on-line practice tests, immediate feedback questions, images/videos/animations, internal and external web activities, on-line crossword puzzles, on-line concept mapping activities, etc.).

Table 2 shows the number and percentage of clicks to each element for each topic. The interactivity index (number of clicks/number of visits) for the Cell Structure, Cell Division, and Evolution units were 0.96, 0.84, and 1.37 respectively. This indicates that students were using the home page primarily to link to each topic. Once on the topics page they linked to the elements. The students were surprisingly consistent in their visits to the elements across topics. They primarily visited the pre-class and consolidation exercises and the objective/glossary. They rarely visited the linked tutorials (1.1%) which were featured on these pages. They also did not use the navigation buttons; but rather kept the pages opened and navigated by the tabs. Thus students were using *Connected Biology* primarily as an electronic study guide.

Table 2: Number and student visits to *Connected Biology* elements.

Element	Cell Structure		Cell Division		Evolution		Total	
	N	%	N	%	N	%	N	%
Objective/Glossary	38	16	134	34.1	54	14.7	226	22.6
Link to Tutorials	6	2.5	2	0.5	3	0.8	11	1.1
Preclass Exercises	82	34.5	112	28.5	131	35.6	325	32.5
Classes	53	22.3	48	12.2	55	14.9	156	15.6
Consolidation Exercises	47	19.7	84	21.4	109	29.6	240	24.0
Navigation Buttons	12	5.0	13	3.3	16	4.3	41	4.1

Each of the above elements contained several Web 2.0 tools. We therefore analyzed how students used the Web 2.0 tools within each element.

How did students use the Objectives and Glossary Element

The interactivity indices (number of clicks/number of visits) for the Cell Structure, Cell Division, and Evolution were 0.1, 0.3, and 0.2, respectively. Students visited this element primarily to read the learning objectives; rarely clicking on the glossary terms (18%).

How did students use the Pre Class Exercises Element

Table 3 shows the number and percentage of clicks to each tool in the preclass element for each topic. The interactivity index (number of clicks/number of visits) for the Cell Structure, Cell Division, and Evolution units were 4.9, 7.7, and 12.2 respectively. Thus, students used this element to interact with the material. They also increased their interactivity over the span of the intervention. They were consistent in their use of the Web 2.0 tools, primarily using the Pre Class Exercises element to click on the immediate feedback questions (60.3%) and the summary of the topics (32.7%). They accessed the images, animations, and videos rarely (5.1%), and almost never accessed the suggested activities (1.2%).

Table 3: Number and percentage of clicks to Web 2.0 tools in the Pre Class Exercises element.

Tools	Cell Structure		Cell Division		Evolution		Total	
	N	%	N	%	N	%	N	%
Information	247	27.1	590	35.2	600	33.2	1437	32.7
Immediate Feedback Questions	598	65.6	884	52.7	1166	64.5	2648	60.3
Images/Animations/Videos	53	5.8	149	8.9	20	1.1	222	5.1
Activities	7	0.8	28	1.7	18	1.0	53	1.2
Navigation/Download buttons	7	0.8	25	1.5	3	0.2	35	0.2

How did students use the Class Element

Table 4 shows the number and percentage of clicks to each tool in the class element for each topic. The interactivity index (number of clicks/number of visits) for the Cell Structure, Cell Division, and Evolution units were 0.55, 1.8, and 0.43 respectively. Thus, students used this element primarily to read the page, perhaps to review what was done in class.

Table 4: Number and percentage of clicks to Web 2.0 tools in the Class element.

Tools	Cell Structure		Cell Division		Evolution		Total	
	N	%	N	%	N	%	N	%
Information	7	21.9	22	25.9	5	20	34	23.9
In-class Activity	13	40.6	61	71.8	14	56	88	62
Activity on External Site	11	34.4	0	0	5	20	16	11.3
Navigation/Download buttons	1	3.1	2	2.4	1	4	4	2.8

How did students use the Consolidation Exercises Element

The interactivity index (number of clicks/number of visits) for the Cell Structure, Cell Division, and Evolution units were 0.90, 0.80, and 0.65 respectively. Thus, students did not interact with this element. That is, they went to the page, read it, and left. Table 5 shows the number and percentage of visits that students made to the tools on the consolidation element of the three topics. Thus, students used this element primarily to do practice quizzes on the topics. They rarely accessed the tutorials, and almost never accessed the on-line crossword or on-line concept mapping tools.

Table 5: Number and percentage of clicks to Web 2.0 tools in the Consolidation Exercises element.

Tools	Cell Structure		Cell Division		Evolution		Total	
	N	%	N	%	N	%	N	%
Quizzes	91	98.9	116	93.5	7	100	214	96
On-line Crossword Puzzles	1	1.1	0	0	0	0	1	0.5
On-line Concept Map Tool	0	0	0	0	0	0	0	0
Link to Tutorials	0	0	8	6.5	0	0	8	3.5

Thus, although most students found *Connected Biology* satisfying, they did not make much use of the embedded Web 2.0 tools. That is, they used the web-site as an electronic Study Guide.

They used it when the topic was covered in class and prior to being tested on the content. They made little or no use of the enrichment tools (videos, activities, tutorials). Science students have a heavy workload, taking on average 3 science courses, a language course, a physical education course, a humanities course, and a complimentary course; therefore they are very strategic in their use of time. They do what they have to do to learn the material, without much exploration.

Students' Conceptual Understanding of Cell Structure and Cell Division

Cell Structure and Function

We collected students' "mental models" of cell structure and function and compared them to the aggregated teacher model. Figures 19a and 19b show the composite model aggregated from seven teachers and 31 students, respectively. The similarity (correlation) between the aggregated teachers' and aggregated students' models is 0.56. The probability that the similarity between the two aggregated models is due to chance is 0.0001.

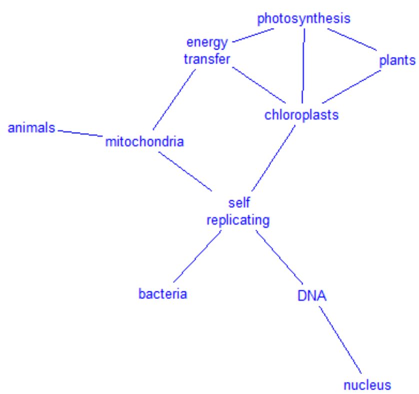


Figure 19a.Composite teacher (7) mental model of cell structure and function.

- The coherence index for the individual teacher's models varied from a low of 0.17 to a high of 0.47 with the coherence index for the composite model being 0.72.
- The similarity index (average of all pairs) is 0.61.
- The probability that the similarity between any pair was due to chance was always less than 0.009.

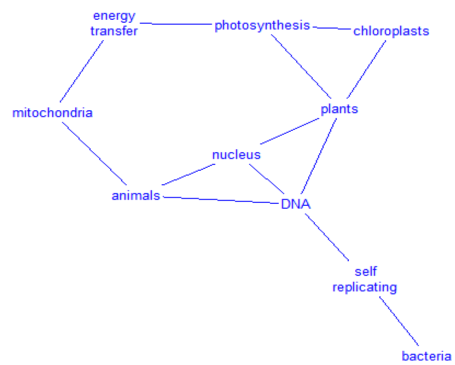


Figure19b.Composite student (31) mental model of cell structure and function.

- The coherence index for the individual student's models varied from a low of - 0.28 to a high of 0.77 with the coherence index for the composite model being 0.31.
- The average similarity between each student's model and the aggregated teachers' model is 0.30 with a low of 0.01 and a high of 0.62.

Most students (except for five) acquired mental models similar to the teachers' aggregated model. The models of those students that were significantly different are presented in Figure 20.

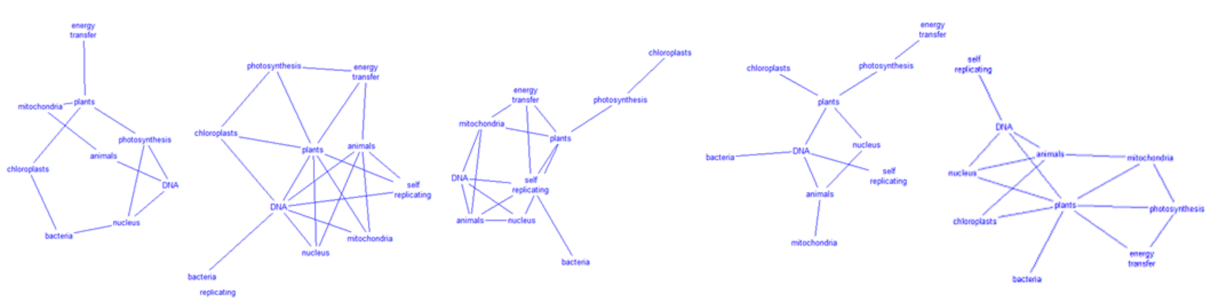


Figure 20. Individual student mental models of cell structure and function differing from teachers' models

There was no correlation between the students' performance on the cell quiz and the similarity of their mental models of cell structure and function to the teachers' mental model.

Cell Division

We collected students' "mental models" of cell division and compared them to the aggregated teacher model. Figures 21a and 21b show the composite model aggregated from four teachers and 36 students, respectively. The similarity (correlation) between the aggregated teachers' and aggregated students' models is 0.51. The probability that the similarity between the two aggregated models is due to chance is 0.0001.

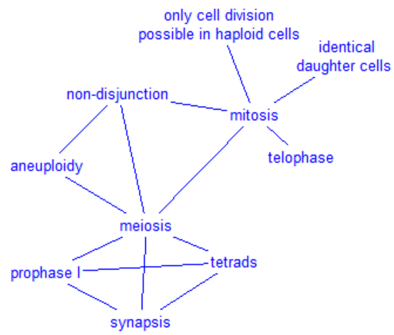


Figure 21a. Composite teacher (4) mental model of cell division.

- The coherence index for the individual teacher's models varied from a low of 0.61 to a high of 0.89 with the coherence index for the composite model being 0.89.
- The similarity index (average of all pairs) is 0.74.
- The probability that the similarity between any pair was due to chance was always less than 0.0001.

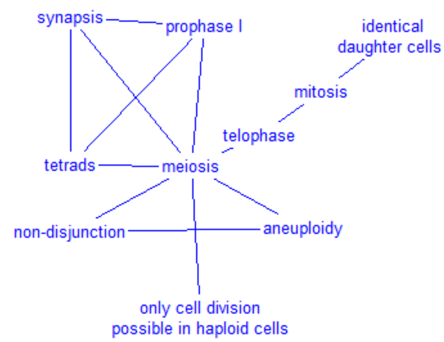


Figure 21b. Composite students'(36) mental model of cell division.

- The coherence index for the individual student's models varied from a low of - 0.21 to a high of 0.81 with the coherence index for the composite model being 0.79.
- The average similarity between each student's model and the aggregated teachers' model is 0.26 with a low of -0.09 and a high of 0.87.

Most students (except for seven) acquired mental models similar to the teachers' aggregated model. The models of those students that were significantly different are presented in Figure 22.

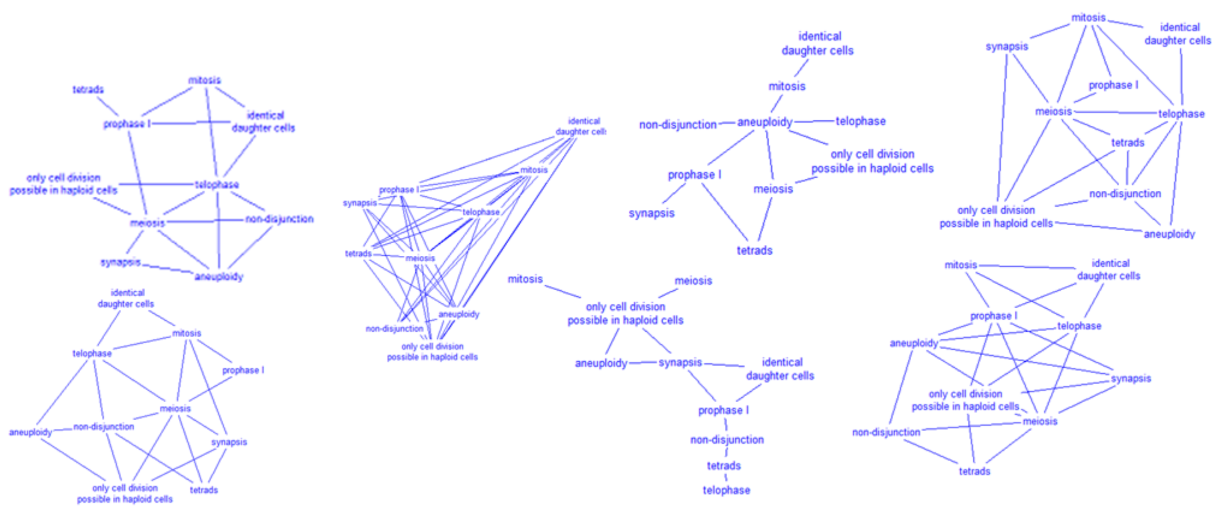


Figure 22. Individual student mental models of cell division differing from teachers'

One important misconception that all seven students had was that they linked *only cell division possible in haploid cells* to *meiosis* not *mitosis*. This can also be seen on the aggregate map of 36 students. Thus, this is an important concept that students did not acquire. This highlights an important use of the technology whereby teachers can easily monitor students' misunderstanding and remediate the problem the next class. There was a significant correlation ($t = 0.36$, $df = 35$, $p = 0.03$) between the students' performance on the cell division quiz and the similarity of their mental models of cell division to the teachers' mental model.

Evolution

We collected students' "mental models" of evolution and compared them to the aggregated teacher model. Figures 22a and 22b show the composite model aggregated from three teachers and 36 students, respectively. The similarity (correlation) between the aggregated teachers' and aggregated students' models is 0.15. The probability that the similarity between the two aggregated models is due to chance is 0.61. That is the two aggregated models are NOT similar.

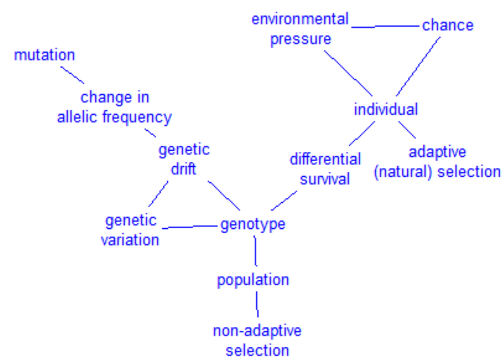


Figure 22a. Composite teacher (3) mental model of evolution

- The coherence index for the individual teacher's models varied from a low of 0.36 to a high of 0.70 with the coherence index for the composite model being 0.70.

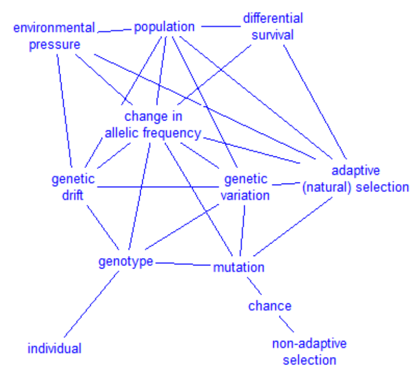


Figure 22b. Composite student (36) mental model of evolution

- The coherence index for the individual student's models varied from a low of - 0.15 to a high of 0.73 with the coherence index for the composite model being 0.15.
- The average similarity between each student's model and the aggregated teachers' model is 0.12 with a low of -0.01 and a high of 0.28.

Most students (20 out of 36) did not acquire mental models similar to the teachers' aggregated model of evolution. This is in agreement with previous work demonstrating that it is necessary to introduce students to complex adaptive systems, in order for them to understand the mechanism of inheritance, the mechanism of evolution, and the role of chance in evolution (d'Apollonia, Charles, & Boyd, 2008). For example, several misconceptions can be observed in both the aggregated student model and individual student models. One common misconception is assigning a phenomenon to the wrong level (e.g., *differential survival* to the *population* level instead of the *individual* level).

Students' Perceptions of the Usability of *Connected Chemistry*

The students in the chemistry class were involved in several projects, they were participating in a problem-based activity using Google Docs, they were using Mastering Chemistry, and they were using *Connected Chemistry.* Thus, the teacher created Connected Biology, showed the web site to the students, and told them that it would help them understand the topic of *Kinetics* by summarizing the information, linking to excellent You Tube videos, and providing them with quizzes with immediate feedback. However, he did not assign grades to their visiting the site. Figure 24 illustrates the Crazy Egg heat map for *Connected Chemistry*. Thus students were scrolling through the whole home page.

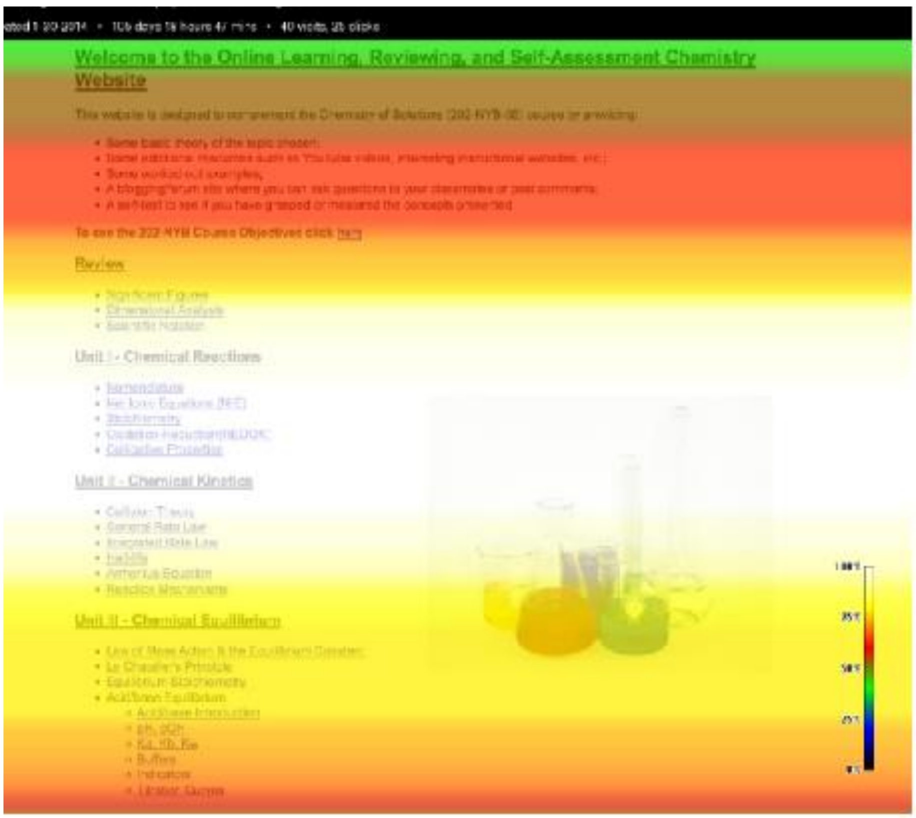


Figure 24. Crazy Egg heat map for home page *Connected Chemistry*

Students visited *Connected Chemistry* 40 times and clicked on linked items only 28 times. Thus, they did not make use of this "optional" activity. No further analyses were carried out.

What Are Teachers' Beliefs About the Usability of Digital Tools in the Classroom?

At the start of the project, several teachers agreed to consider using *Connected Biology*. However, when it was time to get the teachers and their students to formally sign the Consent Form all but one teacher changed their minds. An additional teacher agreed to participate in a related intervention, *Connected Chemistry*. We therefore decided to interview the two teachers that participated as well as the three teachers that decided to not participate. Interviews with teachers were transcribed and coded into pre-existing categories that reflected the research interest: *digital tools used in course, desired digital tools, benefits of digital tools, barriers to the use of digital tools, beliefs about teaching and learning*

What digital tools were used in course

All teachers stated that they used the digital resource packaged with the text book. These included short videos (2), quizzes (2), and tutorials (1). Three teachers reported that they used you-tube videos. Two teachers reported that they used clickers, Smart Boards, external web-sites, teacher-created web-sites (the two participating teachers), and simulations (the two participating teachers). In addition one of the participating teachers reported using Google Docs and Google Spreadsheets. It is noteworthy that none of the teachers stated that they used a course management platform although all did. In addition none of the teachers that use First Class, a collaboration platform, mentioned it. This suggests that their use has become so internalized that teachers consider their use as part of their normal teaching practice.

What are desired digital tools

There were very few responses to the question on what additional digital tools would they desire. Most responses had to do with improving the digital tools that they were already using. Two teachers stated that they would like additional Smart Boards, especially in the lab. Two teachers stated that they would like digital resource material (tutorials, quizzes) better integrated with what they teach rather than with the text book. One teacher responded that he/she would like clickers that allowed for short answer responses. One teacher responded that he/she would like to have student access to on-line journals.

What are the benefits of digital tools

The teachers all saw many benefits to the use of digital tools. The most frequent responses were increases students' engagement and interactions (3), allows you to monitor students' progress (3), allows you to provide immediate feedback (3), increased student understanding (3) and increases students' interest in content (2). The following responses were mentioned once: allows you to monitor students' contributions to group work, allows collaboration on data collection, allows students to pace their studying according to their individualized needs, encourages students to take responsibility for their learning, promotes more teacher collaboration, facilitates revising course materials, and results in better teaching.

What are the barriers to the use of digital tools

There were very few responses to the question on what were the barriers to the use of digital tools. The teachers were quite comfortable using technology and they all spend time preparing their courses. Three teachers responded that student access to the digital tools can be a barrier. Two teachers stated that they would like to have technical support when IT breaks down in the classroom. Two teachers responded that finding and evaluating the tools in the first place is a barrier. One teacher responded that the lack of collaboration within the department in developing and evaluating course specific tools was a barrier.

What are the beliefs about teaching and learning

Teacher A believes that students need to see the relevance of the class content to their lives. He/ she spends a lot of time and resources collecting videos and research papers (suitable for students) and uses them in class to initiate interest and discussion. Teacher A directs students to what sections of the textbook to cover and makes use of the on-line learning activities packaged with the textbook. However, he/she does not require students to do any of these activities because not all students have access.

Sometimes I bring in a YouTube documentary, but very short, and that starts the whole discussions. I think it gets them really stimulated when they see it. So I usually show them 5 minutes, and then that starts … a discussion on that topic.

Teacher B believes that it is important to put together a perfect course (notes, learning objectives, quizzes, etc.) and make them available to students at the beginning. He/she focuses on the course content and on “figuring out” what and how to deliver it. Teacher B directs students to what material they need to know, what readings they should do (that will not be covered in class) and gives them some practice questions. He/she believes there is not enough time to cover all the content in class.

I am still trying to put together the perfect course, to master the information that I want to present, and … how I want to present it. And have all of my course materials ready to go, learning objectives, practice questions and all that stuff.

Teacher C focuses on the text book and does not deviate from it. He/she uses the on-line materials (videos/activities/quizzes) packaged with the textbook in class because not all students have access to them. Teacher C allows students to bring their laptops to class and gives them questions/problems to discuss in small groups.

The textbook pretty much does [it] all, the online activity, it’s because we mainly focus on the content of the textbook, so we don't really diverge ways from textbook. Like they can search on their own for some of our topics but I didn't encourage them.

Teacher D (a participating teacher) believes that students learn by doing and has designed activities for them to do in groups. He/she also believes that students need to be directed to the concepts they need to master, they need to come prepared to class, and need to consolidate their learning. Teacher D uses the teacher resources packaged with the textbook to design assessment questions at a higher cognitive level (analysis/synthesis). Teacher D focuses on how students are learning and what misconceptions they may have.

I've developed a lot of activities in class, educational activities, not just work sheets, but activities so that the students have to work together to do the research in the classroom to find, or discover the answer …. and then present it to the rest of the class.

Teacher E (a participating teacher) uses a suite of graded e-learning and problem-based learning activities which students complete as groups. He/she also uses a web-page that has instructional videos (from YouTube), practice questions, and the on-line materials packaged with the textbook to cover the course content.

We have a smart board [in the classroom] so I used that as a tool, and the way I used it, actually almost never pick up a real pen any more… so everything goes on the smart board, everything gets recorded, everything gets saved, everything gets then saved as a PDF, and everything gets posted for students to see. Then I created a … website for one of my courses, I have videos for theory, solutions, I have some assessment question and I have real questions, sort of quiz type questions, with objectives. And that's my whole course covering every major topic in the course.

The teacher interviews also reveal a teacher-centered pedagogy in which most teachers "stuck" closely to the textbook and associated materials. For example, a common course outline specifies the pages in the text book for which the students are responsible. All teachers, including the teachers that made use of Web 2.0 tools hold a prescriptive model of teaching. This may reflect both the nature of science (as taught at the introductory level) and the assessment practices. Unless work is graded, students do not do the work. However, "the traditional interpretation [of assessment] becomes problematic [in emergent learning networks]" (Romer, 2002 quoted by Williams, Karousou, & Markess, 2011). The Biology course is a multisection course with a common final which includes more than 80% multiple choice questions. This drives students to adopt a learning approach that discourages exploration and promotes focusing on practice questions. In addition, it discourages teachers from adopting more student-centered pedagogies. Given that this context is not likely to change, several questions arise: Is there a place for emergent learning in introductory science courses? If so, what is the optimal balance of emergent and prescriptive learning? Are there certain topics that are more suited to emergent learning and what are they? How do we "open up" assessment practices so that emergent learning is encouraged? How do we design emergent learning environments that are time-efficient for both faculty and students? Many of these questions will have to be answered before the affordances of Web 2.0 tools[7] can be realized in introductory science courses.

[7] An annotated interactive data base of Web 2.0 tools will be maintained on the SALTISE site (http://www.saltise.ca/)

Chapter 5

CONCLUSIONS AND RECCOMENDATIONS

Most students did not make much use of the embedded Web 2.0 tools. That is, they used the web-site as an electronic Study Guide. They used it when the topic was covered in class and prior to being tested on the content. They made little or no use of the enrichment tools (videos, activities, tutorials). Science students have a heavy workload, taking on average 3 science courses, a language course, a physical education course, a humanities course, and a complimentary course. They are very strategic in how they study. They made a great effort to complete the pre-class assignments, focusing on the acquisition of the content and testing their understanding. This had a positive effect on the class in that students came to class prepared. They were thus able to profit from the in-class activities and discussions. Thus, the prevalent student culture is: do the required work, participate in class, and prepare for tests. In other words they follow a prescriptive model (Williams, Karousou, & Mackness, 2011) of learning biology where learning is predictable albeit complicated, the organization of knowledge is hierarchal, verification and correction is provided by the teacher/experts and not negotiable. This view may in fact reflect the reality of formal post-secondary science education, at least at the introductory level. That is, in most science domains knowledge is "created and applied to give control" (Williams, Karousou, & Mackness, 2011, p 43).

The teacher interviews also reveal a teacher-centered pedagogy in which most teachers "stuck" closely to the textbook and associated materials. For example, a common course outline specifies the pages in the text book for which the students are responsible. All teachers, including the teachers that made use of Web 2.0 tools hold a prescriptive model of teaching. This may reflect both the nature of science (as taught at the introductory level) and the assessment practices. Unless work is graded, students do not do the work. However, "the traditional interpretation [of assessment] becomes problematic [in emergent learning networks]" (Romer, 2002 quoted by Williams, Karousou, & Markess, 2011). The Biology course is a multisection course with a common final which includes more than 80% multiple choice questions. This drives students to adopt a learning approach that discourages exploration and promotes focusing on practice questions. In addition, it discourages teachers from adopting more student-centered pedagogies. There are several questions that arise from this research:

- G*iven that this context is not likely to change, is there a place for socially mediated*[8] *learning (promoted by Web 2.0 tools) in introductory science courses*? If so, what is the optimal balance of socially-mediated learning and associative learning?
- *Are there certain topics that are more suited to socially-mediated learning and what are they?*
- *How do we "open up" assessment practices so that socially*-mediated learning is *encouraged?*

[8] Also called emergent learning as opposed to prescriptive or associated learning

- *How do we design socially-mediated learning environments that are time-efficient for both faculty and students?*

Many of these questions will have to be answered before the affordances of Web 2.0 tools[9] can be realized in introductory science courses. One of the most important outcomes of this project may well be the discussions among science faculty of the above questions.

We have several recommendations:

- Faculty in Science departments should discuss whether they wish to introduce Web 2.0 tools into their curriculum, and if so, decide which topics are best suited for this technology.
- Since developing and testing these tools takes so much time, faculty should collaborate in developing and integrating these tools in the curriculum.
- Faculty should collect web analytics on the degree to which students are using these tools.

[9] An annotated interactive data base of Web 2.0 tools will be maintained on the SALTISE site (http://www.saltise.ca/)

REFERENCES

Acton, W., Johnson, P., & Goldsmith, T. (1994). *Structural knowledge assessment. Comparison of referent structures*. Journal of Educational Psychology, **86**, 303-311.

Amiel, T., & Reeves, T. C. (2008). *Design-based research and educational technology: Rethinking technology and the research agenda.* Educational Technology & Society, **7(4)**, 167-175.

Augustine, N. R. (2007). *Is America falling off the flat Earth?* Retrieved January 10, 2010, from National Academy of Science Web site: http://www.nap.edu/catalog.php?record_id=12021

Baillargeon, G. et al, (2001). *Education Indicators, 2001 edition* , Ministère de Éducation, Québec.

Bower, M. (2015). *A Typology of Web 2.0 Learning Technologies***,** EDUCAUSE, Feb 08, 2015.

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

Brown, J. S., (2002). *Growing Up Digital: How the Web Changes Work, Education, and the Ways People Learn.* United States Distance Learning Association. Retrieved on January 10, 2010, from http://www.usdla.org/html/journal/FEB02_Issue/article01.html

Brown, J.S., (2006, March) *Learning in the digital age (21st Century).* Paper presented at the Ohio Digital Commons for Education (ODCE) 2006 Conference retrieved on December 10th, 2009, from http://www.oln.org/conferences/ODCE2006/papers/jsb-2006ODCE.pdf

Campión, R.S., Nalda, F.N., and Rivilla, A.M. (2012). *Web 2.0 and Higher Education: Its Educational Use in the University Environment.* European Distance and E-Learning Network. From http://www.eurodl.org/materials/contrib/2012/Santiago_et_al.pdf**.** Retrieved July 15th, 2015.

Castaño Muñoz, J., Duart, J.M., and Sanch0-Vinuesa, T. (2014). *The Internet in face-to-face higher education: Can interactive learning improve academic achievement?* British Journal of Educational Technology. **45 (1):** 149-159.

Chan, C., Burtis, J., & Bereiter, C. (1997). *Knowledge building as a mediator of conflict in conceptual change.* Cognition and Instruction, 15(1), 1–40.

Collins, A., Joseph, D., & Bielaczyc, K. (2004). *Design research: Theoretical and methodological issues.* The Journal of the Learning Sciences, 13, 15-42.

Commission d'évaluation (2009). Évaluation de programmes du renouveau de l'enseignement collégial, Gouvernement du Québec, Québec.

Conole, G. and Alevizou, P. (2010) *A literature review of the use of Web 2.0 tools in Higher Education*. Higher Education Academy, York. http://www.heacademy.ac.uk/assets/EvidenceNet/Conole_Alevizou_2010.pdf. Retrieved July 15th, 2015

Crazy Egg see https://www.crazyegg.com

d'Apollonia, S., Charles, E., Boyd, G. (2004). Acquisition of Complex Systemic Thinking: Mental Models of Evolution. *Educational Research and Evaluation* , 10(4), 499-521.

d'Apollonia, S., Kunicki, S., and Bronet, M. (2015). *Learners, not Lurkers: Connecting Conceptual and Social Networks in Science Education*. Final Report Programme d'aide à la recherche sur l'enseignement et l'apprentissage (PAREA). ISBN 978-1-5501699-7-3.

Davis, Charles H.F., Deil-Amen, Regina, Rios-Aguilar, Cecilia, and Manuel S. Gonzalez-Canche. (2014). *The Dynamics and Effects of Social Media Use in Community Colleges.* Community College Journal of Research and Practice. **00***:1-14.* https://www.coe.arizona.edu/sites/default/files/social_media_higher_ed_and_community_colleges.ccjrp_.pdf. Retrieved July 15th, 2015

Dror, I. E. & Harnad, S. (2008). Offloading Cognition onto Cognitive Technology. in I.Dror & S. Harnad (Eds.), Cognition Distributed: How Cognitive Technology Extends Our Minds (pp 1-23). Amsterdam: John Benjamins Publishing.

Ellison, N.B., Steinfield, C., & Lampe, C. (2007). *Social network sites: Definition, history, and scholorship*. Journal of Computer Mediated Communication, **12(1)**: 210-230.

Gideon, G., Capretz, L.F., Mead, K., and Grosch, M. 201. *Media usage in post-secondary education and implications for teaching and learning.* Electrical and Computer Engineering Publications. Paper 58 from http://ir.lib.uwo.ca/electricalpub/58. Retrieved July 15th, 2015

Gordon, D. M. (1996). The organization of work in social insect colonies. Nature 380:121-124.

Hargadon, S.(2009). Social Networking in Education: A white paper retrieved January 10th, 2010 from http://www.scribd.com/doc/24161189/Educational-Networking-The-Important-Role-Web-2-0-Will-Play-in-Education

Hew, K.F. (2013). *Use of Web 2.0 technologies in K-12 and higher education: The search for evidence-based practice.* Educational Research Review **9**, 47–64

Hill, D., Rapoport, A. I., Lehming, R. F., & Bell, R. K. (2003). Changing U.S. output of scientific articles: Retrieved on January 10, 2010, from National Science Foundation Web site: http://www.nsf.gov/statistics/nsf07320/pdf/nsf07320.pdf

Hutchins, E. (1996). Cognition in the wild. Cambridge, MA: MIT Press.

Junco, R. (2012). *Too much face and not enough books: The relationship between multiple indices of Facebook use and academic performance.* Computers in Human Behavior, **28(1)**: 187-198.

Junco, R. (2015). *Student class standing, Facebook use, and academic performsnce.* Journal of Applied Developmental Psychology, **36**: 18-29.

Karpinski, A.C., Kirschner, P.A., Ozer, I., Mellott, J.A., & Ochwo, P. (2013). An exploration of social networking site use, multitasking, and academic performance among United States and European university students. *Computers in Human Behavior, 29*, 1182-1192.

Lave, J., & Wenger, E. (1991). *Situated Learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.

Lund, A.M. (2001). *Measuring usability with the USE Questionnaire* . Usability Interphase, 8(2). http://garyperlman.com/quest/quest.cgi?form=USE. Retrieved July 15th, 2015

Manca, S. & Ranieri, M. (2013). *Is it a tool suitable for learning? A critical review of the literature on Facebook as a technology-enhanced learning environment.* Journal of Computer Assisted Learning**, 29:** 487–504**.**

Messina, R., Reeve, R. & Scardamalia, M (2003). *Collaborative structures supporting knowledge building: Grade 4.* Paper presented at the Meeting of the American Educational Research Association, Chicago.

National Center on Education and the Economy. *(2007) Tough Choices or Tough Times.* The Report of the New Commission on the Skills of the American Workforce - National Center on Education and the Economy. John Wiley and Sons.

NPEC (2007). National Postsecondary Education Cooperative. *Deciding on Postsecondary Education: Final Report* (NPEC 2008850), Washington, DC.

Osborne J, & Dillon J. (2008). Science Education in Europe: Critical reflections. London: Nuffield Foundation. Retrieved on September 21st, 2009 from http://www.nuffieldfoundation.org/fileLibrary/pdf/Sci_Ed_in_Europe_Report_Final.pdf

Pacala, S. W., D. M. Gordon and H.C.J. Godfray. (1996). Effects of social group size on information transfer and task allocation. Evolutionary Ecology 10:127-165.

Pellegrino, J. W. (2006).*Rethinking and Redesigning Curriculum, Instruction and Assessment: What Contemporary Research and Theory Has to Offer.* A paper commissioned by the National Center on Education and the Economy for the New Commission on the Skills of the American Workforce retrieved on January 5th, 2010 from http://www.skillscommission.org/commissioned.htm

Piotrowski, C. (2015).*Emerging research on social media use in education: A study of dissertations*. Research in Higher Education . http://www.researchgate.net/profile/Chris_Piotrowski/publication/273366776_Emerging_research_on_social_media_use_in_education_A_study_of_dissertations/links/54ff28420cf2741b69f414fa.pdf. Retrieved July 15th, 2015

Rogers-Estable, M. (2014). *Web 2.0 use in higher education*. European Journal of Open, Distance, and eLearning. **17(2)**:129-141. http://www.eurodl.org/?p=current&article=655. Retrieved July 15th, 2015

Rogoff, B. 1990. *Apprenticeship in Thinking: Cognitive Development in Social Context*. New York: Oxford Univerity Press.

Rosenfield, S., Dedic, H., Dickie, L. O., Rosenfield, E., Aulls, M. & Koestner, R. (2005). Étude des facteurs aptes à influencer la réussite et la retention dans les programmes de sciences aux cégeps anglophones. (FQRSC Action Concertée Grant 2003-PRS-89553.). Montréal: Vanier College.

Siemens, G. (2004). *Connectivism: A learning theory for the digital age*. Retrieved December 10th, 2009 from http://www.elearnspace.org/Articles/connectivism.htm

Siemens, G. (2005). Connectivism. A learning theory for the digital age. *Int. J. of Instructional Technology & Distance Learning*, 2(1): 1-10. (Available online: January 20, 2005 from http://www.itdl.org/Journal/Jan_05/article01.htm

Siemens, G. (2006) *Knowing Knowledge*, Lulu.com, ISBN: 978-1-4303-0230-8.

Siemens, G. and Tittenberger, P. (2009). Handbook for Emerging Technologies for Learning. University of Manitoba. Retrieved December 15th, 2009 from http://www.umanitoba.ca/learning_technologies/cetl /HETL.pdf

Siemens, G. (2009) *The Future of Learning: LMS or SNS?* on Tuesday, November 10th, 2009.

Strawbridge, F., 2010. *Is there a case for Web 2.0 in higher education.* http://online.education.ed.ac.uk/2012/02/fiona-strawbridge-is-there-a-case-for-web-2-0-in-higher-education/ . Retrieved July 15th, 2015.

Suchman, L. (1987). *Plans and situated actions: The problem of human-machine communication*. Cambridge, UK: Cambridge University Press.

Tess, P.A. (2013). *The role of social media in higher education classes (real and virtual) – A literature review.* Computers in Human Behavior, **29 (5)**: A60–A68.

Usability Professionals Association. *Resources: About Usability*, https://uxpa.org/ Retrieved July 15th, 2015

Vygotsky, L.S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Williams, R., R., Karousou, and Mackness, J. (2011). *Emergent learning and learning technologies in Web 2.0.* The International Review of Research in Open and Distance Learning, **12 (3):** 39-59.

Zawacki-Richter, O., Muskens, W., Krause, U., Alturki, U., & Aldralweesh, A. (2015). *Student media usage patterns and non-traditional learning in higher education.* International Review of Research in Open and Distributed Learning, **16(2**): 136-168.

APPENDIX 1

Comparison of Moodle, FirstClass, and LEA.

	FirstClass	**LEA**	**Moodle**
Principle focus	groupware software for communication and collaboration	Online grade-book & document distribution	a modular software for Internet-based courses
Information Distribution			
Send course notifications	yes	Not really	yes
Create webpage	yes	no	yes
Maintain Blog	yes	no	yes
Student accessible grade book	yes	yes	yes
Upload Documents	yes	yes	yes
Email	yes	Poor implementation	yes
Course Calendar	yes	yes	yes
Personal Calendar	yes	yes	yes
Student generated content	yes	no	no
Group projects			
WIKI's	yes	no	yes
Student created communities/groups	yes	no	no
Teacher created communities/groups	yes	no	yes
Networking between peers	Great implementation	no	Available
Instant messaging	yes	no	yes
Appearance			
Change page appearance	yes	yes(blocked by administrator)	yes(partially blocked by administrator)
Create a profile	yes	no	yes
Usability			
For teachers	Relatively simple for basic functions	Relatively simple	Steeper learning curve
For students	simple	simple	simple
Software			
Open source	no	no	yes
Can be modified/tweaked	Yes	no	yes
Downloadable modules/add-ons	Yes	no	yes
Web-based	yes	yes	yes
Cost	$$$$	$$$$	free
User archiving of email/data	no	no	yes
Student Evaluation			
Auto-grade quizzes	no	yes	yes
Submit assignments	yes	no	yes
Surveys	no	no	yes
Monitor student use of docs.	no	yes	yes
Peer-graded activities	no	no	yes
Online interactive lessons	yes	no	yes
Vast array of interactive online activities	some	no	yes

APPENDIX 2

Usability survey for Connected Biology

This survey is to determine what your experience was using the website "Connected Biology".

For questions 1-20, please use the following scale:
A: completely disagree
B: disagree somewhat
C: neither agree nor disagree
D: agree somewhat
E: completely agree

1. Connected Biology helps me be more productive
2. Connected Biology makes class assignments and learning Biology easier to accomplish.
3. Connected Biology saves me time when I use it.
4. Connected Biology is difficult to use.
5. Connected Biology allows me to easily move around the site.
6. I can use the Connected Biology website without written instructions.
7. There were navigation inconsistencies in the Connected Biology website.
8. If I make a mistake navigating the site, I can recover quickly and easily.
9. Connected Biology did not help me learn the course material.
10. Using Connected Biology helped me use other Biology sites.
11. I learned to use the Connected Biology website quickly.
12. Using Connected Biology does not require too much effort.
13. After not using Connected Biology for a few days, I find it difficult to use.
14. I can use the Connected Biology website successfully every time.
15. I easily remember how to use the Connected Biology website.
16. I quickly became skillful with the Connected Biology website.
17. Connected Biology did not meet my expectations as a learning tool.
18. Connected Biology is user friendly.
19. I am satisfied with the usability of the Connected Biology website.
20. I would recommend Connected Biology to another student.

ISBN 978-1-5501699-7-3