CHAPTER FULL TEXT

Handbook of Research on Collaborative Learning Using Concept Mapping

Expanded collaborative learning and concept mapping: A road to empowering students in classrooms

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Abstract

The synergic effects of knowledge accumulation, information technology development, and globalization have produced a new set of social paradigms. The transition towards a post-industrial society became evident at the beginning of the 21st century. New challenges are presented to the educational system, and a revision of methodological procedures is imperative to prepare citizens capable of dealing with complex contemporary issues. This chapter proposes *'expanded collaborative learning'* for didactic activities involving peer review of any material produced by groups of students. In our particular experience, higher education students peer reviewed collaborative concept maps produced during an introductory course about natural sciences. Besides posing an unusual task for students, peer review changes the evaluation paradigm in traditional classrooms, reduces the power asymmetry between teacher and students, and promotes a truly collaborative atmosphere. This learning environment presents favorable conditions for empowering students, fostering them to act as autonomous citizens capable of transforming society.

New challenges for education in the 21st century

The beginning of the 3rd millennium was anticipated with some anxiety by humankind. This new era has brought a promise of changes based on the revision of our practices. The year 2000 software problem (Y2K bug), for instance, is a distant memory of the early 21st century. The millennium bug was a consequence of using two-digit dates in order to conserve computer memory, which was expensive and scarce in the 1960s. Media speculation as well as corporate and government reports at the end of the 1990s caused widespread concern that critical industries and government would cease operating at the stroke of midnight between December 31, 1999 and January 1, 2000 (Murray, 1996). Despite these catastrophic expectations involving the millennium roll-over, the Y2K consequences were minimal because the majority of problems had been fixed correctly through a worldwide collaborative effort. Indian engineers were responsible for correcting a huge number of US computers, illustrating an example of international collaborative work through the Internet (Friedman, 2007).

This computational crisis embodied the changes that have impacted our society since the second half of the 20th century. The knowledge explosion, information technology development and globalization have dramatically affected our society (Friedman, 2007; Hobsbawn, 1996). New social paradigms have emerged since then, making the end of industrial society a certainty. Knowledge, post-modern and post-industrial are labels used to identify this new society that has shaped our contemporary way of life (Bell, 1999; De Masi, 2000; Touraine, 2007; Unesco, 2005). While industrial society was based on work and goods manufacturing, post-industrial society is centered in free time, creative idleness, and service production in the form of symbols, information, values and esthetics (De Masi, 2000). The power in industrial society depended on the possession of manufacturing resources (e.g., factories). On the other hand, the power in post-industrial society depends on the possession of ideation resources, such as research labs, and information (e.g., mass media).

The new challenges posed by the post-industrial society are consequences of scientific-technological development and globalization. Machines and automated systems can carry out repetitive, routine and/or brute tasks more efficiently than humans. Therefore, the desired attributes of the 21st century workforce are quite different than those used by industrial society. A revision of the educational system is desirable in order to meet the new demands of the labor market and to prepare citizens capable of dealing with the complex scenarios posed by post-industrial society.

In contrast with the pronounced social changes involved in the transition to a post-industrial society, the schools have not changed at all. The education designed for industrial society is still prevalent at the majority of schools. They resemble an industrial factory in that their classrooms are equal, their teachers have a standardized discourse, and there is an expectation that all students answer the same questions in the same way (Menezes, 2000). Such standardization, one of industrial society's main features, affected the educational system by allowing only one model to satisfy teachers' and students' diverse expectations.

Traditional schools were build up under industrial paradigms, and their methodological procedures must be revised to respond to the new demands of post-industrial society. Beyond transmitting disciplinary knowledge, education for the 21st century requires the development of skills related to life-long learning, teamwork, creative thinking, and collaborative knowledge construction (Burnard, 2006; Fischer, 2002; Pintrich, 2004; Sawyer, 2006). The powerful combination of these cognitive and communicative skills with confidence, which is related to emotional behavior, can foster students' empowerment in classrooms. Any methodological change in classroom activities in order to fit the needs of post-industrial society must pursue a truly collaborative and empowering environment involving both teachers and students (Mintzes, 1998). The ultimate lesson to be taught in post-industrial classrooms is to learn how to learn (Georghiades, 2004; Novak, 1984).

A schematic representation of the key features of the new post-industrial classroom is presented in Figure 1. Self-evaluation, motivation, creativity, and metacognition are the pedagogical building blocks that compose the key features to pursue life-long learning (metacognition + self-evaluation), confidence (self-evaluation + motivation), teamwork skills (motivation + creativity), and creative thinking (creativity + metacognition). From these key features, methodological strategies can be designed to foster collaborative learning and students' empowerment through teacher-student and student-student interactions.

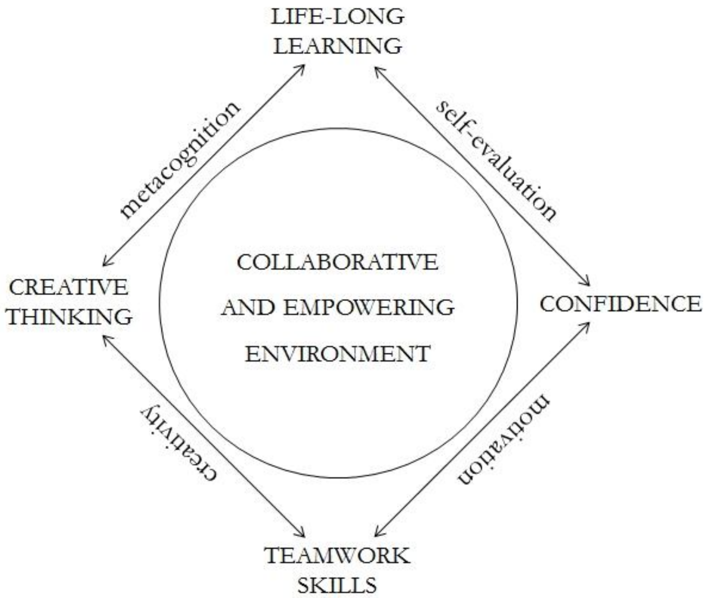

Figure 1. Key features of post-industrial classrooms (upper case) and their contributing pedagogical building blocks (lower case).

The focus of the projects carried out by our research group is on changing instructional and methodological procedures used in schools to teach natural sciences in junior, high school and college classrooms. The need for a response to the complex post-industrial issues involving science, technology, society, environment, life and ethics justifies our efforts. An activity involving concept mapping and peer review was devised to include the key features of the post-industrial classroom in higher education. An *'expanded collaborative learning'* experience involving concept mapping is presented and discussed after some theoretical considerations.

Creativity, creative groups and collaborative knowledge construction

Creativity is a monopoly of mankind and is highly appraised nowadays. One interesting view of the creative process is described by Domenico De Masi. In his opinion, creativity is a synthesis between fantasy and accomplishment (De Masi, 2003). People who present both features well-developed can be considered individual geniuses. Michelangelo was a great artist not only for being appointed architect of St. Peter's Basilica in the Vatican with more than 70 years. Beyond designing its marvelous dome, he was also responsible for getting the Pope's approval and funding for his project, as well as for recruiting and managing a large team of workers (masons, carpenters, craftsmen) over a period of 20 years until his death (Condivi, 1999). Michelangelo had both features, fantasy and accomplishment, required to be a creative individual genius.

Creation is a central value for the post-industrial society. The increasing demand for innovation and creative thinking can not be addressed by scarce individual geniuses. On the other hand, collaboration among people who complement one another can foster collective geniuses. In other words, creative groups can be intentionally composed to create a balanced team in terms of fantasy and accomplishment (De Masi, 2003). As collaboration and creation require a lot of practice, students should work together and collaborate in creative groups, which can be assigned by considering students' profiles in the continuum between fantasy and accomplishment. Opportunities for practicing creativity and collaboration in school must be devised by teachers using innovative methodological strategies.

The creative process that takes places in collaborative groups can be described in three steps. The externalization and elicitation of task-relevant knowledge precede consensus building, which can be conflict- or integration-oriented (Fischer, 2002). The itemized information presented in Table 1 can be useful for understanding how collaborative knowledge construction can take place in classroom.

Table 1. Main steps for describing the collaborative knowledge construction of creative groups in the classroom.

Step	Itemized description
1	Externalization of task-relevant knowledge
	- *Students bring individual prior knowledge into the situation* - *Different points of view can be clarified* - *Exchange of different individual concepts is the starting point for negotiating common meaning* - *Diagnosis and resolution of misconceptions can take place*
2	Elicitation of task-relevant knowledge
	- *Learning partners express their knowledge related to the task* - *Elicitation occurs frequently in the form of questions, which lead to externalizations in the form of explanations* - *Elicitation could be partly responsible for successful learning*
3(a)	Conflict-oriented consensus building
	- *Students seek a common solution or assessment of the given facts* - *Conflict plays an important role in reaching a consensus* - *Different interpretations made by learning partners can lead to a modification of knowledge structure*
3(b)	Integration-oriented consensus building
	- *Consensus can be reached through the integration of various individual perspectives into a common interpretation or solution for the given task* - *Superficial conflict-avoiding cooperation style may be verified in this attempt to incorporate individual views in a common perspective* - *There is a tendency on the part of the learners to reach an illusionary consensus*

Visualization tools can foster the collaborative knowledge construction process (Fischer, 2002). Among other options, concept maps appear as powerful visualization tools for representing knowledge. They can be defined as a set of concepts embedded into a propositional framework (Novak, 1998). Concept mapping can be useful for making idiosyncratic mental models explicit for revising (intrapersonal activity) and sharing ideas (interpersonal activity). Both purposes are important during collaborative knowledge construction because all participants can visualize, interpret and organize their own ideas (intrapersonal), before starting conflict-oriented and/or integration-oriented consensus building (interpersonal). Moreover, collaborative concept mapping can also support discursive meaning mediation and conflict negotiation, even when on-line tools are used (Bennett, 2003; Chiu, 2004; Jones, 2005). CMapTools, for example, is the software developed by the Institute of Human and Machine Cognition (IHMC) for drawing concept maps, and its features allow synchronous and asynchronous collaboration among different authors. Concept mapping is based on the Assimilation Theory of Meaningful Learning proposed by David Ausubel, and it can support students' option for meaningful rather than rote learning (Ausubel, 2000; Mayer, 2002; Novak, 2002).

Collaborative concept mapping is an interesting methodological strategy that responds to some of the educational demands posed by post-industrial society. Recent findings presented in the literature confirm the effectiveness of this strategy when appropriate training is provided to students in order to avoid the naive use of concept maps in the classroom (Basque, 2006; Cañas, 2006; Novak, 2008). In our contemporary context, collaborative concept mapping allows the development of synthesizing and creating minds (Gardner, 2006), as well as teamwork skills, which are formative requisites for 21st-century citizens (De Masi, 2003; Sawyer, 2006).

Peer review can be coupled to collaborative concept mapping to expand collaborative interactions among students in the classroom. After preparing and presenting concept maps in small groups, students from different groups can also evaluate the concept maps made by their counterparts. This innovative approach has the potential to change traditional classroom dynamics towards a renovated post-industrial education.

The impact of expanded collaborative learning in the classroom

Collaborative works should be more than intentions stated in educational projects and plans. They should be present in teachers' praxis. Classrooms should allow time for discussing how the disciplinary knowledge acquired during formal education can be used to understand the complex issues to be solved during the 21st century. Students must have the ability to put all this knowledge into a meaningful context to make independent judgments about global problems such as inequality, democracy and environmental crisis. This condition is compulsory for autonomous citizenship in the post-industrial society. Therefore, teachers must be aware of the role of collaborative works as a methodological strategy for developing students' abilities and attitudes to prepare them for transforming our society.

Peer review is rarely explored as a means of changing traditional assessment procedures; the challenge of students evaluating themselves breaks a paradigm in the classroom and reduces the power asymmetry between teacher and students. Furthermore, students are in about the same zone of proximal development as one another. Peer review offers a different opportunity for them to share knowledge compared to interactions with the teacher, who is not in the same zone of proximal development (Novak, 2002; Vygotsky, 1978).

Peer review goes beyond the collaborative activities developed by small groups of students and, for this reason, the term *'expanded collaborative learning'* is proposed to make a distinction between them. Moreover, the peer review of any students' material produced collaboratively merges *'conventional'* and *'expanded'* collaborative learning. Expanded collaborative learning through peer review changes the roles in the classroom, and students are faced with the new responsibility to judge the quality of the material produced by their peers. This activity can increase their awareness about their own achievements and failures during the learning process. As a consequence, peer review as an assessment exercise can be a safe road towards self-evaluation, which is an important pedagogical building block of post-industrial classrooms (Figure 1).

The repercussion of using peer review to intensify collaboration in the classroom is represented in Figure 2. Power asymmetry and the zone of proximal development are the two variables selected for differentiating three types of collaborative interactions. Vertical collaboration between teacher and students (Figure 2a) is prevalent in traditional classrooms, where the former's task is to transmit disciplinary knowledge, and the latter's task is to receive the transmitted knowledge. High power asymmetry and the difference between the teacher's and students' zones of proximal development characterize this vertical collaboration. On the other hand, a horizontal collaboration is observed when students interact with their counterparts (as happens during peer review, for example). In this case, power asymmetry is minimized and the students' zones of proximal development are similar (Figure 2b). The use of visualization tools to foster collaborative knowledge construction has its maximum potential in the context of horizontal interactions. An intermediate condition can be created when teacher and students interact in a constructivist learning environment (Figure 2c). Power asymmetry in this situation is moderate, because roles in the classroom are not related to transmission and receipt of disciplinary information; rather, knowledge is under a continuous process of construction and revision. The teacher's role is to scaffold and stimulate students to overcome their own conceptual difficulties (intrapersonal level) and to improve their teamwork skills (interpersonal level). The difference between teacher's and students' zone of proximal development remains, and this collaborative interaction has a diagonal resultant due to the simultaneous presence of vertical and horizontal collaboration components.

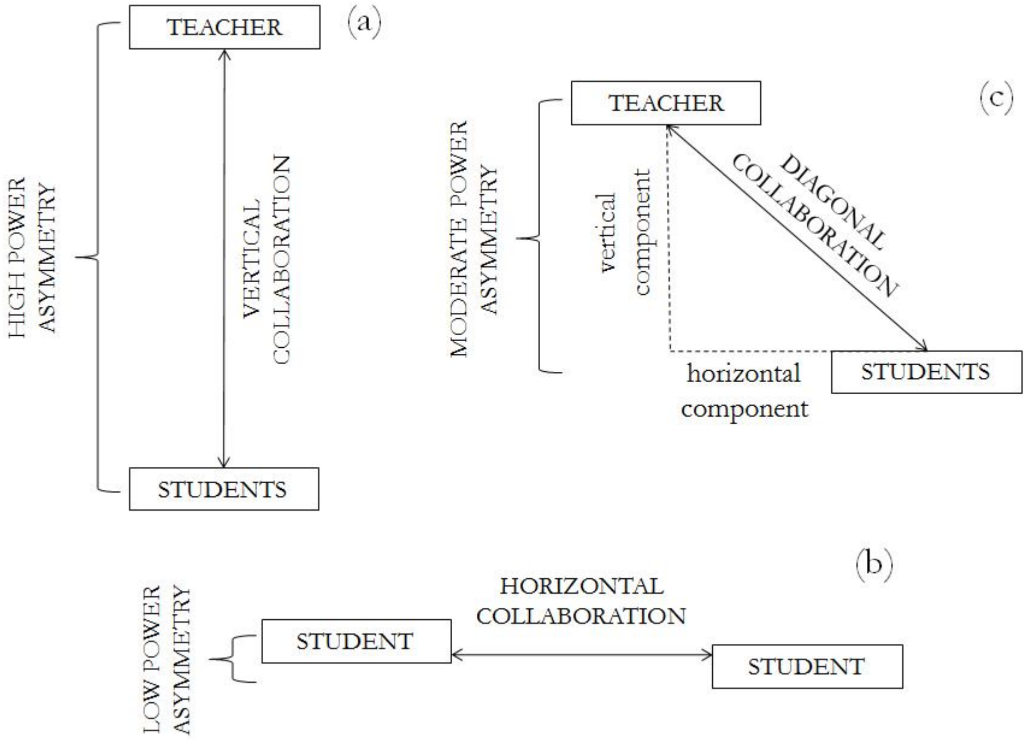

Figure 2. Collaborative interactions that predominate in traditional classrooms (a) and in post-industrial classrooms (b+c).

The constructivist nature of the post-industrial classroom matches with expanded collaborative learning possibilities. Beyond the new roles assigned to teachers and students, it increases the horizontal collaborative component, which is not present in traditional classrooms. Power asymmetry reduction in collaborative interactions is common nowadays, and horizontal collaboration is becoming more and more important in the 21st century (Friedman, 2007). The changes catalyzed by expanded collaborative learning can address the key features of the post-industrial classroom (Figure 1), and they also create favorable conditions for empowering students and fostering them to learn how to learn.

The social impact of expanded collaborative learning

Formal and informal education are always socially contextualized. The teacher's pedagogical task goes beyond the mere teaching and learning process because it has social meaning and significance. At any of its levels, scholar education can be considered as a means to promote students' social formation, because ideas, opinions and ideologies can be socially framed in school (Freire, 2005).

The social environment exerts a great influence on people. The relationships to be socially established depend on the experiences, beliefs and customs assimilated throughout our lives. Such relationships are important for implementing transforming actions in our globalized world. For this purpose, the assimilation of dominant ideas, opinions and ideologies must occur from a critical and questioning perspective. Teachers, who must be intentionally concerned with students' learning, also act as mediators of the influence of the social environment on their students. As a consequence, the teacher/student/knowledge relationship can neither be arbitrary nor authoritarian; on the contrary, it should be dialogical and democratic in order to value the teachers' pedagogical task (Freire, 2000; Freire, 2001). Teachers have the duty to organize content, to select methodologies and to design assessment strategies intentionally to promote students' learning in its broad sense, *i.e.*, considering conceptual and attitudinal changes in order to encourage the development of skills and values. As a social institution, schools have the responsibility to disseminate knowledge to ensure access to culture, work, social justice and citizenship.

Teachers' leadership in the classroom requires professional and moral qualities to mediate adequately between students and society. Communication and dialogue among people is a fundamental condition for supporting the formation process of the individual. As stated by Freire (2001) "the dialogue is the moment when men and women met to reflect about their reality, about what they know and don't know, to build new knowledge as conscious and communicative subjects". Freire's educational perspective highlights the role of each person in this collective building process to promote profound social changes leading to a more egalitarian, democratic, solidary and fair society (Freire, 2005). His Freedom Pedagogy states that all individuals can venture to unveil the deterministic ideologies and concepts hidden in their consciences and, from them, promote social changes (Freire, 2001).

The understanding of social system behavior from a biological perspective is proposed by Maturana (1998). In his opinion, the sum of the individual conduct of each person defines the characteristics of a social system. Profound changes in society depend on changing the individual conduct of its members. As a whole society is manifested in the conduct of the individuals that constitute it, genuine social changes only occur when a real change in the conduct of its members takes place. The human social phenomenon occurs when individual changes assume a contagious state, spreading out and affecting the surrounding members in the society. The cumulative effects of the human social phenomenon can result in genuine social changes.

The classroom can be considered as a complex system where the human social phenomenon can take place. The merging of Freire's and Maturana's perspectives allows us to understand the classroom as the place to foster social transformations through the educational formation of citizens capable of analyzing and changing their own conduct (Figure 3). From our methodological point of view, teachers must promote collaborative learning experiences to challenge students to revise their individual attitudes in a critical and autonomous way. Changing the individuals' conduct from an individualistic (industrial) to a more collectivistic (post-industrial) perspective may promote the required changes in the social system in order to deal with the global problems that have affected us since the second half of the 20th century.

The classroom is a privileged social place to foster students' empowerment to allow them to become active participants in the task of promoting profound social transformations. Intentional choices in terms of content selection and methodological approaches must be carefully made by teachers in order to produce small cumulative changes in their students throughout their formal education (Infante-Malachias, 2007). The use of well-designed methodological approaches such as expanded collaborative learning should be part of any licentiate course which aims to prepare teachers ready to face the challenges posed by the education in the post-industrial society.

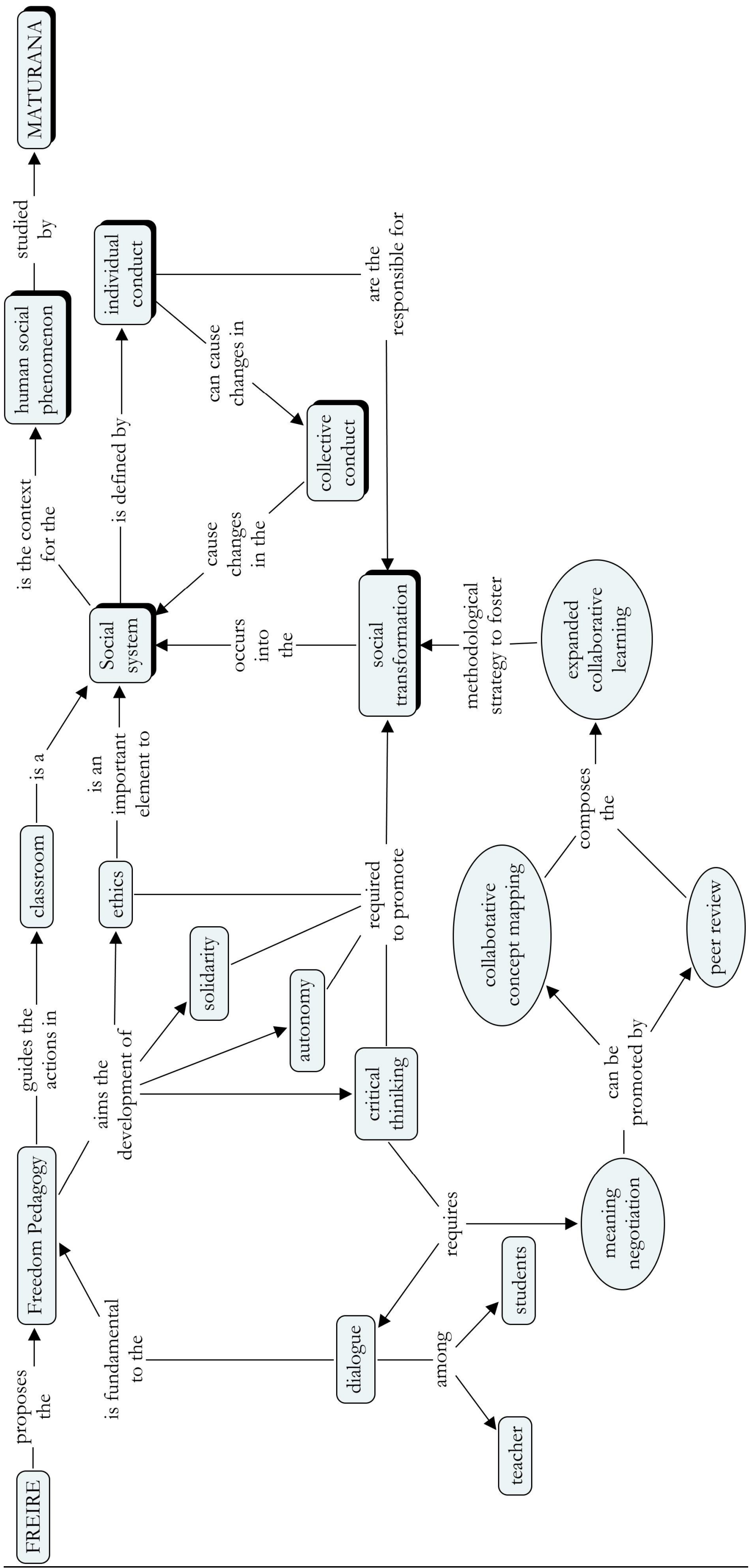

Figure 3. Concept map for merging Freire's and Maturana's perspectives to highlight the social impact of expanded collaborative learning. Focal question: How can expanded collaborative learning foster social transformations? Concepts from Paulo Freire's ideas are in boxes, concepts from Humberto Maturana's ideas are in shadowed boxes, and the concepts related to expanded collaborative learning are in circles.

Expanded collaborative learning in higher education: an experience to empower 1st-year students

The challenge of facing the reality of the classroom occurred during the discipline ACH 0011 Natural Sciences. It is offered for all 1st-year students at Escola de Artes, Ciências e Humanidades (School of Arts, Science and Humanities at São Paulo University). The main goal of this discipline is to provide a broad view of the impact caused by scientific and technological development in our society. Scientific literacy, a new post-industrial demand, is a requisite for an autonomous citizenship. A new contract involving society and science is under negotiation and all citizens must have the right to make their own judgments about ethical aspects of scientific and technological issues (DeHaan, 2005; Donnelly, 2004; Holbrook, 2007). Therefore, scientific literacy needs to be nurtured throughout formal education (Fourez, 1997; Unesco, 2005).

Sixty students from five different undergraduate courses were grouped in the same classroom to attend two-hour weekly classes over a period of 15 weeks. Considering the discipline's introductory scope and heterogeneous audience, the challenge to satisfy students' expectations required innovative methodological strategies. Table 2 presents a qualitative estimate of the students' interest level at the beginning of the discipline considering their undergraduate courses. High, moderate and low interested students can be found in any ACH 0011 Natural Science classroom, according to instructors' testimonies.

Table 2. Students' interest in ACH 0011 Natural Science discipline at the beginning of the semester.

Undergraduate course	Low	Moderate	High
Environmental Management			XXX
Gerontology		XXX	
Information System		XXX	
Leisure and Tourism	XXX		
Licentiate in Natural Sciences*			XXX
Marketing	XXX		
Obstetrics		XXX	
Physical Activity Science		XXX	
Public Policy Management	XXX		
Textile Technology and Fashion		XXX	

**4-year degree that qualifies students to teach in primary education.*

Some instructors chose to use concept maps throughout the discipline. Students are introduced to them and trained to elaborate both manuscript and digital concept maps using CMapTools. The aim is to ensure an adequate training period for the students in order to avoid the inappropriate use of this tool, as highlighted in the literature (Cañas, 2006, Novak, 2008). Table 3 summarizes the discipline schedule and the activities involving concept mapping.

The universe is the central theme during classes 1 to 5. Beyond the discussion involving natural science topics, the students are introduced to concept mapping and they make an individual manuscript concept map. As preparation for test 1, the students revise the initial concept map about the universe and prepare an individual digital version using CMapTools. This final concept map may be consulted during test 1.

Climate changes are the following subject, and discussion occurs during classes 6 to 10. Collaborative concept maps are prepared by 3-student groups for fostering the collaborative knowledge construction steps of knowledge externalization, knowledge elicitation and consensus building (Fischer, 2002), as shown in Table 1. The final version of this collaborative concept map can be used by the students to prepare a short communication about the environmental challenges of the 21st century. These texts are peer reviewed during class 10 to introduce the students to this practice. All 1st-year students experience peer review, which is a procedure widely adopted in science. This strategy makes even more sense considering the scope of the discipline. From the methodological point of view, expanded collaborative learning begins in the classroom.

Bioethics is the last subject to be discussed during classes 11 to 15. Collaborative concept maps are explored again, but test 3 consists of their presentation and peer review. Students present their own maps and pose comments to assigned concept maps prepared by their counterparts. They fill in a form to help the authors to correct, improve and/or include new conceptual relationships. At the end of class 15, each group receives suggestions made by four other students. Moreover, the authors can also take advantage of the good ideas appearing during all presentation sessions. The last adjustments can be incorporated into the concept maps before students send their final versions by e-mail, with a due date of 2 days after class 15.

Table 3. Didactic organization of the ACH 0011 Natural Science discipline.

Class #	Discipline schedule	Concept mapping activities
	Theme #1: Universe Mysteries and the Modern Scientific Revolution	
1	*Historical development of scientific thinking*	*Introduction to conceptual mapping and general guidelines for making manuscript concept maps*
2	*Galileo and the scientific revolution*	*Individual concept map*
3	*Knowledge explosion and astronomy discoveries in the 20th century*	*Revision and discussion of produced concept maps and introduction to the CMapTools software*
4	*Hubble, the galaxies and cosmology*	*Individual concept maps for synthesizing information up to the first test*
5	*Test 1: Preparing a text in pairs*	*-x-*
	Theme #2: Climate Changes and the Environmental Challenges of the 21st Century	
6	*Search for information, selection and set up of a conceptual framework*	*Collaborative concept maps for externalizing and eliciting knowledge (3-student groups)*
7	*Film session: An Inconvenient Truth*	*-x-*
8	*Discussion about the film and revision of the conceptual framework*	*Conflict- and integration-oriented consensus building (3-student groups)*
9	*Test 2: Preparing a short communication in pairs for publishing in a periodical*	*Revision and discussion of collaborative concept maps (3-student groups) as preparation for test 2*
10	*Double blinded peer review of counterparts' short communications*	*-x-*
	Theme #3: Molecular Biology, Modern Medical Procedures and Bioethics	
11	*Search for information, selection and set up of a conceptual framework*	*Collaborative concept maps for externalizing and eliciting knowledge (3-student groups)*
12	*Film session: DNA – The Promise and the Price*	*-x-*
13	*Discussion about the film and revision of the conceptual framework*	*Conflict- and integration-oriented consensus building (3-student groups)*
14	*Debate about bioethics and final revision of the conceptual framework*	*Revision and discussion of collaborative concept maps to be presented in test 3*
15	*Test 3: Presentation of collaborative concept maps and single blinded peer review*	*Peer review of counterparts' collaborative concept maps and final revision from the received comments*

It should be stressed that collaborative concept mapping is preferred over individual concept mapping to explore the diversity of opinions and interests from a heterogeneous audience and to foster collaborative knowledge construction (Basque, 2006; Fischer, 2002). It is also important to ensure enough time for the continuous process of revision and improvement of collaborative concept maps. The students have at least 1 month (4 classes) to prepare the final version of the concept maps about climate changes (classes 6 to 9) and bioethics (classes 11 to 15).

Three concept maps from different students are presented in Figures 4-6. An individual concept map about the universe and the historical evolution of modern science is shown in Figure 4. It is possible to identify 4 different related issues that respond to the focal question *(What are the relations between the observation of celestial events and historical scientific development?)* considering the topics discussed during the classes: historical view of scientific development (concepts in circles), religion and science conflict (concepts in shadowed circles), modern astronomy discoveries (concepts in shadowed boxes) and a description of our location in the universe (concepts in boxes). The student's efforts to organize and revise the conceptual relationships can also be noted by the creative spatial organization of the concepts. He added a comment for the readers: "I made the concept map following the shape of a spiral galaxy in order to match the visualization and the subject under study. The universe is intentionally located at the center of the concept map because it is the focus of our studies". On the other hand, unclear propositions such as 'power involves paradigms' and 'beliefs are paradigms' suggest possibilities for further improvements. As stated by Novak and Cañas (2008) "it is important to recognize that a concept map is never finished. After a preliminary map is constructed, it is always necessary to revise this map. Other concepts can be added. Good maps usually result from three to many revisions". Despite some variations, all individual concept maps made by the students after the 4-week training period were acceptable and collaborative concept mapping could be started at class 6 (Table 3).

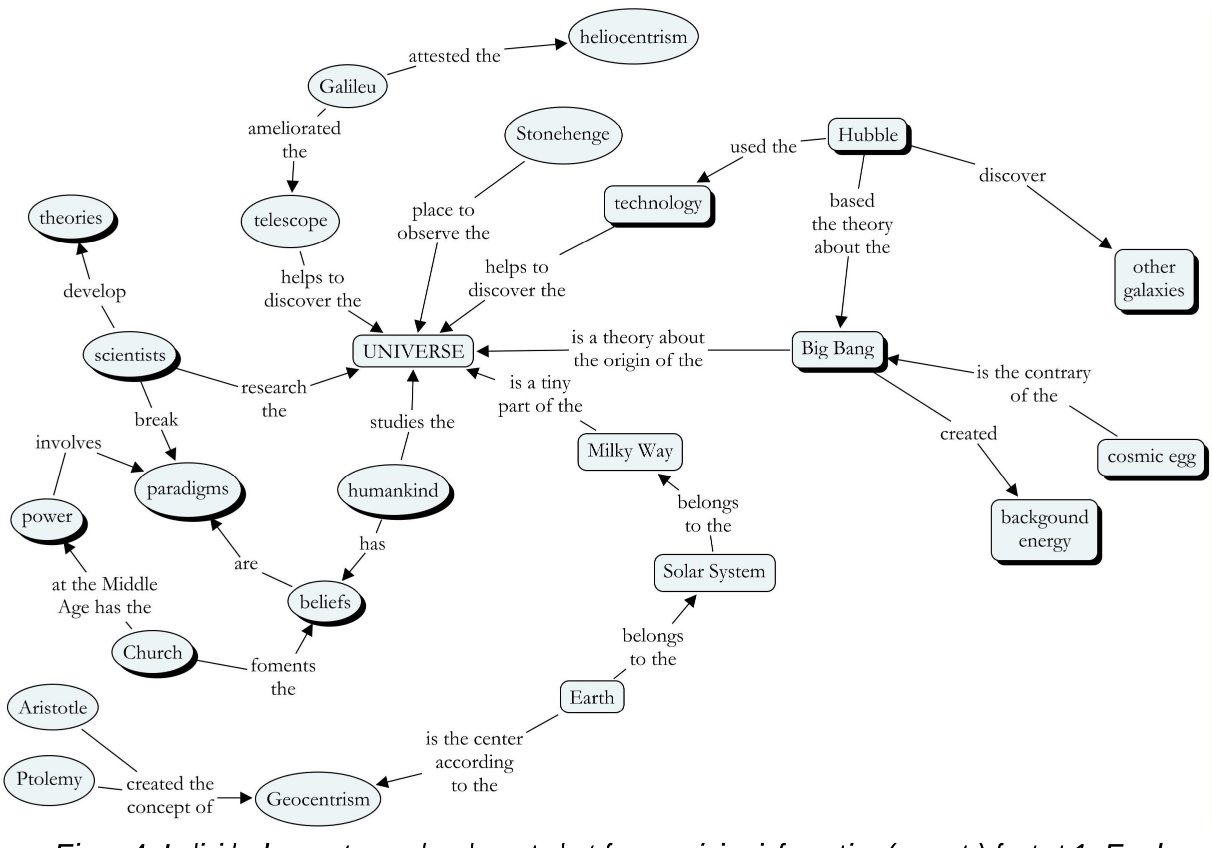

Figure 4. Individual concept map done by a student for organizing information (concepts) for test 1. Focal question: What are the relations between the observation of celestial events and historical scientific development? The form and shadows of the boxes were changed by the authors.

A collaborative concept map about climate changes is presented in Figure 5. The result of the efforts of three students shows the following related issues to address the focal question *(What are the problems and the possible solutions to preserving the environment?)*: the problems associated with fossil fuel burning (concepts in boxes), glacier melting as a consequence of global warming (concepts in circles), possible solutions to mitigate the climate changes (concepts in shadowed boxes) and two central concepts related to social issues (concepts in shadowed circles). The interconnection among environmental problem concepts and possible solution concepts was made by using cross-links from the non-scientific concepts ‘progress’ and ‘cities’. This fact highlights the typical awareness promoted by scientific literacy, which is the main goal of the ACH 0011 Natural Science discipline. Moreover, the cyclic nature of this concept map should be emphasized, as it attempts to establish cause-effect relationships between an environmental problem (climate changes) and possible mitigation actions (use of renewable energy and reforestation). This external cyclic structure may indicate the students’ attempts toward dynamic thinking, which can confirm that they are skilled map-makers (Derbentseva, 2007; Hilbert, 2007). Interesting research questions involving the importance of collaborative knowledge construction to stimulate scientific literacy as well as the role of the conceptual map as a visualization tool to support this process demand further investigation.

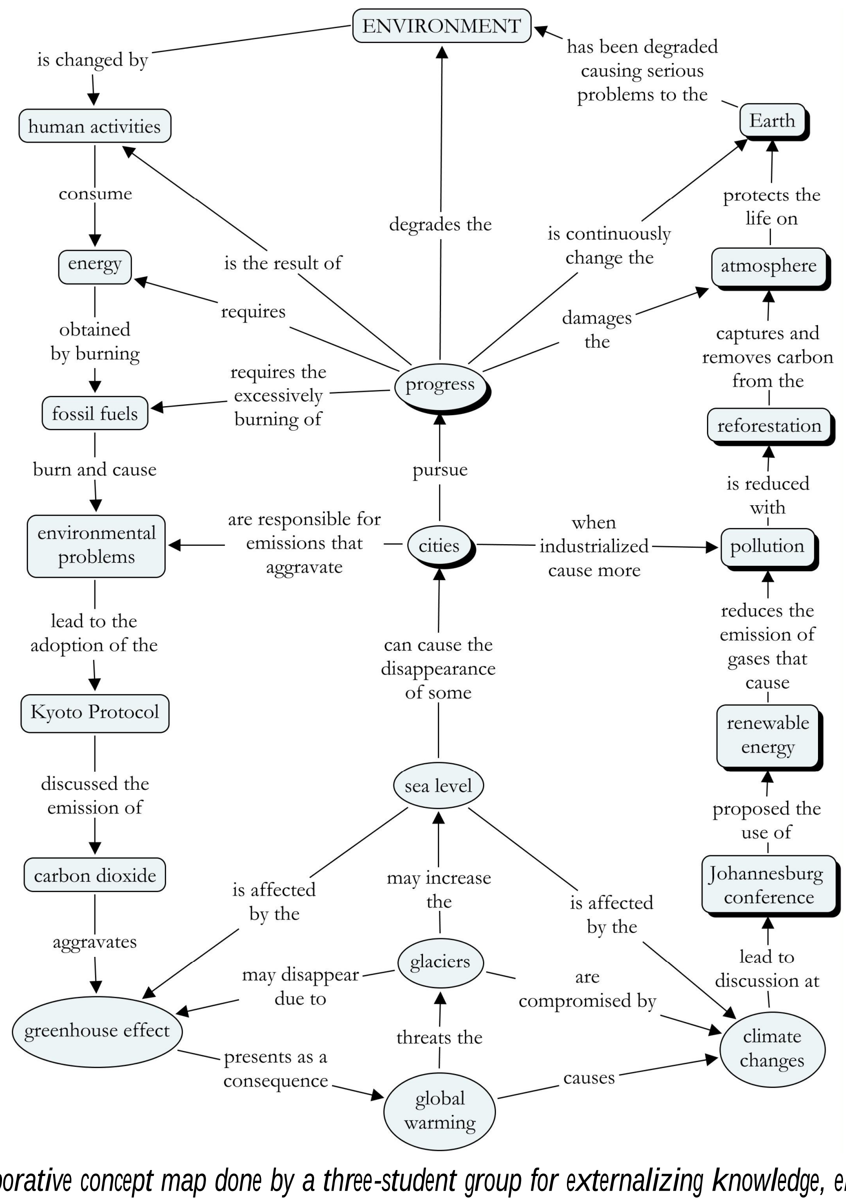

Figure 5. Collaborative concept map done by a three-student group for externalizing knowledge, eliciting knowledge and building a consensus through conflict mediation. Focal question: What are the problems and the possible solutions to preserving the environment? The form and shadows of the boxes were changed by the authors.

Figure 6 presents a collaborative peer reviewed concept map about bioethics. The authors used three different related issues to answer the focal question *(What are the relations among religion, bioethics and science?)*: religion (concepts in circles), bioethics (concepts in shadowed circles) and science (concepts in shadowed boxes). The cyclic structure appears again and the bioethics concepts are used to mediate the differences between religious and scientific points of view. The students also add three examples (abortion, cloning and stem cells) for differentiating the ‘controversial issues’ concept. Non-scientific concepts such as moral, controversial issues and conflicts confirmed the students' awareness involving the impact of science on our society, as well as the need for an ethical discussion to "set parameters for research" (Figure 6). Considering life as the main subject, students presented bioethics to mediate scientific research involving reproduction. However, a tendency can be seen for approving genetic work and for disapproving restrictive actions from the Church. As any idiosyncratic open question, this debate does not have a right answer, and continuous discussion must take place. Finally, the evolution concept was used by the authors in an elegant and sophisticated way: it has different meanings, considering the propositions "conflicts are important for evolution", "Darwin published the Theory of Evolution" and "genetics can change the pathway of evolution".

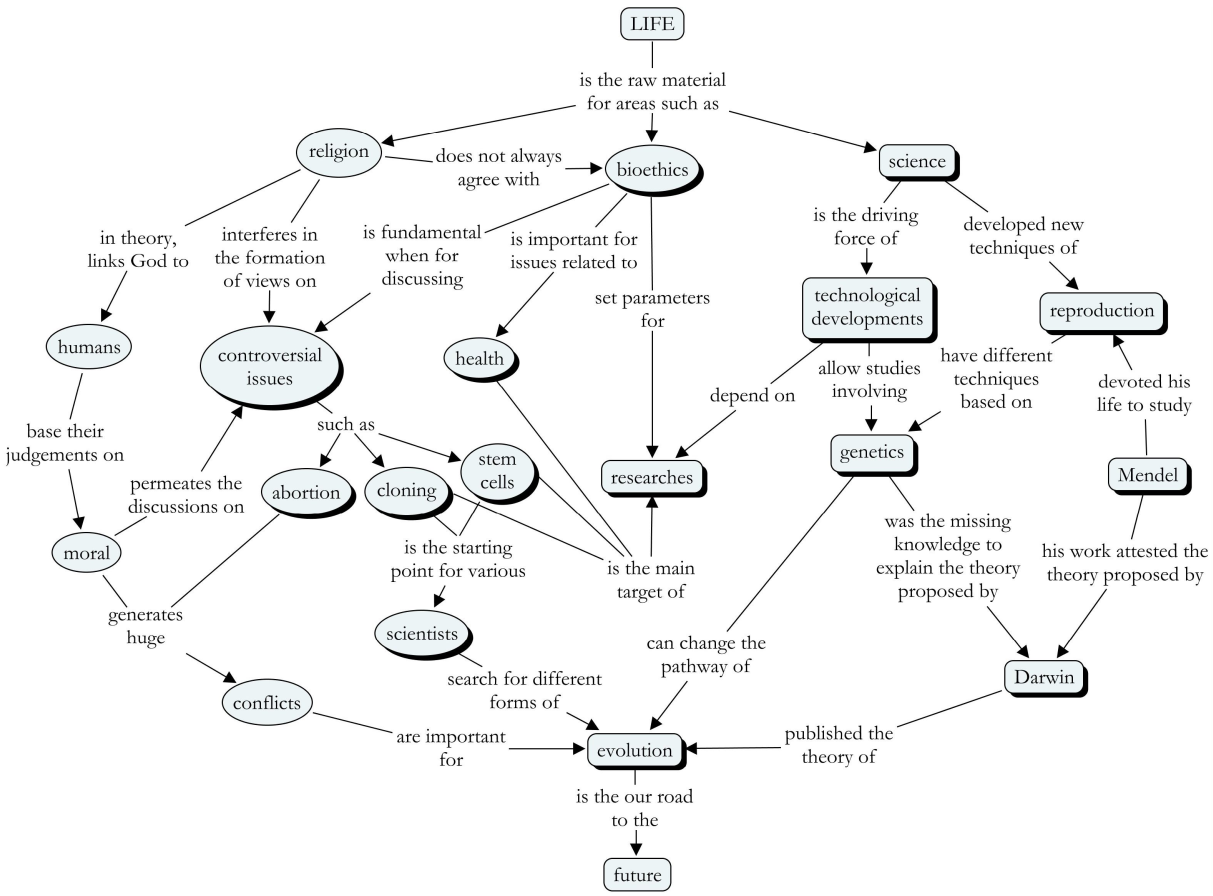

Figure 6. Peer reviewed-collaborative concept map done by a three-student group for externalizing knowledge, eliciting knowledge and building a consensus through conflict mediation. Focal question: What are the relations among religion, bioethics and science? The form and shadows of the boxes were changed by the authors.

A comparison among the students' concept maps is presented in Table 4. The qualitative features suggest that collaboration and peer review can support the development of better concept maps in comparison to individual production. Cyclic structures and the increase of the number of ramification points and cross-links may be attributed to the collaborative knowledge construction that only happens when three students were co-responsible for creating a concept map. Peer review further improved the quality of revised concept maps because the authors take advantage of the good ideas presented by other students. All concept maps could be viewed by all students during the presentation sessions, and the good concept maps were used as model for those students who had difficulties creating a good map. Examples that indicate a refined concept map were mentioned only in the collaborative peer reviewed concept map about bioethics (Figure 6).

Table 4. Comparison of the concept maps produced by students throughout the ACH 0011 Natural Science discipline.

Features	Concept map in Figure 3	Concept map in Figure 4	Concept map in Figure 5
Qualitative			
Individual	Yes	No	No
Collaborative	No	Yes	No
Peer reviewed	No	Yes	Yes
Cyclic nature	No	Yes	Yes
Quantitative			
Related issues	4	3	3
Concepts	24	20	21
Cross-links	1	7	6
Ramification points	3	6	7
Propositions	26	32	31
Unclear propositions	2	2	0
Examples	0	0	3

Final considerations

A new society asks for a new education. Despite not solving all educational problems, innovative methodological strategies can change the traditional dynamics which still prevail in the majority of contemporary classrooms. The new formative demands posed by post-industrial society require more than disciplinary knowledge transmission, and some skills – such as lifelong learning, creative thinking, and teamwork - must be simultaneously developed throughout formal education. Emotional aspects must also receive attention, and confidence is necessary to allow the synergic merge of cognitive and communicative skills to empower students in classroom.

Students' empowerment has a profound social impact considering the new formative demands for 21st-century citizenship. All individuals must be aware of the roles that they must assume in order to transform society. As a complex social system, the classroom is the place to prepare youth to take part in the construction of a more egalitarian, democratic, solidary and fair society. In spite of not being a trivial challenge, teachers must be aware that changing the classroom to foster a collaborative and empowering environment is compulsory for a high-quality post-industrial education.

Peer review and concept mapping can be combined to create an expanded collaborative learning experience, as presented in this chapter. More than a theoretical discussion, this chapter also describes the implementation of expanded collaborative learning in a higher education classroom during an introductory course about natural sciences. The obtained results were promising, and they call for more research on the formation of creative groups. This research should explicitly consider students' idiosyncratic characteristics, the role of concept maps for fostering collaborative knowledge construction, and the potential of expanded collaborative learning as an empowering agent supporting the ultimate lesson to be taught in post-industrial classrooms: learning how to learn. This is the ultimate condition for preparing students to act as autonomous citizens capable of transforming society.

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Key terms and their definitions

Conventional collaborative learning: learning experience based upon consensus building through cooperation by group members.

Creative idleness: a new condition imposed by the post-industrial society. Work time, leisure time and study time are no longer separated as occurred during the industrial society. They are simultaneously merged during the creative idleness, which has changed the relationship between man and work. Post-industrial citizens work, have fun and study at the same time during all the time.

Empowerment: bring students into a state of belief their ability to act effectively

Expanded collaborative learning: learning experience based upon consensus building through cooperation by group members, when most interactions occur among pairs (horizontal collaboration).

Globalization: interweaving of markets, technology, information systems and telecommunications systems in a way that is shrinking the world from a size medium to a size small.

Innovation: the process of making improvements by introducing something new. It begins with creative ideas from individuals or teams.

Lifelong learning: the process of acquiring knowledge or skills throughout life via education, training, work and general life experiences. It also describes the modern global phenomenon where it is has become the norm for people to return to formal education and training at periods during their working life.

Metacognition: the awareness of one's cognitive processes and the efficient use of this self-awareness to self-regulate these cognitive processes. This active control over the process of thinking is necessary to regulate one's the life-long learning.

Peer review: is a process of subjecting an author's scholarly work, research or ideas to the scrutiny of others who are experts in the same field. In unblind peer review the names are not shielded. In single-blind peer review the reviewers know the name of the author. In double-blind peer review neither the author nor the reviewers know each others' identities.

Post-industrial society: is the society that has moved past the stage of heavy industry to an economy that is mainly centered on knowledge-based and service professions.

Scientific literacy: capacity to use scientific knowledge to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity.