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Towards A Design Framework for Mobile Computer-Supported Collaborative Learning

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Abstract. We present one component of a foundation for mobile, handheld device-supported collaborative learning (mCSCL), a design framework. Our design framework proposes that mediation can occur in two complementary layers, social (e.g. rules and roles) and technological. Further we suggest that for mCSCL, the technological layer has two components, representational mediation and networked mediation. A particular design challenge is achieving an effective allocation of supporting structure to each layer as well as simple, transparent flow between them.

Keywords: CSCL, mobile, handheld, design, collaboration

INTRODUCTION

Mobile, handheld devices are growing in importance in education, in part because they are much more affordable than conventional laptop or desktop computers (Norris & Soloway, 2003). Further, mobile handhelds can easily be used in any classroom or field site; hence they can be used more often than computer labs (Vahey & Crawford, 2002). In addition, students may own these devices and be able to take them home, multiplying their potential utility in the learning process (Consortium for School Networking, 2004). In sum, these devices enable a transition from occasional, supplementary use of computing to frequent, integral use (Roschelle & Pea, 2002).

We focus on two affordances that these devices provide which are closely coupled to learning: (1) dynamic representation (e.g. graphing, simulation, mapping, visualizing, modeling) and (2) classroom-area networking. The use of dynamic representation to enhance what and how students learn has a long track record in educational computing (Roschelle, Pea, Hoadley, Gordin, & Means, 2000). Early experiments suggest the power of dynamic representation can translate well in mobile, handheld-sized screens (Tinker & Krajcik, 2001). Classroom-area networking is a newer concept, focusing on the creation of an information flow topology within classrooms that enhances individual, small group, or full classroom activities that are occurring face-to-face (Roschelle, 2003).

Presently mCSCL is a rapidly growing field with much of its intellectual activity focused on discovering, describing, and documenting the effectiveness of specific designs for using these devices in learning. Relative to these activities, a strong design framework could have three important benefits: (1) developers could use a comprehensive framework to more carefully think though their planned design (2) researchers could use a framework in developing taxonomies, comparisons, and data aggregation across individual projects (3) teachers and students could benefit from a more complete, standard way to describe what they should do.

This paper is organized to argue for a candidate design framework for mCSCL. Starting from a literature review, we develop the idea that core design challenge for collaborative learning is designing activities (or tasks) that artfully align and interrelate content and relationship goals, achieving synergies between the imperatives of human relationships and the imperatives of the educational content. We suggest technology plays two mediating roles: (1) representing content to support student reasoning and (2) coordinating the flow of information in support of collaborative learning. We have deployed our framework to describe eight well-known, successful mCSCL learning activities. Due to space limitations, we cover only two here.

LITERATURE REVIEW

We see mCSCL as nested construct, building first upon research on social constructivism and general research findings on how people learn, second upon foundations of collaborative learning and CSCL, and third upon the new affordances unique to this technology.

Social Constructivism

According to Johnson & Johnson (1987), classroom learning improves significantly when students participate socially. Research on constructivist learning environments has shown that children see their classmates as a source of knowledge and help, rather than as a competition. Social cognition creates knowledge and skills in the context of use (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991).

Social constructivism suggests five principles for an educational activity (Newman, Griffin, & Cole, 1989). Educational activities should be:

1. Constructive: existing student knowledge schemes are integrated with new information to acquire new knowledge.
2. Active: each child is expected to participate in generating new knowledge and learning from peers.
3. Significant: learning has to be personally meaningful to the student.
4. Reflexive: the group acts as a mirror for each student's learning process.
5. Collaborative: where the student learn with the other members of a group, the group has the same pedagogical goal, and each member is a potential source of information.

The childrens' experience and knowledge, mutual feedback, and their own and shared reflection allows them to build their answer as a group constructive (Roschelle & Teasley, 1995). Students are encouraged to explain their findings, i.e., the meaning of words (reflexive). The children contribute with their ideas and knowledge socially, interacting and negotiating possible concepts (based on consultation). Finally, every child's contribution should be shown to the other children within the group in a common space (significant, reflexive and collaborative) (Zurita & Nussbaum, 2004).

How People Learn

The foundations of social constructivism resonate with accumulated evidence from the Learning Sciences, as synthesized in the book, *How People Learn* (National Research Council, 1999). Research spanning multiple ages and subject matters suggest that Students come to school with prior knowledge that strongly effects how they learn new subject matter. If this incoming knowledge is not engaged in the course of instruction, students frequently fail to learn desired subject matter concepts. To develop competence in a subject matter, students need to learn facts in relationship to a conceptual structure that organizes their understanding and use of the subject matter. Conceptual understanding is an essential goal for instruction. Teaching should aim to encourage students to be more active in taking control, monitor, and regulate their own learning. Learning strategies are not generic across subject matters, and treating them as generic can lead to failure. Thus such "metacognitive" emphases can and should be integrated into subject matter teaching.

Collaborative Learning

Collaborative or cooperative learning seeks to use small groups for instructional purposes in such a way that students work together to maximize their own learning and the learning of others (Johnson, Johnson & Smith, 1991; Cohen, 1994). In order to achieve collaboration, it is essential that the activity include: opportunities for face-to-face interaction; joint attention to ideas or materials, positive interdependence (each students' contribution is needed for the group to succeed), individual responsibility, interpersonal and small group skills, and group processing (Johnson, Johnson & Smith, 1991; Holubec, 1999; Cohen, 1994, Barron, 2003). When these essential features are present and the above additional considerations are addressed, collaborative learning can produce strong student motivation and achievement.

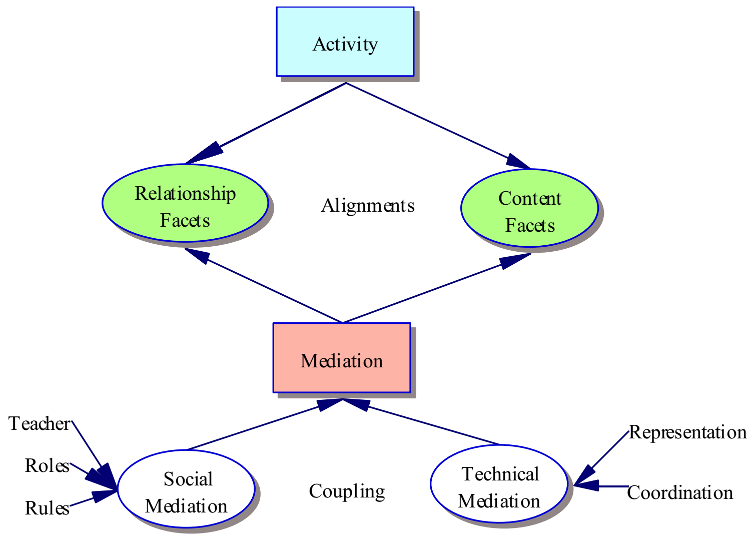
In collaborative learning activities, there is both content to be learned and a relationship between group members that has to be sustained. "Collaboration might productively be thought of as involving a dual-problem space that participants must simultaneously attend to and develop a content space and a relational space (consisting of the interactional challenges and opportunities)" (Barron, 2003, pp. 310). The content space can be defined by the proposals generated by the members about the given content. The relational space is defined as the joint attention to those proposals. According to Barron, more successful groups respond by accepting or discussing the proposals, whereas less successful groups have a high probability of rejecting or ignoring the proposals. According to Dillenbourg (1999), an educational collaborative activity can be successful when there is: (a) a well-defined objective, (b) regulation through rules and roles, (c) a defined domain consisting of the number of group members, the criteria for the group composition, and the specification of the technological mediation, and (d) an adequate environment for the educational context.

mCSCL

Wireless communications are particularly conducive to the sharing and comparing of information and results whenever students work in groups (Vahey & Crawford, 2002). While collaborative learning based on laptop-type computers makes students focus their attention on spaces which are fully contained within the limits of the screen, handhelds increase the space available in exchanges of information (Roschelle & Pea, 2002). Simultaneous interconnection makes the students more active and engaged in the learning process (Inkpen, Mandryk & Scott, 2000; Inkpen, Ho-Ching, Kuederle, Scott & Shoemaker, 1999). mCSCL applications can:

organize the managed information, provide a negotiation space, encourage coordination between the activity states, and mediate synchronization and interactivity, (Zurita & Nussbaum, 2004).

OUR PROPOSED FRAMEWORK



The root construct of our proposed framework is an activity or task—a coherent, planned process that is intended to facilitate a large group of students making significant progress in learning particular content in a bounded time and space. Activities could be more elaborately rendered via Activity Theory (Nardi, 1996) or more simply rendered as lesson plans. Within an activity, the design should encompass two important facets: relationship facets and content facets .

The **relationship facets** of an activity design should describe how the human imperatives of face to face learning will be addressed. Relationship facets include joint attention, group processing, individual responsibility, positive interdependence, and social skills, as described in our literature review above. One of the *How People Learn* constructs, community-centeredness, fits here as well. The **content facets** of an activity design should describe how the subject matter imperatives of face to face learning will be addressed. These facets include learner-centeredness, knowledge-centeredness and assessment-centeredness.

An mCSCL activity cannot be simply simultaneously social and contentful—the social and content facets must be mutually supporting.. The prior literature provides theoretical constructs that may prove useful for giving reason to the **alignment of social and content facets** (e.g., social activity may increase cognitive conflict, leading to pressure to transform conceptual schemes to accommodate new ideas).

Social learning activities do not happen just because they are planned, nor are they necessarily easy to carry out productively. A major focus in design, therefore, is to specify appropriate mediational means to ameliorate expected troubles or activate latent potentials. **Mediation** can be social or technical. In any given mCSCL, both are likely to be employed.

Social mediation may be provided by specifying guidelines for the teacher, roles for students, or rules for their joint work. The teacher may be asked to motivate or instruct the students, coach students on social skills, monitor the process of the activity and make adjustments to facilitate progress, and provide helpful feedback.

Technological mediation, first of all, may be paper-based. The activity designer, for instance, might right rules or roles on paper. Given the small screens of mCSCL devices, paper can dramatically expand the space available to a designer for structuring an activity. Within uses of the devices themselves, we see mediation as broadly representational or broadly coordinative. For example, a graph that controls an animation may be a powerful representation for learning mathematics. Coordinative mediation provides ways of organizing the flow of information among mCSCL devices to support the objectives of the activity. For example, aggregating a set of students answers but only allowing the students to see whether they all agreed or they differed may support the objective of an activity.

It is to be expected that some of the activity will be mediated technically and some will be mediated socially. Thus it is critical, if the activity is to succeed, for the designer to attend to how these two channels are coupled. How for instance can the student talk about “my idea” when it has been transmitted to another students’ device and incorporated into their representation? Likewise, if some important part of the activity is occurring socially, how does the technology become aware of what has happened? Commonly, shared reference to technologically mediated learning may be accomplished by the use of a large, public display.

TWO ILLUSTRATIONS OF USING THE FRAMEWORK

Match My Graph

“Match my graph” (MMG) uses Palm handhelds with infrared beaming to engage students in refining their ability to use concise mathematical vocabulary to describe linear functions. The content facet of MMG involves translating between graphical and linguistic definitions of functions. Students have great difficult describing how linear functions differ; where a mathematician would use terms like "slope" and "y-intercept", students may see a graphed function as "short" or "jaggy." The student descriptions may reflect artifacts of the computer screen than an expert would ignore and the students may ignore the very features an expert finds most salient. The relationship facet of MMG is patterned on the popular game "mastermind" – one student has a secret which the other student tries to guess. If a guess is wrong, the secret-holder provides a hint. Social and content facets are aligned in MMG because the "secret" is a graph that the other student cannot see. Hints are given linguistically; to solve the challenge students must translate the features of their graphed function into a verbal hint, and the other student must translate the hint back into a new graph. The social and content aspects of MMG are aligned because the game motivates students to develop clearer ways of talking about linear functions.

Mediation in MMG is both technical and social. Students sometime have no idea about what kinds of hints they might try. The technical mediation is both representational and coordinative. The representational aspect involves the use of the stylus and the Palm's graphic display to make it easier to sketch and manipulate graphs of linear functions. Because the Palms are small and personal, students can easily hide their "secret" by holding their screen vertically. The Palm also supports coordinative mediation: a student beams a guess to the secret-holder. When the guess is received, the secret-holder can see both functions on one graph. This facilitates comparison between the secret and the guess. Hints, however, are given verbally – not through the technology. Further, teachers mediate hint-giving by coaching students, again socially without technical mediation. The technical and social mediation is linked by consistently color-coding a player's function. This makes it easy to talk about a particular function, e.g. "your red function" vs. "my blue function." After students play MMG several times, the teacher engages the students in a group discussion. The purpose of the group discussion is to reflect on the different ways of describing functions that each student used and on the nature of clear mathematical communication.

Collaborative Construction

The goal of a collaborative construction activity is for students to assemble a creative object from the unique component pieces each student holds. In one simple example, "Silaba," each student receives a syllable (Figure 2). Students work together to assemble their syllables into words (Figure 2). A group of three members is defined (Dillenbourg 1999, Zurita & Nussbaum 2004a). Each child receives an element, i.e. a different syllable. In Figure 2, Miguel receives "si", Gustavo "la" and Rodrigo "si". The children have to find out the correct combination of syllables. For the example, the possible combination is "silaba", "bala", "la" and "si". (In Spanish unlike English several words can be built from a set of syllables).

(a) (b) (c) (d) (e)

Figure 2: Collaborative Construction application; construction of words

We analyze the Relationship Facets following the Social Constructivism principles. The children previous knowledge, mutual feedback, and own and shared reflection allows them to build as a group their answer (constructive). They are encouraged by the teacher to explain their findings, i.e., the words meaning (reflexive). The children contribute with their ideas and knowledge socially, interacting and negotiating possible words (based on consultation). Finally, every child contribution is shown to the other children within the group in a common space (significant, reflexive and collaborative). For example, Miguel selects his syllabus, the machine shows the syllabus to him (Fig 2d) and the other members (for example Rodrigo, Fig 2e) in their corresponding screen and tells also Miguel that he has now to wait for his partners.

The cognitive effort is targeted to the collaborative construction activity. All the necessary information and a structured decision-making procedure is given through the handhelds. The handhelds network provides a negotiation space that encourages coordination between the three activity states. Each child decides how his syllable is used, i.e. when his turn is in relation to the rest of the group, allowing collaborative discussion on the construction procedure, mediating the handhelds synchronization among the members.

Finally we have the role of technology, i.e., representation and coordination. This includes assignment of tasks; within each group, each member receives his own syllable. Since the syllable is only available to one member, s/he has to inform the other members, providing interdependence and interactivity within the group. In terms of representation, the screens provide a space for sharing the current state of the group construction. In Figure 2c, 2d, and 2e Miguel and Rodrigo share what Miguel did. Since the word is constructed simultaneously on all screens, the technology provides a visual negotiation space. Technology forces synchronicity blocking the child that already chose his her syllable.

CONCLUSION

Mobile, handheld, wireless devices are opening new possibilities for collaborative learning. As interest in mCSCL grows, researchers, developers, and teachers will look for ways to organize, analyze, and synthesize resulting knowledge. We suggest that articulating a design framework that potential spans many mCSCL activities can contribute the foundations of further work in this area.

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REFERENCES

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*(18), 32-42.

Consortium for School Networking. (2004). A guide to handheld computing in K-12 schools.

Dillenbourg, P. (Ed.). (1999). *Collaborative learning: Cognitive and computational approaches*. Oxford: Pergamon.

Johnson, D. W., & Johnson, R. T. (1987). *Learning together and alone: Cooperative, competitive, and individualistic learning*. New York: Allyn & Bacon.

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

Nardi, B. (Ed.). (1996). *Context & consciousness: Activity theory and human-computer interaction*. Cambridge, MA: MIT Press.

National Research Council. (1999). *How people learn: Brain, mind, experience, and school*. Washington, DC: National Academy Press.

Newman, D., Griffin, P., & Cole, M. (1989). *The construction zone: Working for cognitive change in school*. London: Cambridge University Press.

Norris, C., & Soloway, E. (2003, April). *The viable alternative: handhelds*. Retrieved May 12, 2003, from http://www.aasa.org/publications/sa/2003_04/soloway.htm

Roschelle, J. (2003). Unlocking the learning value of wireless mobile devices. *Journal of Computer Assisted Learning, 19*(3), 260-272.

Roschelle, J., & Pea, R. (2002). A walk on the WILD side: How wireless handhelds may change computer-supported collaborative learning. *International Journal of Cognition and Technology, 1*(1), 145-168.

Roschelle, J., Pea, R., Hoadley, C., Gordin, D., & Means, B. (2000). Changing how and what children learn in school with computer-based technologies. *The Future of Children, 10*(2), 76-101.

Roschelle, J., & Teasley, S. D. (1995). Construction of shared knowledge in collaborative problem solving. In C. O'Malley (Ed.), *Computer-supported collaborative learning*. New York, NY: Springer-Verlag.

Tinker, R., & Krajcik, J. (Eds.). (2001). *Portable technologies: Science learning in context*. New York: Kluwer Academic/Plenum Publishers.

Vahey, P., & Crawford, V. (2002). *Palm Education Pioneers Program: Final Evaluation Report*. Menlo Park, CA: SRI International.

Zurita, G., & Nussbaum, M. (2004). mCSCL: Mobile computer supported collaborative learning. *Computers & education, 42*(3), 289-314.