Perspectives on Creativity in Web Learning

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Abstract. Creativity is an important asset in today's fast changing environment. We believe it can and should be stimulated in educational environments, through the use of tools and careful design of activities and work groups. In this paper, we present and briefly discuss a checklist of eight activities to support creativity and should be applied when designing educational courses. We discuss the benefits of group work and present some educational perspectives to support it. We then relate creativity and collaborative learning and analyze a dynamic geometry system in relation to this checklist.

1 Introduction

The Internet has created a new reality for education, one where synchronous and asynchronous communication, long distance interaction and information exchange between students and teachers is relatively easy and accessible. The Internet brings to life the possibility of reaching greater numbers of people and providing high-level education at lower cost.

The rapid growth of the Internet and increase of competitiveness has also turned creativity into a major asset. Companies need to keep up with an ever-changing environment, in which changes come at great speed. To cope with these changes, they must be able to frequently redefine themselves in order to stay ahead in the market. For these reasons, creativity has become something companies look for in individuals. In this scenario, it is important that a student learn how to think and how to creatively solve problems, as opposed to simply learning conventional processes, from an early age. Collaborative, long-distance learning, coupled with creativity techniques might generate more creative individuals, better prepared to deal with today's challenges and to handle local problems in creative ways.

Ben Shneiderman [16] defines a creative cycle and a set of guidelines for the design of creativity support tools and interfaces. Some aspects are in close agreement with pedagogical theories. We explore how these could be applied to Web/Distance Learning settings and how these would work in collaborative learning situations. We analyze Tabulæ, a Dynamic Geometry teaching tool in relation to the guidelines.

In section 2, we introduce aspects of creativity and Shneiderman's guidelines. In section 3, we discuss educational approaches, followed by some previous work in

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creativity and distance education. In section 5 we introduce Tabulæ and discuss how it may be used to promote creative learning and finish with a conclusion in section 6.

2 Aspects of Creativity

According to the dictionary, something is creative when it shows "imagination and originality as well as routine skill" (from the Oxford Paperback Dictionary, Oxford University Press, 1979). Among computer scientists, a commonplace definition seems to be that creativity is "something that deals with a process resulting in a novel and useful product" [3] or "the ability to produce new and original objects" [2]. Every definition emphasizes novelty, which implies the use of imagination.

An important aspect is that an act might be creative in a personal or societal level: if a student produces a bubble sort program without precious exposure to a bubble-sort algorithm, that is a personal creative work, even if not societal. This personal novelty (or discovery) is far more commonplace than societal novelty, which occurs when something never before experienced is produced [18]. We believe such personal creative acts can and should be stimulated in educational settings, in an effort to increase creative thought among students, in line with constructivist theories.

Many authors have tried to create models to map the creative process. It remains, however, an elusive topic. There are theories and studies on creative processes and factors leading to creative solutions to problems. Some models and computer systems have been proposed to assist in the performance of creative work and certain application areas have been identified. In the following subsection, we outline the creative cycle as proposed by Shneiderman [16].

2.1 The Creative Cycle

Csikszentmihalyi emphasizes the social aspect of creative work, describing an individual working within a domain, presenting work to the gatekeepers of that domain, who will judge whether it should be accepted to the domain as a creative contribution. He stresses the benefits of consultations with other domain experts and the necessity for dissemination within the field [5]. The existence of a social aspect of creativity has become widely agreed upon and Csikszentmihalyi's approach has been widely accepted, as scientists recognize their own research methods and the workings of their social research networks and domain areas. Inspired by Csikszentmihalyi's work, Ben Shneiderman defined a framework for generating excellence (GENEX), which describes four phases of creativity [16] and attempts to take into account the social aspects of the creative process. Note that creative work may require returning to earlier phases and much iteration.

The GENEX framework is founded on the beliefs that: (1) new knowledge is built on previous knowledge. This is in agreement with the basic premises of constructivism, that knowledge is constructed; (2) powerful tools can support creativity. This follows the lines of Piagetian thinking, whereby inquisitive interaction with the real world causes the development of intelligence; (3) refinement is a social process. According to Vygotsky, the interaction with peers causes the development of intelligence; and (4) creative work is not complete until it is disseminated.

The four GENEX phases are: (1) Collect – Learn from previous works stored in libraries, the Web and other resources. (2) Relate – Consult with peers and mentors at early, middle and late stages. (3) Create – Explore, compose and evaluate possible solutions. (4) Donate – Disseminate the results and contribute to libraries, the Web and other sources.

These are somewhat related to Nonaka's knowledge creation spiral, according to which there are two kinds of knowledge: explicit, which can be expressed in word and numbers and shared in the form of data, formulae, manuals and the like, and tacit, which is highly personal, hard to formalize and difficult to communicate: subjective insights, hunches, intuitions, etc. [10]. Knowledge creation is a spiraling process of interactions between explicit and tacit knowledge, which lead to the creation of new knowledge. This process is composed of four steps: (1) Socialization, which involves the sharing of tacit knowledge between individuals (relate); (2) Externalization, which requires the expression of tacit knowledge and its translation into explicit knowledge (donate); (3) Combination, which involves the conversion of explicit knowledge into more complex sets of explicit knowledge, also related to experimentation with problems and solutions (create) and (4) Internalization, which is the conversion of explicit knowledge into the organization's tacit knowledge (collect). In fact, knowledge management (KM) systems might provide useful insight into the construction of educational systems. KM frameworks have been proposed to integrate and share data and create collaborative work environments to increase user synergy and cooperation, such as SpeCS [13].

Analyzing some scenarios, Shneiderman identifies eight activities performed during the creative process, and suggests that an integrated creativity support tool should offer all of these. The activities and how they relate to the GENEX phases are shown in Figure 1. The relation shown is the primary one, but these activities could be performed at any of the phases.

Shneiderman's list follows, with a brief discussion of each of the activities.

- Searching and browsing digital libraries, the Web and other resources. Searching accelerates collection of information about previous work. Searches might also be performed to find peers or potential co-workers. A system should include tools for searching the web, dictionaries and other resources, including improved search tools for image, sound and video retrieval.
- Visualizing data and processes to understand and discover, invent or create relationships. Drawing mental or concept maps of current knowledge helps users organize their knowledge, see relationships and possibly spot missing items.
- Consulting with peers and mentors for intellectual and emotional support. An important part of collaborative work, peers can aid in problem solving and new idea generation (this is strongly related to concepts of peer learning introduced by Vygotsky, which will be explained in a later section). Consultation tools include email, chat and instant messenger applications.
- Thinking by free associations to make new combinations of ideas. Brainstorming or lateral thinking should be encouraged, in an environment where new ideas aren't immediately discarded.
- Exploring solutions: what-if tools and simulation models. Individuals should be able to conduct experiments and simulations about the implications of decisions and create several scenarios. Simulations open a person's mind to possibilities and

allow them to explore safely and to understand complex relationships. Simulations can be fun and popular, such as the computer game SimCity.

- Composing artifacts and performances step-by-step. The ability to easily build and change prototypes is very important. In this way, individuals can rapidly explore and refine their solutions to problems. Tools range from simple word processors to complex music composition tools.
- Reviewing and replaying session histories to support reflection. History keeping, or the capacity to record, review and save activities, is missing from many tools. The existence of a history feature allows users to return to previous steps, review a certain problem solving strategies, store frequent patterns and share them with peers and mentors.
- Disseminating results to gain recognition and add to the searchable resources. Once finished, work should be disseminated. One possibility is to send notifications to every person whose work influenced the project at hand or to others who referenced the same work. Dissemination tools include email, web pages, conferences, classes and publications.

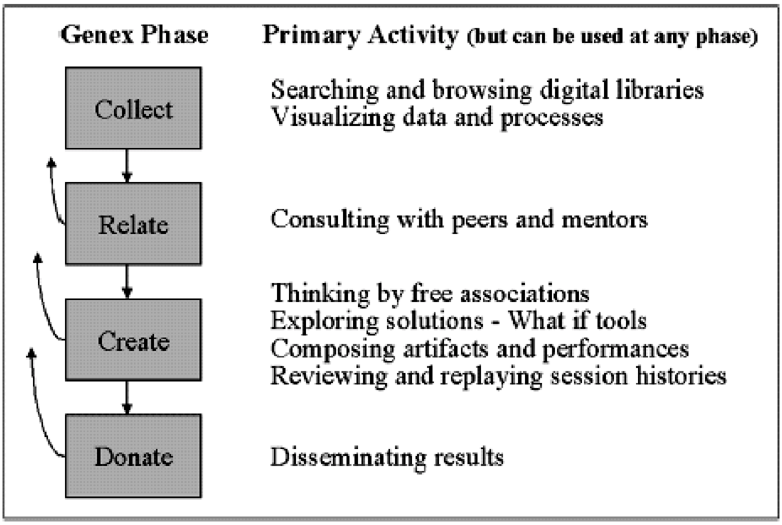

Fig. 1. GENEX phases and their primary relation to the activities

All of these steps can be performed by teams as well as by individuals working alone. When dealing with experts from different areas, one's ignorance in relation to another's domain of expertise can be used as a stimulus to creativity. This has been referred to as symmetry of ignorance. Bringing different points of view together and trying to create a shared understanding among all stakeholders can lead to new insights, ideas and artifacts [6]. This implies that work groups should be carefully chosen, so as to best leverage each person's strengths and weaknesses. This point is often overlooked, as most groups are formed at random or based on criteria such as friendship or personal relations, when different configurations might have generated better (and more creative) results. In these situations, it becomes necessary for individuals to instruct each other about their areas of expertise, externalizing their tacit knowledge. Externalization causes a person to move from vague mental conceptualizations of an idea to a more concrete representation of it, providing a means for others to interact with, react to, negotiate around and build upon it. It also provides an opportunity for the creation of a common language between parties.

3 Pedagogical and Educational Aspects

In this section we briefly outline three educational theories that are related to creative and cooperative learning systems. According to Freinet [Freinet, 75], cooperation is the driving force of educational processes. For him, cooperation and productive work are natural forms of interaction for students and therefore essential to any educational environment. Piaget [12], in his constructivist approach, states that a person builds his or her intelligence and knowledge as a result of the interactions with objects and the real world. When manipulating these objects and solving problems deriving from this interaction, a person develops his or her mental structures. Vygotsky [19] stresses the role of interaction between peers in the development of higher thought structures. He demonstrates that cooperation between individuals at different mental development stages not only facilitates, but also encourages intellectual growth. With these theories in mind, we see the potential for intellectual development that resides in the interaction between students mediated by their interaction with the computer (object).

Freinet suggests that the learning process should stem from necessary actions and through the production of objects that are useful to the apprentices. He emphasizes the value of an individual's production it's place in the greater scheme of things and that it can be modified and enhanced through their colleagues' interference [Freinet, 75]. One should note that his work presupposes collaboration not only between students but between teachers as well.

Piaget sustains that a person's intelligence is composed of structures that are developed by him or herself through the actions he or she operates on real-world objects. Development happens through a sequence of stages: sensorimotor; pre-operations; concrete-operations and formal operations. These are, in turn, divided into sub-stages. Evolution between stages happens through assimilation and accommodation in these structures and sub-structures. This evolution occurs because a person needs to structure and organize the information he or she receives from the environment. Intelligence is constructed as a structure necessary to support the knowledge produced by the subject in his or her interactions with objects and problems posed by the environment. These theories spawned constructivism. The name stems from the fact that knowledge is a mental construct, product of the interaction of a person with the environment [Piaget, 70]. This implies that educational institutions should offer students an environment that will lead them to work with real world objects, run experiments, interact with classmates, teachers and researchers and reach their own conclusions, registering and testing them with new experiments to verify their validity.

In Vygotsky's work, we find support for the establishment of groups and development of peer relationships. Vygotsky holds that there is a close relation between cooperation among peers and learning potential [Vygotsky, 89]. He defines "real development level" as the already established mental functions of an individual, stemming from the development stages already covered by the person. This is, therefore, the level of development verifiable through testing and direct problem solving, which the individual can handle by him or herself.

Vygotsky argues that, to understand what a person's real learning capacity is, the "zone of proximal development" must also be taken into account. He defines the "zone of proximal development" as the distance between the "real development level", usually determined through independent problem solving, and the "potential development level", usually determined through the solution of problems under the guidance of an instructor or in collaboration with more capable peers.

In the notion of "zone of proximal development", we find the importance of group study and the establishment of peer learning relationships. This "proximal development zone" is created when the individual interacts with others and observes how they handle and solve problems. Often these solutions are not reachable by the observer, but can be understood once they see peers or tutors reach them. Interaction with colleagues thus permits them to reach higher degrees of intellectual development.

More recently, proponents of Activity Centered Design build on Vygotsky's ideas and the concepts of distributed cognition and Activity Theory and view learning as a complex process in which an individual's cognition is defined by its relation to the material setting and the forms of social participation encouraged by these settings [8]. Thus, Activity Centered Design emphasizes the use of computer mediated environments to support and structure the interactions and interdependencies of an activity system, including interrelations between students, instructors, tasks they undertake and inscriptions they use. In Activity Centered Design, the focus is neither the teacher nor the student, but the design of activities that help learners develop the ability to carry out socially formulated, goal directed action through the use of mediating material and social structures.

4 Existing Systems

In this section we describe a few computer systems created to support creativity and web learning. Some online courses use email, online conferencing and web pages to enable group learning and activity development, in conjunction with face-to-face sessions. Communication and joint work over the Internet can be difficult for students and burdensome for teachers. These difficulties lead instructors to develop new strategies for group formation and ad-hoc problem solving when students have difficulties sharing knowledge or accessing each other's work. It has been argued that tools such as online discussion forums are powerful tools to aid in the development of critical thinking and decision-making abilities and that these forums are more inclusive than face-to-face ones, since they minimize the presence of more eloquent students and make participation more equalitarian [4].

Using a combination of traditional web technologies and tools, the CyberEd program, at the University of Massachusetts Dartmouth is an example of implementation and development of online education. Dartmouth offers university level courses on the Internet, and students enrolled in CyberEd courses receive college credits in chemistry, finance, history, commercial techniques and astronomy. Non-credit courses are also offered.

GRACILE (Grammar Collaborative Intelligent Environmet) is an example of an intelligent agent applied to Computer Supported Collaborative Learning [1]. An agent was developed to support the application of domain knowledge and effective collaboration between students. Agents mediate situations in which a student might learn from another while performing educational tasks. This usually means that the task requires the application of knowledge elements already internalized by other students that could also be internalized by him or her. These elements are usually relevant to the acquisition of more complex knowledge elements. GRACILE was designed for small (two to four students) heterogeneous groups.

Computer systems can facilitate creativity on at least two distinct levels: they can aid in knowledge gathering, sharing, integration and idea generation and they can enable the generation of creative artifacts in a particular domain by providing critical functionality in clear, direct and useful ways [9]. Most researchers recognize the importance of preexisting domain knowledge when solving a problem and the introduction of new, external knowledge when generating innovative solutions and many systems revolve around the management of existing knowledge and introduction of new knowledge in problem resolution. Creativity support systems range from kiosks at museums or exhibits to desktop design or composition systems.

Roast describes a system to support Active Reading, where the reader fills in blanks in the story [14]. Active Reading refers to how a reader's individual interpretation of a literary work influenced by its textual variants and how the reader may take the role of editor. Research is focused upon building tools to support creative understanding of a literary work and the articulation of that understanding in terms of alternative novel editions of the work being studied. In the system proposed, a literary piece is presented, with variant points inserted (displayed as question marks). The reader can "fill in the blanks" and then compare to other versions created to other users. Even though this system was created for literary researchers, to aid in the study of very old texts, which have been partially lost, it could certainly be used in an educational setting, with other kinds of texts and objectives (for instance, vocabulary practice and development).

Shibata and Hori [15] propose a personal creativity system, to support long-term idea-generation in daily life. Their system is essentially a knowledge management system, which allows a user to store and retrieve ideas when they are spontaneously generated. Their system consists of two subsystems: one for idea and problem management called IdeaManager and a personal information system called iBox, which stores notes, memos, papers, etc. When storing information on problems or ideas in IdeaManager, related information from iBox pops up on the user's screen, suggesting relations between the information. By showing related information, the authors hope to promote idea generation. This system has no formal educational pretensions. However, according to Freinet, work is a form of education. It could cretainly be used in group settings, to facilitate knowledge sharing between students, group problem solving and possibly help the generation of new ideas, following Vygotsky's approach.

5 Creativity and Web Learning

In this section we explore links between creativity and learning systems, and how these could be combined.

We believe that, in an educational setting, group activities should be designed in order to promote the eight activities as suggested by Shneiderman, and tools should be provided to support them. The eight activities, as explained earlier, are: search, visualize, consult, think, explore, compose, review, disseminate. If a particular educational software does not provide support for all activities, other supplementary tools may be used to fill in the needs. In addition, assignments should be planned to contemplate these activities. Furthermore, the instructor should carefully put together the student groups, in an attempt to enhance the quality of the work produced and provide externalization of ideas.

5.1 Case Study: Tabulæ

Tabulæ was developed to address the problem of teaching Euclidean Geometry using the Internet for synchronous and asynchronous communication [10]. Tabulæ is what is called "dynamic geometry" software, and it is built using client-server architecture. Dynamic geometry software is a system to aid in the study of plane geometry, which is based on the construction of geometric figures on a computer screen, as shown in Figure 2. Through a few icons it is possible to access commands that draw lines, circles, perpendiculars, parallels, reflections of figures, etc. It is also possible to move these constructs around using a mouse, without altering the predefined properties. Tabulæ permits the rapid creation of a virtual classroom, where each student receives, on his or her screen and in real time, the steps of the geometric construction the teacher is working on at the moment.

In Tabulæ, when objects are moved, geometric properties are observed. This is one of its greatest strengths: it allows a student to manipulate and experiment with abstract concepts, such as lines, points, angles, etc. as if they were concrete objects. It thus allows students to build constructs based on rules and properties they would otherwise not be able to manipulate, like medians and bisectors.

In traditional classroom settings, instructors construct their explanations on a blackboard, pointing out relevant issues as they appear. This process is static, that is, one cannot easily go back to a previous step or keep a history. Once they are erased, the constructs are gone. Tabulæ provides a blackboard for each student (on screen), on which the teacher can build each construct step by step, not necessarily following a predetermined guide. It allows the instructors to answer unexpected students' questions through exploration, composition and evaluation of possible solutions. It is desirable that students maintain control of their machines, so that they can experiment; propose variations to the solutions shown or disagree with a position, keeping an active and creative attitude. The students may save their constructs and those of the teacher and colleagues, in the same way they would copy the blackboard in a traditional class. Active participation allows each student to play the role of tutor (a temporary instructor) if the group feels the need for it.

These types of features allow students in different locales to create shared activities where each one is responsible for part of the process, creating animations to reflect this process that will later be discussed by the whole class. The whole group evaluates the process, which may lead to a new procedure that perfects the activity. Student participation is promoted by the teacher.

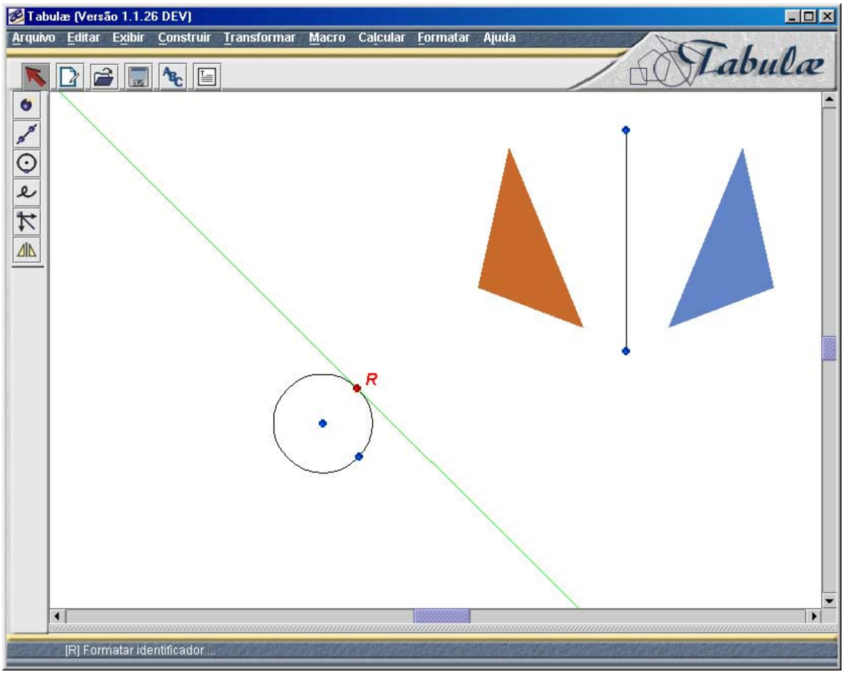

Fig. 2. Tabulæ Screenshot

These types of systems encourage students to participate in investigative activities and can be used so as to force externalization and the justification of results, which develops deductive reasoning. Tabulæ supports the eight creativity activities described earlier as follows:

Search: Tabulæ allows searching for constructs and properties others have created but doesn't directly support external searches. The instructor can propose activities that require some research, forcing the students to search the Internet or libraries for information. Educational activities should be designed in order to promote some external research.

Visualize: Tabulæ allows the students to visualize constructs and abstract properties in graphical form, and to perform operations on constructs that reflect on the graphics on their screen. In this way, a student might build new constructs and perceive relations between them.

Consult: Tabulæ permits sharing of one's screen with peers through the network. This enables the students to view each other's solutions and discuss them, to share problems or pieces of graphical objects. Better exchange tools are needed to enable further sharing and allow the students to reach their potential development level. Other media could be made available, such as video and audio and other communication methods, such as messaging.

Think: Tabulæ encourages creative thought by allowing free experimentation with constructs while class is going on and permitting the insertion of related external insights from other students or the instructor. It is a problem-solving environment. This could be enhanced with the introduction of related insights from the real world, such as the real-world application of the rules and properties being studied.

Explore: Tabulæ enables the student to apply rules, change and experiment with constructs, and permits the students to save them or go back to previous steps if necessary. In this fashion, a student may explore possibilities and create simulations without fear of making mistakes, and may save the best results for further exploration.

Compose: Tabulæ is a mathematical composition tool. It allows students to quickly build mathematical constructs based on geometric properties, formulae and rules, easily creating prototypes. They can create, experiment with and manipulate abstract constructs. These capabilities might be expanded to allow students to simulate real-world constructs using the mathematical ones, creating a link between the two knowledge areas.

Review: Tabulæ keeps the construction history and allows the creation of routines with animations that show the process of building mathematical constructs. This allows the students and teacher to review any given step and replay animations. This is an important feature, and could be enhanced through the use of annotations in the process.

Disseminate: Tabulæ supports sharing and externalization of constructs with peers through the tutor mechanism. In this fashion, a student takes the stand and shows what he or she has been working on, opening discussion on it. Dissemination could be wider. It should also occur between classes, different levels of students and between teachers, who might share solutions created by their students.

Regarding group formation, instructors need to know their students well to be able put together good working groups. When that is not the case, there might be a need for questionnaires or careful evaluation of a person's school history, hobbies, etc. Diversity should be sought after, in order to promote discussion and the introduction of external knowledge.

An experiment is currently being planned where a teacher will be at the Institute of Mathematics at the Federal University of Rio de Janeiro and the students will be at different schools of the public school network in Rio de Janeiro. In this experiment, the instructor will conduct a geometry class in which the main concepts will be formulated and discussed with the students. This may also be an opportunity to apply and verify the checklist in a real-world educational setting, proposing educational activities to fit the list.

6 Conclusion

We have presented some perspectives on creative work and explored how these might guide the design of activities in educational settings. We discussed a set of guidelines that we think should be followed when designing online courses. We believe that creativity should be stimulated from an early stage, in educational settings. As seen, there is a close relation between the phases in the creative cycle and the constructivist perspective of knowledge development, as well as a relation to Vygotsky's theories of peer development. We believe the activity checklist proposed by Shneiderman can and should be used to design educational activities. Through the exploration of these activities, we can propose computer-supported educational structures and activities focusing on experimentation and creative problem resolution and strongly based on constructivism and on collaborative learning. We believe these aspects haven't been fully explored yet.

We presented a computer system, Tabulæ, which allows teachers to quickly set up a virtual classroom, where each student views, on his or her own computer and in real time, the steps of the geometric construction the teacher is working on. During this process, students may modify the construct or add new elements and they may express opinions regarding the construction as well as questions and suggestions. Students may also send their work to colleagues and the instructor to share it and have it criticized. In analyzing Tabulæ, one can see that it has some creativity support features, but could be enhanced. One issue that comes to mind is the creation of construct libraries so students can archive and retrieve their and others' works. This would certainly increase the potential for exploration, as students would have the opportunity to explore and work on previous designs (including designs from previous classes) and build on top of them. Other improvements could be reached through the use of additional tools or creative design of activities. An interesting point to note is that Tabulæ has been proving very useful for teacher training. With the tools at their disposal, students are becoming more innovative and asking more questions. Teachers have had to become more flexible and learn to explain concepts in different ways, including sharing other students' works.

It should be noted that we're not looking to produce earth-shattering innovations in class. Rather, we aim for personal creativity, exploration and discovery. Stimulating creativity in educational settings, we hope to form more creative individuals, able to think in new ways and propose innovative solutions to problems. We believe the checklist will prove useful in designing educational systems that promote creativity.

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