Communication in the Implementation of a Metacognitive Strategy for Learning to Design

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This paper describes an instructional communication strategy that makes use of time-based media techniques (story boarding and animation) in order to empower design studios with means to promote their students' awareness on the acquisition of metacognitive knowledge and skills.
This paper highlights the importance of including the communication of the design processes in the evaluation of learning outcomes. Moreover, the paper proposes that the students should be made constantly aware of their design processes and how effective are the methods they use. It is in this state of awareness that metacognitive knowledge is acquired: knowing how to learn to design. We can cultivate, exploit and enhance the capabilities of design learners, making them more confident and independent as learners as they understand what they need to know and what kind of strategies might work for different design problems and learning opportunities.
In the development of an instructional strategy to accomplish this learning goal, the paper proposes it may be possible and potentially beneficial to transfer current metacognitive support strategies from a course on computer visualization techniques to the design studios. The paper elaborates on how these communication strategies could be transferred and implemented in a design studio setting. The results of a recent controlled experiment and considerations about the cognitive style of design students will be used in the preparation of recommendations for future full scale implementations in early design studios.

Keywords: *Design learning; metacognitive learning strategy; time-based media.*

Problem

Design studios in schools of architecture aim to provide students not only with the opportunity to acquire design knowledge and skills -and therefore learn to design, but also the opportunity to "learn how to learn to design". Our graduates may not be fully developed as designers but should certainly be fully developed as independent learners. This understanding is not always consistent with the way in which we implement design studios and evaluate their outcomes. Frequently, the design studio products have been regarded as the main indicator of the learning outcomes of the design studio (Oxman, 1999). Much emphasis has been given to the communication of design solutions and little to the communication of design process and the students' ability to control their learning process.

Hypothesis

This research collects evidence that supports de believe that students will perform better in design tasks if metacognitive strategies for successful learning are applied. For many years we have been teaching classes on Computer Techniques for Design Visualization (ENDS270 and ENDS170 in the curriculum of Texas A&M University) (Vásquez de Velasco & Angulo, 2002) and have asked the students to implement specific metacognitive strategies, basically to narrate the process that they have followed in order to solve any given assignment. We have informally collected a large amount of anecdotal evidence regarding the benefits of this method on student self-monitoring and the evaluation of the personal strategies used. By narrating their design process, the students have been able to link their final results with the design process they have followed, and by means of introspection, they have been also able to evaluate their degree of learning on a given subject. Through this study, we want to formally measure learning outcomes in a limited controlled experiment and ask if it is possible and potentially beneficial to transfer similar current metacognitive support strategies from this design visualization course into the design studios.

Theoretical Framework

Historically, the concept of metacognition was introduced by Flavel (1976) as "any knowledge or cognition that takes as its object, or that regulates any aspect of any cognitive endeavor". Brown (1978) who emphasized the regulation and control aspects of metacognition suggested that planning, monitoring, and revising one's thinking are important executive processes. Although during the past 30 years several authors have provided variable definitions, portraying different emphases on mechanisms and processes associated with metacognition (Giorgiades, 2004), there seem to be a general consensus that a definition of metacognition should include at least these notions: knowledge of one's knowledge, processes, and cognitive and affective states; and the ability to consciously and deliberately monitor and regulate one's knowledge, processes, and cognitive and affective states (Hacker, 2005)

Metacognitive skills predict success in academic endeavors and other aspects of life. Students with high metacognitive skills outperformed those with lower metacognitive skills (Pintrich & De Groot, 1990; Swanson, 1990). There has been abundant research into children's metacognition, but relatively little about metacognition in adults. Most theorists believe that development of metacognitive knowledge begins at young age, and continues through adolescence (Schraw & Moshman, 1995). A tacit assumption in much of the research is that metacognitive skills are fully developed by adulthood. However, Baker (1989) suggests that there is substantial evidence that suggests that metacognitive awareness and skill continue to develop in adulthood, making the latter assumption faulty. In a study comparing self-regulated learning in college undergraduates and graduate students (Lindner et. al,1996) research showed a strong correlation between metacognition and degree completion.

All the studies examining metacognition in education agree on the benefits of applying metacognitive strategies on learning whether directed to normal children and adults, or subjects with disabilities. Moreover, they all agree that metacognitive skills require deliberate, on-going practice. The learners need to become aware of themselves as self-regulatory organisms who can consciously and deliberately achieve specific goals (Kluwe, 1982). So students with very different metacognitive abilities can learn to better regulate their cognitive activities. In this study, we want to make use of several metacognitive strategies to enhance the learning of design. For this purpose, students will be taught not only how to approach a design problem (domain knowledge on processes and results) but also how to develop and implement metacognitive strategies for planning, monitoring, and assessment of the learning task, but especially for "awareness" of what they know and want to know and for the "reflection" of what they have learned and how it was learned, making them fully qualified to continue learning on their own.

The Experiment

The main purpose of this study was to investigate the relations between the metacognitive abilities of students and their performance in a design task using computer techniques. The target group was represented by 12 novice design students learning Computer Techniques for Design Visualization (ENDS170-200) in the Honors section. In general terms, they learn to apply digital visualization techniques to perform diverse design tasks as drawing, painting, modeling and rendering with computer techniques. In this particular experiment, they learned to use digital imaging techniques to design a music CD cover (Figure 1). Because of the dynamic nature of knowledge in the computer applications domain, these students needed to reinforce their awareness regarding learning strategies. What do you need to know to solve the task? What tools will be more appropriate? How much time should you allocate to solve all and parts of the task? These are just few of the questions that relate to the metacognitive knowledge and regulation of their thinking process during the performance of this task. The nature of the experiment as such was not communicated to the students; they only knew this was a graded assignment. The achievement of a good grade was an overall goal that provided motivation for students to complete not only the design task but also to follow all suggested instructional methods (i.e. recording of the design process as they developed their assignment).

Implementation

There are different ways to implement metacognitive learning strategies; the instrumentation varies depending whether these will be applied before, during, or after the cognitive activity—in this case the design of the CD cover. Before the actual undertaking of the assignment, students were encouraged to describe all what they knew about the topic and predict what else they needed to learn (awareness or self-representation stage). They were also encouraged to plan, in general terms, how to subdivide the design tasks and when to tackle each related part. To help the students to instrument these aspects, the issues were discussed and critiqued during the working sessions. During the actual making of their assignment, they were asked to record their progress by filling out a project log, including how they monitored their progress (self-regulation stage). After the undertaking of the assignment they were asked to reflect upon their achievement (self-evaluation or reflection-on-action stage) by filling a questionnaire.

One of the most interesting metacognitive learning strategies included in this experiment consisted on the description of the procedures during the preparation of the assignment. This narrative was included as the "project log". It had several required topics that the students can develop using any narrative style or format including adding sketches or

Figure 1
Sample work of the music CD cover assignment

pictures as illustrations or examples. The procedures suggested in the form of questions were about their previous knowledge regarding graphical design using digital media, graphic design concepts, image editing software, and about methods to learn imaging editing software; the description of the main design idea or inspirational idea in the preparation of the CD cover; the narration of the step by step design process and digital tools used; the description of the main characteristics of their design result; the description of the most original aspects of the design result; and towards the end of their exercise, the description of any design issue to be subject of improvement.

After the design task, the students were interviewed to identify their metacognitive ability. They were asked to fill a questionnaire that we use as a tool for "debriefing of the thinking process". The questionnaire had two parts: the first part measured their metacognitive abilities (11 multiple choice questions) and the second part served to collect data on their learning preferences (5 true-false questions). The first part was divided in 3 sections: the first section included questions on self-representation (awareness of one's self, learning strategies and strategies use), the second section included questions on self-regulation (setting of goals, planning, assessment, and debugging of learning), and the third section included questions about self-evaluation (reflection-on-action). The students put on evidence what they knew about their learning experience and how they would eventually perform if facing a similar design problem. The questionnaire took approximately 15 min. to be completed by the class.

Data Analysis:

This questionnaire is similar to the Metacognitive Awareness Inventory (MAI) (Schraw, G. & Dennison, R., 1994) which is recognized as a general measure of metacognition. We used several of the general components of the MAI adapting them to the domain specific interest (11 versus 52 statements). The questionnaire differs in the use of multiple choice questions instead of the Likert type scale of the MAI; our questionnaire is therefore less grained. Our method, as the MAI uses a summative scoring method (more metacognitive knowledge is better). The results did not considered age difference among students or gender. As freshman students of the Honors class, they were all regarded having the same level of prior knowledge in design with computer techniques. The statistical packages used gave us an indication of level of metacognitive ability (mean and standard deviation) and the results were compared with the grades obtained by the students in that assignment. The Table 1 reports on the performance of the student group for the 3 sections of part one of the questionnaire.

Table 1
Metacognitive abilities of the student group

Variables	Mean	Standard Deviation
Self-representation	63.89	48.9
Self-regulation	65.28	36.3
Self-evaluation	87.5	33.9

The Table 2 compares the cognitive score (assignment grade) and the metacognitive scores of the student group: group 1 with 2 students exhibits high cognitive performance & low metacognitive profile, group 2 with 1 student exhibits low cognitive performance & low metacognitive profile, group 3

Table 2
Mean responses in cognitive and metacognitive abilities by student group

Groups (# students)	Cognitive score	Meta-cognitive score	Self-representation	Self-regulation	Self-evaluation
1 (2)	0.9	0.5	0.66666	0.3333	0.75
2 (1)	0.77	0.5454	0.3333	0.5	1
3 (2)	0.815	0.7272	1	0.5833	0.75
4 (7)	0.91	0.7532	0.7142	0.7619	0.92857

with 2 students exhibits low cognitive performance & high metacognitive profile, group 4 with 7 students exhibits high cognitive performance & high metacognitive profile.

Results

The table 1 shows that students perform well on assessing their own performance (self-evaluation) after the cognitive activity has taken place, but are not so confident on knowing what they know (self-representation) and tend to struggle to monitor their learning (self-regulation) during the performance of the cognitive activity. The table 2 shows, as it was just demonstrated in table 1, that all groups perform well on the self-evaluation component; the group 1 exhibits the lowest metacognitive performance due to a poor self-regulation component but has obtained a good cognitive score due to better self-representation; the group 2 gets the lowest cognitive score that correlates with the lowest self-representation component; the group 3 confirms our hypothesis that awareness of self and strategies has a great impact on the actual performance. The results indicated that those students that were more optimistic than realistic about their own knowledge have difficulties performing in the cognitive task. The lower the self-representation scores the more the difficulties to regulate their performance and their learning. The group 4 (where most of the students gravitated) offers a very well balanced picture of metacognitive performance. In this case the best self-representation, self-regulation and self-evaluation scores correlate with the best cognitive score. It is our instructional implementation target to obtain a well-balanced metacognitive performance.

Recommendations

Can we use the same methods? What do we want the student to be aware of? Is it possible to record all what we do during design? Is it possible to use non-intrusive methods to do so? Can the representations we create during design tell the story of what we think and how we design? Can we add complementary media that provides awareness without distracting: add text to graphics; add animated graphics to still graphics? Add digital models to physical models and vice versa? To give answer to these and other relevant questions we want to combine the findings of what we have learned in our experiment about metacognitive strategies together with our understanding about the student's learning profile.

We will assume that during the design activity, at a metacognitive level, the designers will tend to go through the stages of self-representation, self-regulation, and self-evaluation upon their design learning. During self-representation, the designer will assess his/her own metacognitive resources in order to tackle the design task. During self-regulation, the designer will set goals, organize tasks, manage resources, asses learning and strategies used, and debug strategies to correct errors. During self-evaluation, the designer will look at the learning so far, will analyze it and evaluate its effectiveness. If the designer is at the end of the task, his/her reflection will report back as metacognitive knowledge on the learning performance. We need to support each of these stages for a well-balanced metacognitive performance of the students.

We also believe that the student's learning profile has an impact in the effectiveness of metacognitive learning strategies. Learning style can be described as a set of factors, behaviors, and attitudes that facilitate learning for an individual in a given situation (Reiff, 1992). An objective of education should be to help students to build their skills in both their preferred style and be challenged to learn in their less preferred mode of learning. Felder & Silverman (2003) have synthesized findings from a number of studies to formulate a learning style model for engineering education in specific but that can be also regarded as relevant to design education in general (Watson, 2003) This study shows evidence that the learning style of most engineering students include preference for visual than verbal input; sensing than intuitive perception; inductive than deductive learning; and active rather than reflective processing of ideas. If we compared these findings with the survey of part two of the questionnaire performed in our experiment, we can conclude that there is indeed some correlation (Table 3)

Table 3
Survey on learning preferences among the student group

Topics	Mean	Standard Deviation
Self-paced learning	0.833333	-0.3
Inductive learning	1	0
Introspection / Reflection on action	0.916667	-0.122
Critics on evolving project	1	0
Access to information	0.833333	-0.3

Design of a metacognitive strategy for learning in design studios

We expect to translate our findings and apply them in a beginners design studio. For this kind of design studios we promote the use of traditional and digital media on opportunistic basis; the topic of the design exercise will be basic in terms of function and tectonics, and more geared towards the solution of the formal aspects of the project. The metacognitive strategy for learning will be implemented before the actual undertaking of the design exercise; throughout the design exercise as reflection in action (Schon, 1987); during desk-critic sessions and the project review for the communication of design results; and after the submission and presentation of the assignment as reflection on action or deliberation (Koschmann, 1994; Kvan, 2000). On implementation terms, it will include the production of a project log (recording of activities before and throughout the design process); the presentation of the project log along with the design results (partial presentations during critic sessions and final presentation during the review); and the filling of a debriefing questionnaire (after the completion of the project). We believe that the preparation and the presentation of the project log will go beyond promoting learning in action; it will offer opportunities to the students for improving their awareness and reflection upon their design process and their learning. Similarly, the questionnaire will promote understanding of what has been accomplished from a cognitive and metacognitive point of view; and will provide us with additional insight on the effectiveness of the instructional communication strategy to facilitate learning. So it is envisioned that the final assessment of learning will include not only the quality of the final product, but also the students' ability to demonstrate their design procedures and their awareness upon their design learning.

The instrumentation

The instructional metacognitive strategy we want to implement will make use of time-based media techniques that match the design student learning's profile. It will make use of substantial amount of visual material: still pictures, animations, videos, and recordings of real-time interaction to generate the project log in the form of an animated storyboard (Figure 2 and Figures 3 to 5). The benefits of utilizing digital time-based media will include formally recording the use of precedents, concepts, and references illustrating the type of knowledge used during the specific design; recording the opportunistic use of traditional and digital media in the production of different representations depicting the design prob-

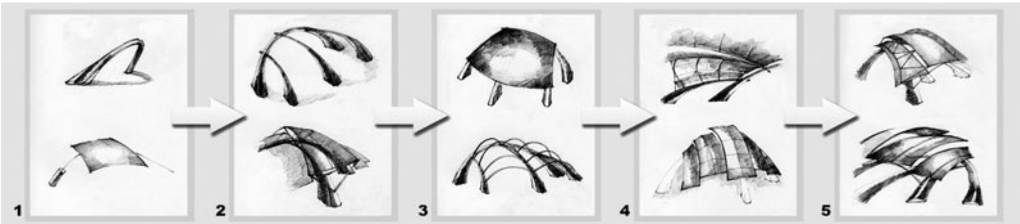


Figure 2
The still graphics storyboard

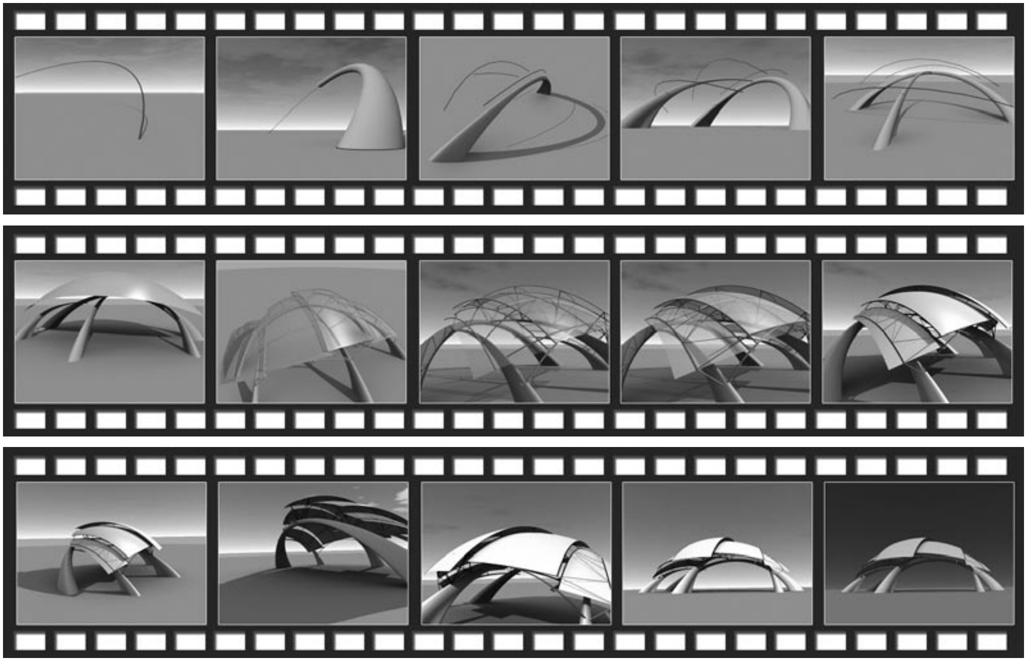
lem, and the production of representations of the solution at different design stages. It will also aim to formally gather data regarding the conditions that trigger the switching between types of representations and media.

Future Work

We are very encouraged to continue into the implementation of the next stage of this study, to conduct experiments in the design studios and to report our findings. The following paragraphs describe our expectations on the future of our work.

Researchers on metacognition agree that one of the most problematic aspects is to record and make available to others our own metacognitive thoughts. Identifying and measuring metacognition rely on the researchers' interpretation of what is cognitive and what is metacognitive. The "debriefing questionnaire" we hereby have proposed in this study is a very important tool for measuring students' metacognition. It is our intention to refine the questionnaire for a more comprehensive and easy interpretation of the findings that would lead us to device better metacognitive learning strategies.

It is also very important to identify the type of media that can promote non-intrusive recording of those metacognitive thoughts by means of the "project log". Similarly, if the process of preparing the project log is an additional burden to the design task, then it will not be effective. Researchers on multimedia applications suggest there is a preference for time-based applications among visual-spatial learners (Mayer, 2005). Our design students are visual-spatial learners that will benefit from the preparation and presentation of project logs using a multimedia format consisting of words and images; and moreover they are likely to achieve better learning outcomes when animated graphics are included (Rieber, 1990)



Figures 3 to 5
The animated storyboard

ence on Computer Aided Architectural Design Research in Asia. Singapore 18-19 May 2000, pp. 181-190.

The desk-critic sessions and the final review are excellent opportunities to promote reflection and also to encourage the students to communicate their expectations, limitations, achievements, and findings. These episodes have proven to be especially beneficial to design students that are not particularly skilled on verbalizing about the content of their design projects.

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