



Reinforcing Metacognition in CAD Education using Videotutorials

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ABSTRACT

The teaching of Computer Aided Design (CAD) constitutes a major challenge today. Designers from various academic disciplines (architects, engineers, graphics designers, etc.) who are more or less familiar with CAD technology seek more creative ways of expression. Since these technologies are in the midst of a rather rapid evolution, tailoring instruction to meet these potential challenges calls for an ongoing modernization as well as a constant adaptation of our teaching methods in order to satisfy the fluctuating needs, not only of the business world, but also of the contemporary teaching practices of adult education. In this paper, an attempt is made to provide an overview of various teaching practices geared toward the creation of a sound learning environment within the CAD laboratory while managing existing concept maps. The goal here is to help reinforce students' metacognitive abilities since they have been proven paramount in their learning journey. One of the most promising teaching practices illustrated herein is the use of videotutorials as well as the use of video-recordings from student's screens in the monitoring and improvement of metacognition in individual students.

Keywords: CAD, metacognition, teaching methods, videotutorials.

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1. INTRODUCTION

In order to meet various growing demands, many schools of architecture expand their scientific fields [22] and rely heavily on computers in order to fulfill their communicative purposes and needs. They provide their students with the required skills to help them fine-tune their abilities to organize, process and distribute information. Evidently, CAD becomes the focal point of their instruction. Let's bear in mind that whatever one learns in the CAD laboratory (design studio), this can be directly applied in a variety of courses through individual or group projects.

Nevertheless, the application of basic teaching strategies in CAD is quite demanding in nature. Apart from basic computer literacy skills, CAD teaching is called upon to bridge the lack-of-experience gap on the part of the student, to deal with the complexities of the CAD interface software and to help instructors meet and successfully fulfill the learner's expectations and vice versa. In essence, we are basically premising our teaching practices on the students' abilities and idiosyncrasies [15].

2. CONTROL OF THE LEARNING ENVIRONMENT

An effective learning environment which fosters cooperation constitutes the foundation upon which we can build a series of sound teaching practices which are conducive to learning on one hand and which boosts the cooperation among learners, instructors, learning goals, materials and available funds. According to Galbraith, within every classroom there is the natural and psychological or emotional environment [14]. Galbraith describes the laboratory's natural environment as being

determined by various factors which can be partially regulated by the instructor team and these include the following: workstations orientation, movable furniture, light control and decoration. What really makes a difference in the learning process are all those factors which render the learning experience in a positive way, give to students a strong feeling of presence and make them feel that a portion of space belongs to them. On the other hand, the term “psychological environment” denotes the relationship between the student and the instructor through observable manifestations of such relationships. The objective of CAD education -whether that be branded as demanding, uncomplicated, useful or vital- and the instructor’s attitude in the overall learning environment (i.e., supportive, free-spirited, limited, competitive and degree of cooperation) constitute major regulating factors.

For assessing adult learning environments Darkenwald developed an evaluation scale which he terms “Adult Classroom Environment Scale” (ACES) [10]. Its basic dimensions are the following: affiliation, teacher support, task orientation, personal goal attainment, organization and clarity, support influence and involvement. All of the above are directly influenced by the human factor, the environment and the specific discipline. Other similar instruments are more specialized on science laboratory classes of higher education [13],[33]. The acceptance of the instructor’s overall stance heavily depends on the manner by which he/she diffuses problematic situations, regulates and secures the quality of learning and adheres to the principles of fair assessment.

Student’s outcomes also seem to be positively influenced by the control of the psychosocial environment [29]. Also, younger students who perceive the psychological environment as oriented in learning goals and not only in grades achievement have a positive attitude and set high standards [19]. Equally important is one’s previous experience with computers -be it through video games or via the common internet use. Similar observations have been reported in other studies as well [6] in the sense that instructional methods and other academic specialties cannot be examined separately.

3. HANDLING DIFFERENT CONCEPT MAPS AND STRATEGIES

Within the wider CAD framework, basic principles, commands, abstract functionality and strategies must be deeply understood to achieve efficient use of CAD systems [3]. On a technical level, 2D or 3D design procedures require students to achieve high spatial abilities, to be creative, self-organized and to practice in time-management to meet deadlines. To certain extent the combined use of creative and functional mental processes can be more effective [36]. Koestler coined the term ‘bisociation’ to explain the difference between routine skills of thinking and creative act [21]. All students can be creative in their own way since there are no barriers between creative and non-creative people [30]. Another important parameter that must be taken into consideration is insight [32]. That is the combination of both the use of drawing commands, as well as other interface functions, which lead to complex designs. Cheng argues that the manner with which words are used to create sentences, similarly CAD features can be combined to construct a communicative vehicle [6]. Under no circumstances does a mere recalling of ready-made solutions nor previously taught examples constitute an act of creativity. But being creative in CAD presupposes that students first can figure out and focus on working concepts about procedures.

During a working concept, a student’s difficulty to resolve a conflict through assimilation is referred to as a “cognitive conflict” [18]. In such instances the learner feels that his/her conceptualization of a problem differs from the dominating or “popular” one [35]. Preexisting knowledge and concepts based on previous experiences on hand drawing or different CAD software are causing conflicts in modeling strategy [39]. In order to bypass this impasse, he/she must transform his/her initial cognitive structure and adapt it to the new situation. Research has shown that students with different preexisting knowledge can learn efficient strategies in limited time [4] and thus command and strategic knowledge can be combined [7]. In this fashion, our primary instructional goal is to separate specific software tools from solving strategies and emphasize on Euclidian properties of planar or solid geometry [38].

The role of the computer graphics in architectural design is quiet debatable since many scholars in Greece have yet to reach a consensus. For some of them, computers ought to assume the role of a mere digital tool where major emphasis is placed on the commands and the final product. For others though, things are seen from a totally different perspective where CAD is predominantly a composite of variables, procedures and dynamic design. Now which viewpoint scholars subscribe to depends on their previous experiences, their teaching style and what they consider as common sense practice [17].

Another reason why instructors and curricula designers should not rely on specific software tools is that CAD software manufacturers constantly modernize their products with new, updated and enhanced versions. Thus, the designer must constantly keep abreast of the current software tools in the market, adapt the manner with which he/she organizes his/her working habits and constantly reconstruct the existing concept maps. In this competitive world, the designer must learn to revise, to seek the more productive without sacrificing quality and to maximize his/her capabilities and intellectual capacities and to seek his/her personal growth.

4. METACOGNITION AND COMPUTER AIDED DESIGN

Due to its nature, designing with CAD requires the ability to employ a wide variety of cognitive as well as motor sensory skills. Metacognitive skills focus on “how to learn” and they have been proven vital in the learning process [16]. According to Lockwood metacognition includes major elements of Planning, Realization, Integrating, Monitoring, Evaluating and Attitudes [26] as shown in figure 1.

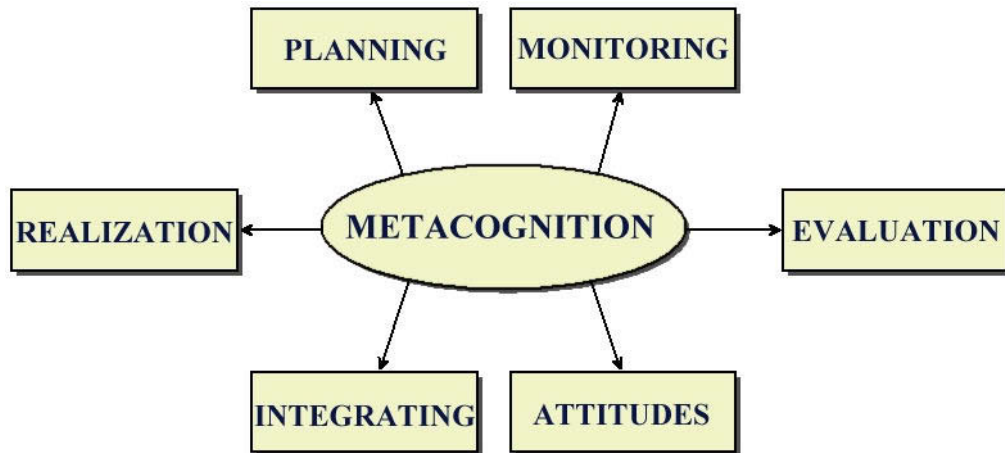


Fig. 1: Major elements of metacognition.

Flavel implies that metacognition, is the highest form of one’s intellectual capacity and when developed to its fullest potential in a sound learning environment, it can make the learner realize that designing projects are a product of his/her own ingenuity and creativity [12]. Students are inspired to see a complete drawing which is a representation of their thoughts, choices and hard work. It sort of reminds us of Anderson’s famous line about metacognition where “...[you] make your thinking visible” [1]. Research has shown that students with poor metacognitive skills find it quite difficult to appreciate their efforts in a challenging situation [23]. It is quite difficult just through plain knowledge to trace one’s metacognitive skills because they are not overtly expressed but rather constitute an indicator of one’s academic success and one’s ability to solve problems [34],[9].

Despite the fact that metacognitive skills are predominantly a private matter for every learner, their use can be, nonetheless, greatly intensified through the instructor’s conducive-to-learning attitude. Lane, who is a major proponent of this claim, asserts that “metacognitive skills can be taught” [24]. What the instructor can do in CAD laboratory is to help the learners mobilize all their resources in regards to assessing critical thinking skills, analyzing and managing emotions and coming to terms with personal learning styles. On the other hand, the instructor’s realization that his/her role is to be a regulator and adaptor of metacognitive strategies constitutes a revolutionary idea which introduces the notion of metacognitive instruction [25].

5. MOTIVATION AND AIMS

What is examined is the learning conditions and activities which characterize the CAD laboratory while focusing on the students’ metacognitive processes. The driving force behind this research is the fact

that research projects which seek to apply their theoretical underpinnings of daily practice to CAD teaching are generally rare.

It has been observed that non flexible teaching practices do not target student's "designing ingenuity" but are rather limited to the memorization of designing procedures of ready-to-use objects and templates. Such teaching practices hinder the students' creativity because each individual's learning style and pre-existing concept maps are not taken into consideration. This could explain why some students are still not familiar with modern CAD systems [28]. We recommend that the instruction in the laboratory should focus on illustrating the concept maps which are currently in use and also on delineating the particular metacognitive strategies which students employ during the courses. Furthermore, we seek teaching methods which can reinforce metacognition within a sound learning environment using videotutorials (video demonstrations on designing tasks).

Our primary goal in the teaching of CAD is to encourage designers to tap into their creative streak and display their knowledge and designing abilities through cutting edge and high standard design-oriented projects. Thus, the reinforcement of their metacognitive abilities becomes extremely crucial if one takes into consideration the fact that CAD technologies are undergoing a rapid evolution and future designers should be in the position to adapt these changes to meet their professional needs.

6. COURSE ELEMENTS

Through our students' (re)acquaintance with the CAD software, we managed to record and analyze the metacognitive processes as a way of assessing their thinking process along with their intuitive attempt to control their learning journey. The observation team was comprised of undergraduate students (predominantly sophomore/junior aged 19-21) with no prior experience in Computer Aided Design in the Department of Landscape Architecture at the Technological Educational Institute (TEI) of Kavala, Greece. During the course of a 15 week semester, each course was distributed as follows: 2 hours of theoretical instruction, 2 hours of lab (practice) and 3 hours of extra tutorial sessions. Our laboratory, on the other hand, has a total of twenty one computers which was ideal since it could accommodate a full class of twenty students. In other words, there was a one-to-one pc/user ratio.

The views reported in this paper are based on 6 semesters of formal observations beginning from the winter of 2005 and onwards. In terms of methodology, students' projects and related video files were observed and notes were taken systematically.

The AutoCAD 2006 (Autodesk) was the basic CAD software used, although SketchUp (Google) was demonstrated as an alternative. The course began with the basic commands and ways of personalizing the working environment. This was then further compounded by more gradually complex exercises through which students were required to combine the previously taught designing commands. The last sessions of the course focused on the introduction of 3D CAD design, materials editing and rendering effects. Students were required to go through at least two individual assessments and submit a group project at the end of the semester. Particular emphasis was given on the first part of laboratory sessions (5 weeks) when each student had to develop self confidence using the CAD software.

7. OUR APPROACH

7.1 Error Management Training

It has been observed that the control of emotions, aggravation and stress during the use of CAD software is directly linked to the underlying error managing policy. At this point, the instructor's role is very crucial in the sense that he/she can make students' view an error not as a mere sign of failure, but as a positive and fruitful learning experience full of great potential for personal growth. Due to the fact that designing software today is very useful though quite complex, a potential error on the part of the student can be exploited in a productive way. In error management training, student's disappointing experiences are being transformed into something valuable that can dramatically boost motivation and reduce any signs of frustration and agony. The student, then, feels comfortable verbalizing and explaining the reasons behind his/her choices leaving room for the instructor to provide alternative ways of tackling the problem as well as potential solutions. Findings of Keith & Frese in computer laboratory came to conclusion that in error management training, emotion control and metacognitive activity leads to higher transfer performance in contrast with the traditional "error avoidant approach" [20]. In table 1, a summary of the most frequent student's errors is presented, following the basic categorization (command/strategic knowledge) proposed by Bhanvani [4].

<i>Command Knowledge</i>	<i>Strategic Knowledge</i>
Unknown situation (command, procedure or displayed message)	Not applicable strategy for a given situation
Fault choice of command	Difficulty of formation of a strategy
Misunderstanding of a command or procedure (wrong estimation about the outcome)	Difficulty to estimate the distance to the solution. (to recognize the completion time of a given task)
Wrong spelling of a command because of mistyping or existence of two similar commands	Misunderstanding about a method or an algorithm (wrong knowledge assimilation)
Reverse order of two coupled commands	Wrong attitude about the usability of CAD software for given design tasks
Wrong command parameters (mostly arithmetic)	Wrong methodology or algorithm
Mistaken estimation of the current CAD conditions, settings or global variables	Incorrect knowledge transfer (alternative methods & tools) from different CAD software
Tracking of a wrong route on command procedure (in case of commands that use multiple separate phases of execution)	Difficulty to recognize visual controls of the working environment because of different personal settings (for amateur users) or different version of known software
Distraction (loss of awareness) because of environmental conditions or lassitude Computer malfunction or loss of stability (not student's responsibility)	Apply previous knowledge on design tasks with dissimilar conditions

Tab. 1: Most frequent student's errors during design tasks.

The above frequent errors were observed during practice on given design tasks and final exams during the last 6 semesters (as of 2005). In general, student's mistakes in command knowledge are easier to be observed and recorded in contrast with mistakes in strategic knowledge. It comes natural that in some cases students are "unable to explain their strategies of decision making" [31].

7.2 The Use of Video-tutorials

The teaching of CAD is basically a series of tightly-knitted units. Here is where the problem of intensive instruction and active student participation emerges. It is easily understood that keeping a detailed and updated attendance record and stipulating a limit on the number of excused absences do not necessarily guarantee that students will attend nearly all sessions. On the other hand, one can not possibly master the skills taught in the laboratory just by merely reading the suggested bibliography. Furthermore, it would be extremely difficult for a student who hasn't been present to every session to complete the tasks of the course since he/she would not be "in tune" with the learning environment in the laboratory.

An alternative solution was the creation of a series of videotutorials which covered the 100% of what was actually taught in the laboratory in one semester. The combination of traditional teaching practices and the use of video-tutorials increases students' motivation and interest and contribute to their overall progress [27].

In our case, video-tutorials are delivered as flash type video files, audio enabled and recorded from the instructor's screen. More than 51 videotutorials currently available were recorded during off-laboratory hours and contain exercises and design problems that one might encounter in an actual laboratory setting. The remaining batch contains either authentic activities which took place during actual session on specific dates or suggested answers to evaluation exercises. All video-tutorials are archived in organized units and have been posted on a simple e-learning platform (Figure 2) driven by

a video database developed by the instructor. The analysis of technical aspects of the platform is outside of the scopes of this paper. Focus will be given to the suggested uses of videotutorials.



Fig. 2: A snapshot of videotutorials entry page.

For consolidation and recapitulation. Research shows that the human brain can not retain the totality of information it receives at any given moment. Only a fraction is stored in the long-term memory while the rest begins to fade away [11]. The solution to retention of knowledge is repetition and in our case the repetitive display of the proper use of commands constitutes such an example. Due to the intense nature of CAD, the suggested readers (which are predominantly based on image and text) aren't the most appropriate ones for the elucidation of how the software can be used effectively. Only those who follow the minimalist teaching model [5] may consider them useful. Videotutorials, on the other hand, have a natural flow of information, can better illustrate the various design practices and are available online on a 24/7 basis. Access is available to every matriculated student regardless if he/she has registered for the class or not.

For fulfilling learning gaps. Those students who for one reason or another missed a couple of sessions, now have the opportunity to catch up with the rest of the class just by watching the videotutorials. Thus, any problems that a few absences may have created are now diminished. The instructor's explanation of the use of the video-tutorials and his/her expectations are crucial since they can not be seen as mere substitutes for the actual session.

For applying feedback. During the practical part of the session where the exercises can be used for student assessment, solutions to every example are provided in video. During the video presentations many alternative solutions are provided since the laboratory's general philosophy is the acceptance of diverse opinions for the solutions of given design problems. Feedback through video-tutorials is useful to every student and specifically to those who have learned to absorb many things from detailed representations, known as visual learners [2].

For enhancing metacognitive skills. The use of video, however, is not merely used for tape recording the instructor's examples. In addition to feedback, it is also used as a means for enhancing

metacognitive skills -a factor which is of paramount importance for personal growth [37]. The way the verbalizing of the students' explanations enhance their metacognitive skills [8], the same way video captured from student's screens during practice on given tasks is suggested as an effective method of enhancing the students' metacognitive skills.

Both the instructor and the students consent to the recording of the ongoing activities displayed on the screen for as long as is necessary. The level of difficulty is regulated in such a way that the available time to complete the tasks at hand spans roughly 5-10 minutes. The level of difficulty for CAD tasks is based on the students' overall progress and the results of the previous evaluation sessions. The students' learning style and the goals which are expected to be achieved are taken into consideration. This method is both feasible and practical since the participants are no more than 20 per class.

The video archives from these sessions are constantly evaluated by the instructor in order for the class' overall progress to be assessed, for any deficiencies to emerge or learning gaps to be fulfilled and in order for every student's personal designing style to be reviewed. It should be mentioned, however, that these will not be taken into consideration when assigning their final grade. This is purely done in order for the students' to feel comfortable with being video-taped. Once this is done, the instructor schedules individual 20 minute meetings with every individual. During these meetings, the instructor tries to analyze the problems which have emerged, responds to students' inquiries and discusses techniques to fine-tune their skills.

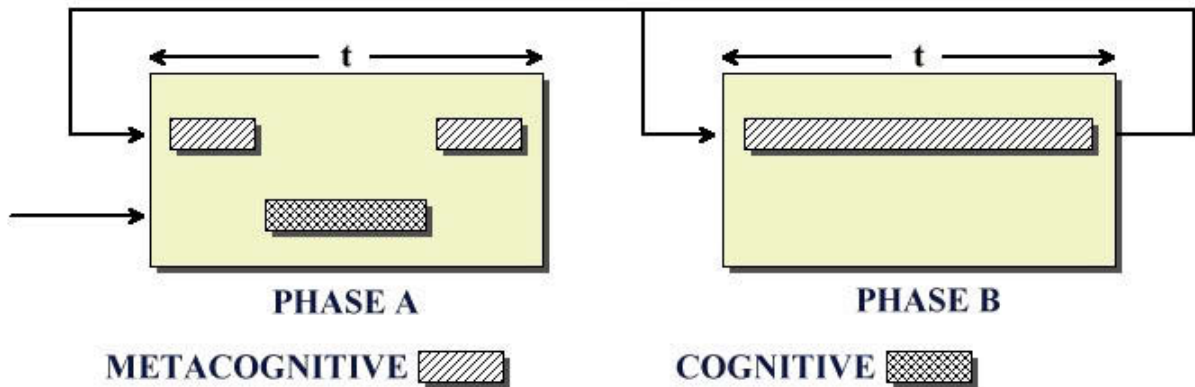


Fig. 3: Exchange between used mental skills (cognitive and metacognitive). Phase A: execution of task, Phase B: reflecting on the video-taped version of the task by the student.

In Figure 3 the entire process can be visualized. During phase A, the student completes a specific design task. The duration of the task is given by t . With his/her consent, this process is video-captured from computer screen. We can observe that there are two metacognitive phases and one cognitive phase at play here in a "Hamburger" alignment. This schema can be repeated continuously until the task is considered complete. The limits between Cognitive and Metacognitive knowledge may not be fixed and the real distinction depends on how students use the gained knowledge [12]. During the preparation stage, the student develops a specific strategy and mentally plans the way with which he/she will complete the given task. After the actual design phase, estimation about completeness of the task is taking place. To save time, phase A is being done simultaneously by everyone. During phase B, the metacognitive functions are dramatically enhanced. Each student carefully goes through the video with the instructor and together they discuss the various strategies employed, choices of designing tools, error correction strategies, completion time and individual difficulties that may have been raised. Once this is completed, they have to choose between two options: 1) the student repeats the task having acquired new knowledge and can monitor his/her progress on his/her own. This is mostly appropriate for tasks with minimal difficulty 2) if the instructor feels that the student can complete the task fairly well and bring about the desired results, then the student proceeds to the 'mental representation procedure'. This procedure does not entail the use of the computer to complete the task but rather requires the student to mentally visualize the procedure (share thoughts and talk

aloud) which will bring out the desired result. The student is called upon to imagine the procedure he/she will follow and detail all the required steps that need to be taken in order to achieve the desired goal.

The most impressive aspect of phase B is that the student cooperates with the instructor not on personal judgments but on objective assessment of his/her progress. As the students watch themselves in the video, they meditate on their followed strategy, see their mistakes but they also highlight their strong areas as well. Therefore, the video-recording procedure becomes an indispensable learning tool. We might say that this method has numerous advantages by being an objective assessment tool with its descriptive, detailed and comparative nature. Common metacognitive skills which have been identified are:

- Description of what they are designing.
- Description of their goals and an assessment of the final product.
- Identifying strong and weak areas, deficiencies and abilities.
- Analyzing their choices (i.e., tools and strategies employed).
- Identifying their current level through comparison with other students.
- Reflecting on alternative ways of achieving their goal.
- Assessing their individual designing style.
- Reviewing their progress.
- Making effective use of new knowledge.
- Recognizing a change in attitude.
- Controlling the intensity of their effort and presence.
- Mental application.

8. VIDEO EXAMPLE

According to her profile, B. is a sophomore female student in the Landscape Architecture Department and, as is expected for her level, she lacks experience in CAD. She is acquainted with the various forms of architectural design through other courses. She regularly attends every laboratory session and shows great interest in this subject since she is very much aware that CAD will be an integral part not only of her academic studies but also of her professional career.

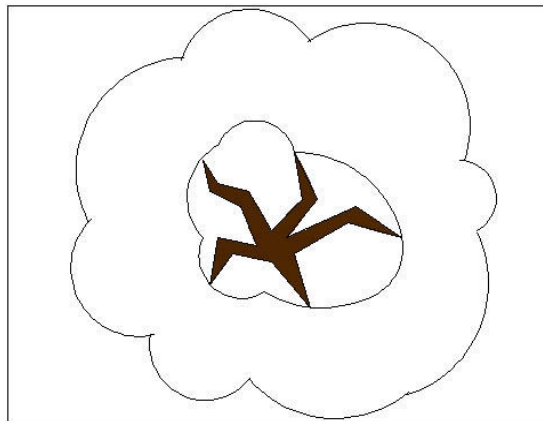


Fig. 4: Example of a student's unfinished design of a tree (cropped screenshot from video).

The difficulty she is currently facing in the course has to do with the use of "object snaps". In figure 4, a screenshot from her submitted work (.dwg file) can be seen. For this task, students were asked to design the symbol of a tree which would be used in a plan of vegetation. The table (2) below contains an excerpt from a conversation between the student and the instructor where they both analyze the video showing her work. The conversation was recorded on a portable digital device and it was translated from Greek.

A/A	<i>Conversation while watching a video captured from student's screen</i>	<i>Comments</i>
1	Student: Sir, what I basically understood in the tree example was "hatch" but I tried to place it in the outer green area and it didn't go. So, I put it only in to the inner part.	The analysis of this dialogue reveals various metacognitive functions which are activated in second plane (Phase B - watching the video). The beginning is recognition of the procedure (i.e., pre-existing knowledge - the placement of hatch). Then, the problem is presented, and the mistakes are acknowledged. The phrase "I tried to place it in the green area" reveals an awareness of purpose and conceals the gap between it and the ultimate goal. In the third line, the phrase "The inside doesn't have a problem" signifies that success has been recognized. Then, the student recalls something the instructor had said "You said that..." She tries to justify her mistakes by claiming that she faithfully followed the instructions. She then describes in great detail every step she took to perform the task, and it seems as if she remembers it well. Yet the confusion is still evident. In lines 4,5,6 we find out that the object snaps haven't been properly used. In line 7, she states that she understands the proper use of object snaps but hasn't changed her mind regarding the result of their usage since she couldn't link them to the problem that had emerged. In line 8, the instructor explains the relationship between the two. This leads the student, in line 9, to change her stance and discover a brand new rule that we always use Osnaps. This rule is more than enough to explain the problem but still collides with the previously acquired knowledge (i.e., so why didn't we do this in the previous two examples?). In line 10, an alternative solution is provided which seems to make sense to the student in line 11. Also in line 11, the rule initially created in line 9 is restated but with a much deeper understanding of its exceptions.
2	Teacher: Yes I saw it. So you know how "hatch" works.	
3	Student: The inside doesn't have a problem. The outside though...here take a look. You said that we should try different sizes. But here look. I begin with 0,1, I go to Pick Points and then... nothing. This message comes out.	
4	Teacher: Let me see for a second. Ok look. The scale (of the hatch) is not really the problem. If we take a step back (pause), ... you place the end of the arrows where the previous one ends without having activated the object snaps.	
5	Student: You mean the little magnets?	
6	Teacher: Yes those. It's not enough just to zoom in, to bring it very close to you and then to try to grab its end. You can maintain its continuity just by using Osnap.	
7	Student: Ok that's fine but I was telling you about "hatch"...	
8	Teacher: But that's the problem. Look, if you have left just a small distance between them... the lines are not continuous. So when you choose Pick Points to choose an area for the hatch, the program can find a closed area.	
9	Student: Ok. We always use the object snaps first. So there is no chance for us not to use them? So why didn't we do this in the previous two examples?	
10	Teacher: In the previous examples, we left some imperfections on purpose so the tree could appear more natural. We were not intending to use "hatch" later on. But this is hardly the problem though. If you have one arrow intersecting another one, then the area you are making is closed.	
11	Student: So the problem then is when they do not intersect. Ok. And for the other examples...they should always be closed unless we want to use "hatch."	

Tab. 2: An excerpt from instructor-student conversation during video watching and comments.

9. RESULTS

Imposing one's expectations in the classroom without delving deeper into an understanding of the conceptual maps and beliefs regarding CAD cannot possibly lead the student population to achieve the lesson's and their personal goals. During the completion of design tasks, the guidance of the students'

thinking patterns as well as their learning journey become a spontaneous defense mechanism. However, when a student sees a video-recording version of him/herself on the screen, he/she acknowledges the choices and mistakes he/she makes and becomes aware of the metacognitive strategies employed through the instructor's guidance. Many times students are quite surprised by the fact that they tend to reconstruct many details from the procedure they followed when completing the task. Overall, the students react positively to this because they receive a strong feedback from the instructor which is adapted to meet the needs of their preferred learning speed and style.

Prerecorded videotutorials were found very helpful in relation to functional knowledge, especially during the beginning courses. It is characteristic that after the mixed learning solution followed by the instructor, all introductory courses about 'Draw' and 'Modify' toolbars in AutoCAD were shortened into two lectures without affecting the learning workload of students. The belief that students should be teaching themselves how to fine-tune their intellectual functions such as metacognition and self-adjustment was reinforced. To this end, video-recording the students' progress and reflecting on this later can prove quite efficacious both in the classroom and beyond bringing forth grade results. It was observed that after the use of videotutorials the student's grades were not impressively higher than in previous semesters. The grades were increased by about 10-15%. The key point here is that more students completed the course successfully. Before, 25% of students quitted the course or did not submit the required projects on time. After uploading the videotutorials in the local network and the use of mixed learning solution during lectures, this percentage was limited to less than 10%.

10. CONCLUSIONS

Since CAD interests many people today from a diverse scientific and professional background, teaching digital design becomes quite essential. We examined the contribution of a positive learning environment in the laboratory along with a method for reinforcing the students' metacognitive skills through effective interventions. Designing with ease and acknowledging one's mistakes pave the way to creativity and constitute a refined use of the abstract language of CAD design. For future research, an e-learning platform with social network characteristics is under investigation. Our future plans are based on the hypotheses that a virtual community related to CAD learning can be proved very stimulating for academic students especially if communication is based on video exchange between users.

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