121st ASEE Annual Conference & Exposition
Indianapolis, IN
June 15-18, 2014
Paper ID #8790

Assessing Metacognition During Problem-Solving in Two Senior Concurrent Courses

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Abstract

Metacognition refers to people's abilities to predict their performances on various tasks and to monitor their current levels of mastery and understanding[1]. Flavell[2, 3] distinguished two characteristics of metacognition: *knowledge of cognition* (KC) and *regulation of cognition* (RC). KC includes knowledge of the skills required by different tasks, strategic knowledge and self-knowledge. RC includes the ability to monitor one's comprehension and to control one's learning activities. There is a considerable amount of data that supports the value of a metacognitive approach to instruction[4]. It includes an emphasis on learning with understanding and on problem solving, but part of the emphasis is on understanding the cognitive and emotional processes involved in these kinds of activities[1-5]. We designed and implemented several problem-solving learning environments[6, 7] (PSLEs) for two chemical engineering senior concurrent courses entitled Kinetics and Homogeneous Reactor Design and Mass Transfer Unit Operations I at *Universidad de las Américas Puebla* (Mexico).

The *Metacognitive Awareness Inventory* (MAI) designed by Schraw and Dennison[8] was utilized as a pre- (first day of classes) post- (last day of classes) test. MAI is a 52-item inventory that measures adults' metacognitive awareness. Items are classified into eight subcomponents subsumed under two broader categories, KC and RC. Furthermore, in order to assess metacognitive awareness during problem-solving activities, students had to answer the corresponding problem as well as 2-3 embedded problem-solving prompts[7] and 4-6 embedded metacognitive prompts (from MAI, chosen based on the level of complexity of the problem and the type of knowledge and skills required to solve it). A final design challenge was used to simultaneously assess student attainment of learning outcomes for both courses, through the synthesis and analysis of the reaction and separation stages in a chemical plant. Students were asked to carry out a presentation of their solution methodology, obtained results and conclusions for this challenge. Presentations were videotaped to be further examined.

Results for the pre-post MAI exhibit a significant ($p<0.05$) increase in student metacognitive awareness. Notable progress was also noticed by means of the embedded MAI prompts while solving different kinds of problems (such as story problems, decision-making problems, troubleshooting/diagnosis, and design problems) throughout studied courses, in which students also improved the quality of their embedded problem-solving answers and corresponding partial grades. Analysis of final presentations allowed us to identify students' abilities to solve complex problems as well as their argumentative and metacognitive skills. The vast majority of students attained expected both courses' learning outcomes at an acceptable level.

Introduction

Nowadays, there is a growing need for preparing students to think critically and creatively as well as develop several skills such as decision-making, information sharing, teamwork, and innovation. Based on this challenge, the role of schools should be renewed in such a way that students acquire more sophisticated and flexible problem solving skills, along to collaboration and communication abilities[9]. Several studies show that students learn more as well as different abilities when active learning and challenge-based formats are utilized instead of traditional formats of learning[10]. Challenge-based is a general term for a variety of approaches to instruction that includes case-based instruction, problem-based learning, learning by design, inquiry learning, anchored instruction, and so forth[11]. This is due to problem solving being recognized as the most authentic learning activity, because it involves intentional learning, where knowledge is understood, retained, and therefore can be transferred to different situations[6, 7]. Therefore, the primary purpose of engineering education should be to engage and support learning to solve problems[5-7]. Hence, we designed and implemented several problem-solving learning environments (PSLEs), a term that represents problem-solving instruction in a more open-ended way than problem-based learning[7]. Learning to solve problems requires practice in solving problems, not learning about problem solving[7]. PSLEs assume that learners must engage with problems and attempt to construct schemas of problems, learn about their complexity, and mentally wrestle with alternative solutions[7, 12]. Therefore, we built PSLEs to engage and support students in learning how to solve problems by practicing solving problems[5]. PSLEs were developed as described elsewhere[5] by following the design activities proposed by Jonassen[2].

A technique for problem solving becomes a cognitive strategy when learners are aware of how and when it should be used. Furthermore, in order to get the ability to design strategies for solving problems it is essential to be conscious about the cognition and reflection processes required for achieving a feasible solution; these processes are known to be part of metacognition. Metacognition refers to people's abilities to predict their performances on various tasks and to monitor their current levels of mastery and understanding[1]. This approach is typically found it in constructivist theories of meaningful learning that respond to the need for a transition, in students, from passive learners willing to learn adaptive and reproductive forms, to constructive learners who are searching for the significance of what they do[13]. Flavell[2, 3] distinguished two characteristics of metacognition: *knowledge of cognition* (KC) and *regulation of cognition* (RC). KC includes knowledge of the skills required by different tasks, strategic knowledge and self-knowledge. RC includes the ability to monitor one's comprehension and to control one's learning activities. There is a considerable amount of data that supports the value of a metacognitive approach to instruction[4]. It includes an emphasis on learning with understanding and on problem solving, but part of the emphasis is on understanding the cognitive and emotional processes involved in these kinds of activities[1-5].

Methodology

Along the fall 2013 semester we designed and implemented[1, 4-7, 12] several PSLEs for two chemical engineering senior concurrent courses entitled Kinetics and Homogeneous Reactor Design (IQ407) and Mass Transfer Unit Operations I (IQ412) at *Universidad de las Américas Puebla*. Learning outcomes for IQ407 include that students will be able to: 1) determine reaction rate expressions from experimental data; 2) use basic concepts of kinetic, mass and energy balances, as well as principles from thermodynamics to design ideal homogeneous reactors; and 3) assess and propose reactor operation conditions to achieve a specific objective[5]. Learning outcomes for IQ412 include that students will be able to: 1) use basic principles of phase equilibria in binary and multi-component systems, in order to analyze the variables of an equilibrium stage; 2) use basic concepts of mass and energy balances, as well as principles from thermodynamics to design different separation process; and 3) identify, formulate and solve engineering problems related to the design and operation of different unit operations in equilibrium stages.

Together with the teacher of the studied courses, we identified problems relevant to both courses, analyzing them for creating a causal model of the problem spaces. Then we conducted an activity theory analysis to identify the type of problem, as well as factors that affect its solution on the context chosen. Based on such analysis we constructed case supports and cognitive scaffolds for each PSLE as described elsewhere[5]. Fifteen students, seven of them female, integrated both classes population. In order to support a metacognitive approach to instruction, the teacher of both courses created a supportive social environment and inserted a series of question prompts during PSLEs as a form of coaching, where the problems to be solved were represented as cases that were utilized in several ways (worked examples, case studies, structural analogues, prior experiences, alternative perspectives, or simulations) as instructional supports[6, 7, 12].

In order to assess students' metacognition awareness, the *Metacognitive Awareness Inventory* (MAI) designed by Schraw and Dennison[8] was utilized as a pre- (first day of classes) post- (last day of classes) test. MAI is a 52-item inventory that measures adults' metacognitive awareness (see appendix A). Items are classified into eight subcomponents subsumed under two broader categories, KC and RC. Furthermore, in order to assess metacognitive awareness during problem-solving activities, students had to answer the corresponding problem as well as 2-3 embedded problem-solving prompts[7] and 4-6 embedded metacognitive prompts (from MAI). No additional instruction on metacognition was given. MAI prompts were chosen based on the level of complexity of the problem and the type of knowledge and skills required to solve it. In every case, students were asked to briefly describe the procedure they utilized to solve the problem, as well as their confidence level on their answers.

A final design challenge was used to simultaneously assess student attainment of learning outcomes for both courses, through the synthesis and analysis of the reaction and separation stages in a chemical plant. Students were asked to carry out a presentation of their solution methodology, obtained results and conclusions for this challenge. Presentations were videotaped to be further examined.

Examples of PSLEs

Story problems are commonly used for enhancing variable recognition and the use of algorithms[5-7]. This type of problems was utilized to support students' learning in order to describe relationships as mathematical models for IQ407[5, 14] while in IQ412 story problems were designed in order to support data interpretation[15]. In both courses, the degrees of freedom for this type problems were completely specified, thus the obtained models can be used to determine unknown variables (Figure 1). As part of this story problem activity, students answered seven items from MAI (items numbered 10, 12, 16, 17, 20, 32, and 46 on Appendix A) related to *knowledge of cognition*, particularly associated with declarative knowledge[5, 8].

PROBLEM 1

Kinetics and Homogeneous Reactor Design (IQ407)	**Mass Transfer Unit Operations I (IQ412)**

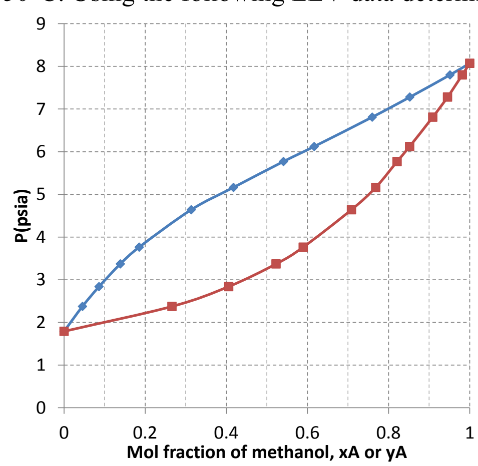
The following reactions are taking place simultaneously in gas phase.

$$A \leftrightarrow B + C$$
$$B \leftrightarrow D + C$$

The equilibrium constant for each one is 6 and 4, respectively. The total pressure is 2 bar and it remains constant along the process.

Determine the partial pressure for each component at equilibrium, if reactor is fed exclusively with A and it is operated isothermally.

A liquid mixture containing 45% mol methanol and 55% mol of water, is isothermally expanded from 8 to 2 psi at 50°C. Using the following ELV data determine:



a) The pressure at which vaporization begins
b) The composition of the first vapor bubble at equilibrium with the saturated liquid
c) The composition and temperature of the residual liquid when 25% of the initial liquid has been evaporated.

Figure 1. Story problem examples
(Adapted from Tiscareño[14] for IQ407 and Seader *et al.*[15] for IQ412).

Troubleshooting/diagnosis problems were assessed in both courses (Figure 2). Students were asked to manipulate a process variable to achieve a specified goal. For IQ407 the objective was to adjust the feed flow-rate to achieve a specified conversion in a CSTR[16] while IQ412 students were asked to adjust the reflux ratio and the feed stage location in order to obtain the product purity in a distillation column for a binary separation, using a pre-defined graphical method[17]. Once more, students had to describe the methodology they employed to solve the problems and ten MAI items (numbered 3, 14, 15, 18, 26, 27, 28, 29, 33, and 35 on Appendix A) related to *knowledge of cognition*, several of them particularly associated with procedural and conditional knowledge, were used as a form of coaching [5, 8].

PROBLEM 2	
Kinetics and Homogeneous Reactor Design (IQ407)	**Mass Transfer Unit Operations I (IQ412)**
Mixed flow reactor (CSTR) is used for carrying out the next first order reversible reaction: $A \leftrightarrow B$ The reactant A is fed with a composition of 1 M. The equilibrium conversion is 66.7% and the actual conversion is 33.3%. We are looking for raising the actual conversion to 50%. You are asked to determine how we must adjust the feed flow-rate to achieve that goal.	A binary mixture of methanol and water is to be separated using a conventional distillation column. The feed stream contains 40 mol/s of methanol and 60 mol/s of water, introduced as a saturated liquid at 1 atm. It should recover 95% mol of methanol in the distillate stream with a purity of 98%. A conventional distillation column is available to carry out this separation, which contains 7 stages and a partial reboiler. The feed stream can be introduced at any stage and the reflux stream can be adjusted to meet the product specifications. Using the McCabe Thiele Method, determine the feed stage location and the steam produced at the reboiler to carry out this separation.

Figure 2. Troubleshooting/diagnosis problem examples
(Adapted from Levenspiel[16] for IQ407 and Doherty and Malone[17] for IQ412).

Examples of decision-making problems assessed in both courses are described in Figure 3. In IQ407 students had to decide (and justify their decision) the order for placing both reactors, based on their reactor and kinetic knowledge[14], while IQ412 students were asked to define operating conditions in order to obtain the product purity in a distillation column for a multicomponent separation; in this case the selection of the applied methodology was not pre-defined[17]. Further, students had to describe the methodology they employed to solve the problems and answer sixteen MAI items (numbered 2, 6, 8, 11, 13, 21, 22, 23, 34, 37, 38, 40, 41, 42, 44, and 48 on Appendix A), related to *regulation of cognition*, most of them particularly associated with planning and monitoring, which used as a form of coaching[5, 8].

PROBLEM 3	
Kinetics and Homogeneous Reactor Design (IQ407)	**Mass Transfer Unit Operations I (IQ412)**
There are two reactors available for installation, the first one a CSTR with a 5m3 volume and the second one a PFR with 2 m3 volume to process 80L/min containing 0.5 M of A and 0.1 M of B. The desired product C may continue reacting to a side product with no commercial value. The important reactions are: $$A+\frac{1}{2}B\rightarrow C$$ $$C+\frac{1}{2}B\rightarrow D$$ The kinetic expression for each reaction, which are referred to component B [mol/L min], are: $$-r_{B1}=0.0068C_AC_B^{0.5}$$ $$-r_{B1}=0.0745C_BC_C$$ Determine the proper order to install both reactors.	Consider 100 kmol/h of a saturated liquid feed containing 40% A, 20% B y 40% C that is to be separated by distillation. The bottoms product is obtained with a flow rate of 40 kmol/h with the composition x_C=0.954 and x_B=0.039. The VLE can be represented as an ideal solution with the following relative volatilities: 5, 3 and 1. For this separation the minimum number of stages are 5. There is available a column with 10 stages. ¿How many theoretical stages are required in each column section and what operating reflux ratio do you recommend?

Figure 3. Decision-making problem example
(Adapted from Tiscareño[12] for IQ407 and Doherty and Malone[17] for IQ412).

A final design problem was used to simultaneously assess student attainment of learning outcomes for both courses, through the synthesis and analysis of the reaction and separation stages in a chemical plant. The final project was assigned for teamwork (groups of three to four students) on the last week of the semester and students had a period of two weeks to develop their proposal, which they presented as their final exam. The same chemical process, styrene production, taken from the Design Projects Web Page developed by Dr. Richard Turton[18], was utilized for every assessed team. Students were asked to present a written report and to carry out a formal presentation of their solution methodology, obtained results and conclusions for this design challenge. For assessment of their problem solutions we utilized three different Value Rubrics (Problem Solving, Oral Communication, and Written Communication) developed by the Association of American Colleges and Universities (AACU)[19, 20]. For the final presentations, every student performed a self-evaluation and peer-evaluation regarding oral communication and problem solving skills using the corresponding rubrics. For the written report only two appraisals by means of the corresponding rubric were considered, team self-assessment and teacher's assessment of the reports. Since the design problem is open-ended, a number of alternative solutions can be generated, so students had to take an ill-structured problem and define their own goals and the methodology to constrain the number of scenarios to be evaluated. As stated before, this final project was utilized to assess students' transfer of expected learning outcomes of both courses and their problem solving skills (however, this transfer of learning study is not part of this research and will not be presented here).

Results and discussion

Pre-post *Metacognitive Awareness Inventory* total mean scores are presented in Figure 4. The red bars represent *knowledge of cognition* while the green bars display *regulation of cognition* results. The blue bars summarize total MAI scores. It is clear that significant progress ($p<0.05$) in students' *metacognitive awareness* as well as specifically in *knowledge of cognition* and *regulation of cognition* were achieved as previously reported for a chemical engineering junior course at our university[5], professional educators at Weber State University[21], dental hygiene students at Malmö University in Sweden[22], as well as in a photography class at Florida State University[23]. At *Universidad de las Américas Puebla*, chemical engineering students exhibited an increase in the MAI mean total score, from 74.4 to 86.4[5], Malmö odontology students increased on their scores from 62.1 to 68.6[22], while Florida State University photography class students exhibited an increase in MAI mean total score from 65 to 68[23]. Increases in scores were in every case out of 100 possible points.

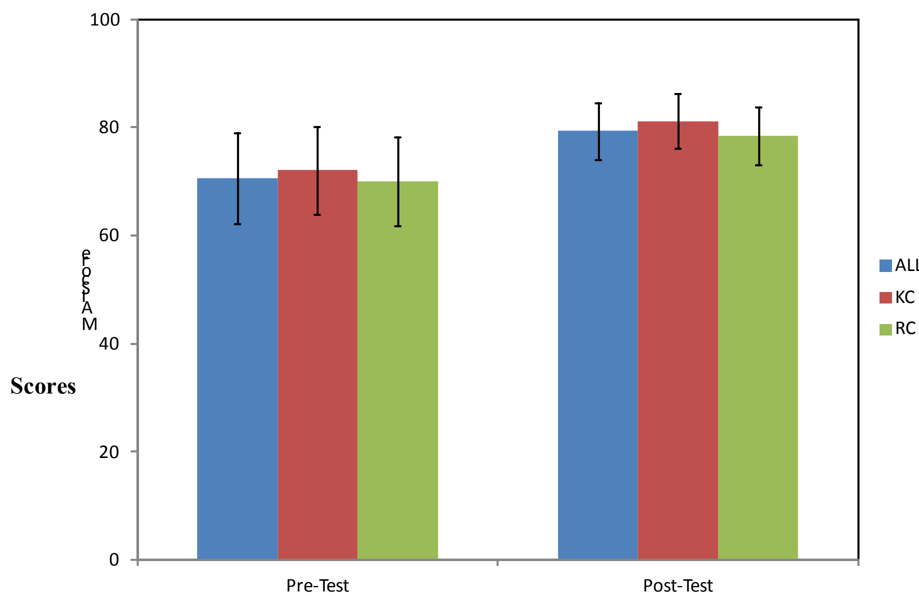


Figure 4. Pre-post (first-last day of classes) students' total *Metacognitive Awareness Inventory* (ALL), *knowledge of cognition* (KC), and *regulation of cognition* (RC) mean scores (n = 15) and standard deviations (error bars).

The studied approach helped almost every student, regardless of its gender or academic strength (data not shown). In general, students that achieved high scores in the pre-test obtained minor gains in metacognitive awareness scores in their post-tests while students that achieved lower scores in the pre-test obtained larger gains in metacognitive awareness scores in their post-tests. Moreover, higher progresses were observed for students with lower pre-test MAI scores.

Furthermore, students' MAI scores were also analyzed by gender. Figure 5 displays pre-post global *metacognitive awareness* (in which KC and RC are included). An important observation arises from the pre-test, female participants recognize themselves as more metacognitive than male participants. However, male and female participants showed no significant difference at the post-test ($p>0.05$) in MAI.

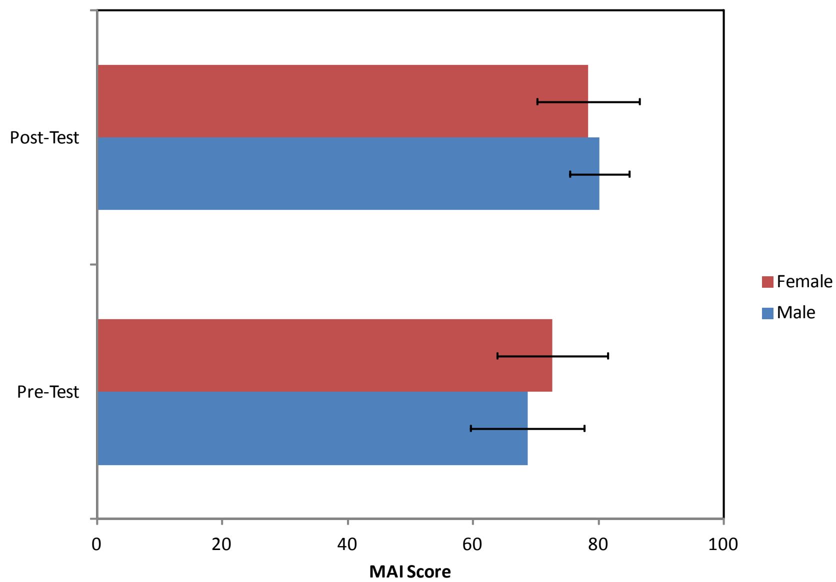


Figure 5. Pre-post (first-last day of classes) students' *Metacognitive Awareness Inventory* total mean scores and standard deviations (error bars), classified by gender.

Along the semester, several MAI items were included within the problem-solving activities simultaneously in both courses. In order to analyze the development of student's metacognitive awareness, the obtained results were compared to those obtained in the MAI pre-test corresponding items. A summary of results is presented in Table 1; growth was also noticed by means of the embedded MAI prompts while solving different kinds of problems (such as story, decision-making, troubleshooting/diagnosis, and design problems) throughout studied courses.

According to our findings, the *knowledge of cognition* of students steadily and significantly increased ($p<0.001$) form pre-test to problem 1 but no significant progress was observed in the case of the second problem in both courses ($p<0.123$ and $p<0.563$ for IQ407 and IQ412, respectively). This result can be related to the kind of problem and the metacognitive processes assessed during its resolution. In the first activity, a story problem (the less complex of studied problems) was implemented, while for the second one a troubleshooting/diagnosis problem was utilized; at this stage of the semester students had solved few problems of the second type, and although in both cases MAI items were related to *knowledge of cognition*, in the first problem those items were mainly related to *declarative knowledge* while for the second problem MAI prompts were associated mainly with *procedural* and *conditional* knowledge.

Table1. Comparisons of students' *Metacognitive Awareness Inventory* (MAI) mean scores regarding MAI prompts' scores (KC: *knowledge of cognition* and RC: *regulation of cognition*) to MAI pre-test corresponding items' scores for each studied problem (1: story problem, 2: troubleshooting/diagnosis problem, 3: decision-making problem) at studied courses (Kinetics and Homogeneous Reactor Design: IQ407 and Mass Transfer Unit Operations I: IQ412).

			Mean	**Standard deviation**	**Significant* difference at p<**
KC	Pre-Test		72.04	20.60	
	Problem 1	IQ407	84.73	15.68	0.001
		IQ412	79.37	17.93	0.001
	Problem 2	IQ407	75.27	18.19	0.123
		IQ412	73.19	19.98	0.563
RC	Pre-Test		69.98	21.58	
	Problem 3	IQ407	78.46	15.61	0.001
		IQ412	82.56	16.26	0.001

*Significant results by using Mann-Whitney Test

It is important to remember that *knowledge of cognition* comprises three sub-processes that facilitate the reflective aspect of metacognition: *declarative knowledge* (knowledge about self and about strategies), *procedural knowledge* (knowledge about how to use strategies), and *conditional knowledge* (knowledge about when and why to use strategies). KC includes knowledge of task, strategy, and personal variables[2, 3, 5].

In the case of the third activity and corresponding problems, *regulation of cognition* of students significantly ($p<0.001$) increased form pre-test to problem 3 (decision-making problem), in which MAI items were associated mainly with *planning* and *monitoring* activities; this third activity was applied close to the end of the courses. Furthermore, students also improved the quality of their embedded problem-solving answers and corresponding partial grades.

A particular observation that is worth mentioning is the improvement regarding their communication skills. As mentioned before, in each activity students were asked to describe shortly the procedure they utilized to solve the corresponding problem; at the beginning of the semester students wrote extremely short descriptions (one or two sentences) while at the end of the semester their descriptions were well constructed paragraphs including explanations with enough details about their problem solving strategy. Despite the fact that writing proficiency was not achieved along these activities, meaningful progress was observed, particularly in the final project report.

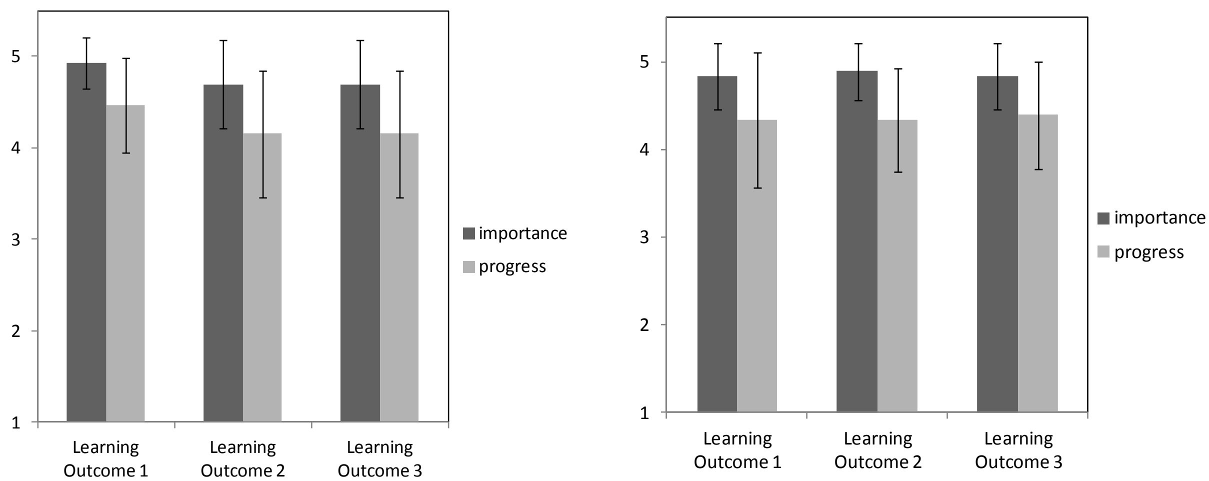
Regulation of cognition covers five areas: *planning* (goal setting), *information management* (organizing), *monitoring* (assessment of one's learning and strategy), *debugging* (strategies used to correct errors), and *evaluation* (analysis of performance and strategy effectiveness after a learning episode). RC includes the ability to monitor one's comprehension and to control one's learning activities. The self-regulation factor of metacognition describes activities that regulate and oversee learning such as planning (predicting outcomes, scheduling strategies) and problem-monitoring activities (monitoring, testing, revising and rescheduling during learning). Self-regulation also involves evaluation.

That is, metacognitive knowledge includes knowledge of the skills required by different tasks, strategic knowledge (knowledge of alternative learning strategies and when to use them) and self-knowledge (knowledge of one's abilities and the abilities of others) [2, 3, 5, 8, 21-23].

The analysis of final presentations allowed us to identify students' abilities to solve complex problems as well as their argumentative and metacognitive skills. In every case, students recognized that reactor operating conditions define the separation stage requirements, so both unit operations are extremely interlinked and it must be taken into account in order to obtain a practical solution; they were able to organize and recognize useful information, get the missing data, and construct a general schema to represent the problem. Several approaches were presented and the vast majority of students attained expected both courses' learning outcomes at an acceptable level. Teams achieved mean values from 2.8 to 3.7 out of 4.0 in the Problem Solving, Oral Communication, and Written Communication AACU Value Rubrics; which correspond to values from advanced milestone to almost capstone level performances[19, 20].

At last, in order to identify the students' perception on the importance and the progress achieved by them regarding to expected learning outcomes of both courses; a final survey was carried out (Figure 6). The dark gray bars indicate the importance that students assign to course learning outcomes, while the light gray bars display the progress achieved by them regarding achievement of course learning outcomes according to their own perception.

It can be observed that students consider that course learning outcomes are very important and felt very confident with their progress in achieving every assessed learning outcome for both studied courses.



a) IQ407 Course Learning Outcomes

Students will be able to:
1) Use basic concepts of kinetics, mass and energy balances, as well as principles from thermodynamics to design ideal homogeneous reactors
2) Identify, formulate and solve engineering problems related to the design and operation of chemical reactors
3) Determine reaction rate expressions obtained from experimental data

b) IQ412 Course Learning Outcomes

Students will be able to:
1) Use basic principles of phase equilibria in binary and multi-component systems, in order to analyze the variables of an equilibrium stage
2) Use basic concepts of mass and energy balances, as well as principles from thermodynamics to design different separation process
3) Identify, formulate and solve engineering problems related to the design and operation of different unit operations in equilibrium stages

Figure 6. Studied Courses Learning Outcomes' Assessment. Importance and progress in achieving them (in a scale from 1: "none" to 5: "a lot") according to students own perception (error bars are standard deviations).

Final remarks

Results for the pre-post *Metacognitive Awareness Inventory* exhibited a significant ($p<0.05$) increase in student metacognitive awareness as previously reported for a chemical engineering junior course[5], professional educators[21], dental hygiene students[22], as well as in a photography class[23]. Male and female participants showed no significant difference ($p>0.05$) in their *knowledge of cognition* or *regulation of cognition* at the end of the semester. Notable progress was observed by means of the embedded *Metacognitive Awareness Inventory* prompts while solving different kinds of problems (such as story, decision-making, troubleshooting/diagnosis, and design problems) throughout studied courses, in which students also improved the quality of their embedded problem-solving answers and corresponding partial grades. It is important to note that with respect to the students, no resistance to this approach was noticed. The vast majority of students attained expected both courses' learning outcomes at an acceptable level. In both studied courses, the teacher realized that instructional activities implemented along each tested problem enhanced students' conceptual and procedural knowledge, while promoting students' metacognitive awareness.

Acknowledgments

We acknowledge financial support from HEWLETT-PACKARD (HP) through the HP Catalyst Grant Initiative for the project "Critical Support Systems to Enhance the Development of 21st Century Expertise in Engineering Students: Using Tablet PCs and Associated Technologies, the *Framework for 21st Century Learning*, and Guidelines from Research on *How People Learn*". Author Reyes Guerrero acknowledges financial support for her PhD studies from *Universidad de las Américas Puebla*.

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APPENDIX A: Metacognitive Awareness Inventory (MAI)*

1. I ask myself periodically if I am meeting my goals. (M)
2. I consider several alternatives to a problem before I answer. (M)
3. I try to use strategies that have worked in the past. (PK)
4. I pace myself while learning in order to have enough time. (P)
5. I understand my intellectual strengths and weaknesses. (DK)
6. I think about what I really need to learn before I begin a task. (P)
7. I know how well I did once I finish a test. (E)
8. I set specific goals before I begin a task. (P)
9. I slow down when I encounter important information. (IMS)
10. I know what kind of information is most important to learn. (DK)
11. I ask myself if I have considered all options when solving a problem. (M)
12. I am good at organizing information. (DK)
13. I consciously focus my attention on important information. (IMS)
14. I have a specific purpose for each strategy I use. (PK)
15. I learn best when I know something about the topic. (CK)
16. I know what the teacher expects me to learn. (DK)
17. I am good at remembering information. (DK)
18. I use different learning strategies depending on the situation. (CK)
19. I ask myself if there was an easier way to do things after I finish a task. (E)
20. I have control over how well I learn. (DK)
21. I periodically review to help me understand important relationships. (M)
22. I ask myself questions about the material before I begin. (P)
23. I think of several ways to solve a problem and choose the best one. (P)
24. I summarize what I've learned after I finish. (E)
25. I ask others for help when I don't understand something. (DS)
26. I can motivate myself to learn when I need to. (CK)
27. I am aware of what strategies I use when I study. (PK)
28. I find myself analyzing the usefulness of strategies while I study. (M)
29. I use my intellectual strengths to compensate for my weaknesses. (CK)
30. I focus on the meaning and significance of new information. (IMS)
31. I create my own examples to make information more meaningful. (IMS)
32. I am a good judge of how well I understand something. (DK)
33. I find myself using helpful learning strategies automatically. (PK)
34. I find myself pausing regularly to check my comprehension. (M)
35. I know when each strategy I use will be most effective. (CK)
36. I ask myself how well I accomplish my goals once I'm finished. (E)
37. I draw pictures or diagrams to help me understand while learning. (IMS)
38. I ask myself if I have considered all options after I solve a problem. (E)
39. I try to translate new information into my own words. (IMS)
40. I change strategies when I fail to understand. (DS)
41. I use the organizational structure of the text to help me learn. (IMS)
42. I read instructions carefully before I begin a task. (P)
43. I ask myself if what I'm reading is related to what I already know. (IMS)
44. I reevaluate my assumptions when I get confused. (DS)
45. I organize my time to best accomplish my goals. (P)
46. I learn more when I am interested in the topic. (DK)
47. I try to break studying down into smaller steps. (IMS)
48. I focus on overall meaning rather than specifics. (IMS)
49. I ask myself questions about how well I am doing while I am learning something new. (M)
50. I ask myself if I learned as much as I could have once I finish a task. (E)
51. I stop and go back over new information that is not clear. (DS)
52. I stop and reread when I get confused. (DS)

Knowledge of cognition (KC): declarative knowledge (DK), procedural knowledge (PK), and conditional knowledge (CK). R*egulation of cognition* (RC): planning (P), information management strategies (IMS), monitoring (M), debugging strategies (DS), and evaluation (E).

* Schraw, G. and Dennison, R. S. 1994. Assessing metacognitive awareness. *Contemporary Educational Psychology*, 19: 460-475.