Fostering the Development of Critical Thinking in an Introduction to Chemical Process Engineering Design Course

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Abstract

Critical thinking is the art of analyzing and evaluating thinking with a view to improving it[1, 2]. This paper describes how a second semester cornerstone course is fostering the development of critical thinking in Chemical, Food, and Environmental Engineering students at *Universidad de las Américas Puebla* (Mexico) by developing students' self-directed, self-disciplined, self-monitored, and self-corrective thinking. Course two major projects were presented to experts in the field that assessed students' critical thinking by means of a specialized rubric[3]. Instructor, peer-, and self-assessments were also performed throughout the course on several assignments (formative) as well as on two major projects (summative). Possible performance levels were from *exemplary* (value 4, skilled, marked by excellence in clarity, accuracy, precision, relevance, depth, breadth, logicality, and fairness) to *unsatisfactory* (value 1, unskilled and insufficient, marked by imprecision, lack of clarity, superficiality, illogicality, inaccuracy, and unfairness).

Mean values from rubric assessment of two major projects were 2.78 ± 0.58 for *purposes* (meaning that in average, students demonstrated an understanding of the assignment's purpose), 2.77 ± 0.77 for *key questions, problems, or issues* (students defined the issue; identified the core issues, but may not fully explored their depth and breadth), 2.85 ± 0.47 for *information* (students gathered sufficient, credible, and relevant information, included some information from opposing views, and distinguish between information and inferences drawn from it), 2.67 ± 0.74 for *interpretations and inferences* (students followed some evidence to conclusions, but inferences are more often than not unclear, illogical, inconsistent, and/or superficial), 2.23 ± 0.69 for *assumptions* (students are failing to identify assumptions, or failing to explain them, or the assumptions identified are irrelevant, not clearly stated, and/or invalid), 2.58 ± 0.67 for *concepts* (students identified some key concepts, but use of concepts was superficial and inaccurate at times), 2.53 ± 0.59 for *implications, and practical consequences* (meaning that in average, students are having trouble identifying significant implications and consequences and/or identifying improbable implications). The vast majority of students attained projects' expected critical thinking outcomes between the level of competent, effective, accurate and clear, but lacks the exemplary depth, precision, and insight, and the level of inconsistent, ineffective thinking; showing a lack of consistent competence: often unclear, imprecise, inaccurate, and superficial. Therefore, it is suggested to further integrate critical thinking in subsequent courses in order to foster its meaningful development in Chemical, Food, and Environmental Engineering students[4].

Introduction

Recently *Universidad de las Américas Puebla* (UDLAP) generated new curricula for its undergraduate degrees in chemical (CE), food (FE), and environmental engineering (EE). These new "integrated and spiral" curricula[5-11] includes several departmental courses considered chemical, food, and environmental engineering "pillars", which are designed to enhance the development of 21st century expertise in students from each of the undergraduate degrees[12-14].

Chemical, environmental, and food engineering students have in these “pillar” courses a great opportunity for a multidisciplinary collaborative experience. The “pillar” courses of these new curricula are:

- Introduction to Chemical, Food, and Environmental Engineering Design
    - 2nd semester course for CE, FE, and EE
        - Cornerstone course
- Material Balances
    - 2nd semester course for CE, FE, and EE
- Energy Balances and Thermophysical Properties Laboratory
    - 3rd semester course and corresponding lab for CE, FE, and EE
- Modeling and Simulation in Chemical, Food, and Environmental Engineering
    - 5th semester course for CE, FE, and EE
- Statistical Control of Products and Processes
    - 6th semester course for CE, FE, and EE
- Quality Assurance
    - 7th semester course for CE, FE, and EE
- Chemical Plant Design (CE), Design of Equipment for Environmental Control (EE), or Design and Development of Food Products and Processes (FE)
    - 8th semester courses.
        - Capstone course

Using the *Framework for 21st Century Learning*[12], and Guidelines from Research on *How People Learn*[15, 16] UDLAP defined the standards for chemical, environmental, and food engineering 21st century expertise; created formative and summative assessments to evaluate student attainment of 21st century expertise; designed instruction activities that promote 21st century expertise; developed professional development opportunities for instructors of the “pillar” courses; and generated corresponding learning environments that promote 21st century expertise[12-14].

Standards for chemical, environmental, and food engineering 21st century expertise include: Core Engineering Subjects (as proposed by NAE[7, 8], ABET[17], and IFT[18] in the US, as well as ANFEI[5, 6] in Mexico) and 21st Century Themes (such as global awareness, financial, economic, business and entrepreneurial literacy, civic literacy, health literacy, and environmental literacy), Learning and Innovation Skills (such as creativity and innovation, critical thinking and problem solving, and communication and collaboration), Information, Media and Technology Skills (such as information literacy, media literacy, and information, communications and technology literacy), and Life and Career Skills (such as flexibility and adaptability, initiative and self-direction, social and cross-cultural skills, productivity and accountability, leadership and responsibility) as proposed by the Partnership for 21st Century Skills[12-14].

Critical thinking

Everyone thinks; it is our nature to do so. But much of our thinking, left to itself, is biased, distorted, partial, uninformed or downright prejudiced. Yet the quality of our life and that of what we produce, make, or build depends precisely on the quality of our thought. Shoddy thinking is costly, both in money and in quality of life. Excellence in thought, however, must be systematically cultivated[1, 4].

Critical thinking is the art of analyzing and evaluating thinking with a view to improving it[1]. According to Elder and Paul[2] whenever we think, we think for a purpose within a point of view based on assumptions leading to implications and consequences. Thus, a well-cultivated critical thinker[1, 2]:

a) Raises vital questions and problems, formulating them clearly and precisely
b) Gathers and assesses relevant information, using abstract ideas to interpret it effectively
c) Comes to well-reasoned conclusions and solutions, testing them against relevant criteria and standards
d) Thinks open-mindedly within alternative systems of thought, recognizing and assessing, as need be, their assumptions, implications, and practical consequences
e) Communicates effectively with others in figuring out solutions to complex problems.

Figure 1 shows how critical thinkers routinely apply the intellectual standards to the elements of reasoning in order to develop intellectual traits[1].

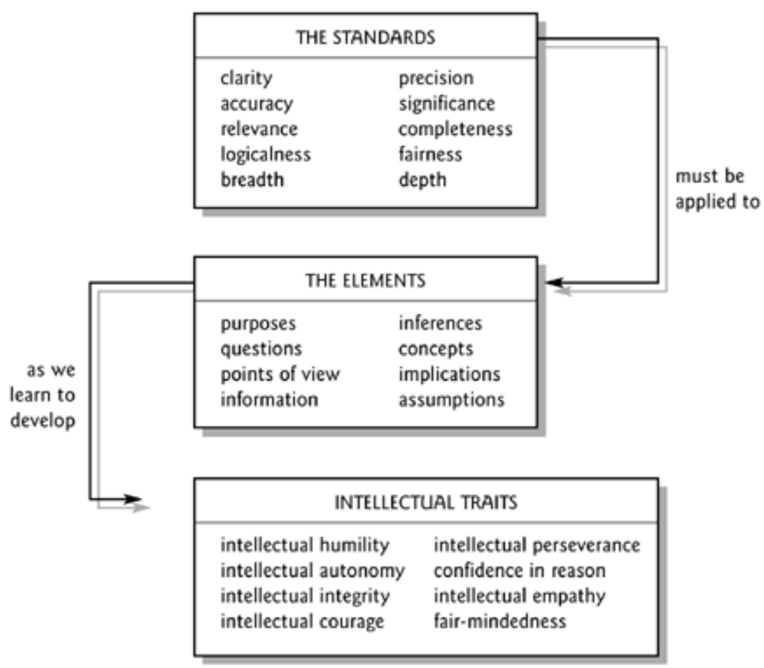

Figure 1. Paul and Elder[1] Critical Thinking Model

Our ability to be fair-minded is the result of cognitive and socio-emotional development. We must all recognize that to be fair-minded we must develop traits such as intellectual humility, intellectual integrity, intellectual courage, intellectual autonomy, intellectual empathy, intellectual perseverance, and confidence in reason[1, 2]. Fair-mindedness requires:

a. *Intellectual humility*: to develop knowledge of the extent of one's ignorance, being aware of one's biases and prejudices as well as the limitations of one's viewpoint, and it recognizes that one should not claim more than one actually knows.
    - What do you do when you are challenged on something you think you know?
    - Can you name some of your false beliefs, illusions, prejudices, myths and misconceptions?

b. *Intellectual Courage*: facing and fairly addressing ideas, beliefs or viewpoints even when this is painful, recognizing that ideas that society considers dangerous or absurd are sometimes rationally justified or simply a matter of subjective taste. To determine what makes sense to believe, one must not passively and uncritically accept what one has learned.
    - Have you ever questioned your beliefs and then questioned your identity?
    - Have you ever held to certain beliefs because of the fear of rejection?

c. *Intellectual empathy*: to put oneself imaginatively in the place of others on a routine basis, so as to genuinely understand them. It requires one to reconstruct the viewpoints and reasoning of others accurately and to reason from premises, assumptions, and ideas other than one's own.
    - What's it like to have a disability?
    - What's it like to be male/female/gay/lawyer/priest…?

d. *Intellectual integrity*: to be true to one's own disciplined thinking and holding oneself to the same standards that one expects others to meet. It means practicing daily what one advocates for others (walking the walk).
    - Have you ever experienced cognitive dissonance? This is believing one thing and doing another.

e. *Intellectual perseverance*: the disposition to work one's way through intellectual complexities despite frustrations inherent in the task. Some problems are complicated and cannot be solved easily (tolerate uncertainty).
    - Have you ever tried to understand something or someone and given up, or been invited to give up?

f. *Confidence in reason*: based on the belief that one's own higher interests and those of humankind at large are best served by giving the freest play to reason, by encouraging people to come to their own conclusions through the use of their own rational faculties. People can learn to think for themselves, form insightful viewpoints, draw reasonable conclusions, think clearly, accurately, relevantly and logically and persuade each other by appeal to good reason and sound evidence.

- Have you ever said "oh, you just don't understand and never will…"?

g. *Intellectual autonomy*: thinking for oneself while adhering to standards of rationality, thinking through issues using one's own thinking rather than uncritically accepting the viewpoints of others. Independent thinkers are not willful, stubborn, or unresponsive to the reasonable suggestions of others.
   - Have you ever conformed to a belief that you later came to reject?
   - Have you ever been rejected by your independent beliefs?

As can be seen in Figure 1, for thinking to be of high quality, we must routinely assess it by applying intellectual standards to our thinking[1, 2]:

- Focusing on clarity in thinking. Can I state it precisely?
- Focusing on precision in thinking. Am I providing enough details?
- Focusing on accuracy in thinking. Am I certain that the information I am using is accurate?
- Focusing on relevance in thinking. How does my point bear on the issue at hand?
- Focusing on logicalness in thinking. Given the information I have gathered, what is the most logical conclusion?
- Focusing on breadth in thinking. I wonder whether I need to consider another viewpoint(s)?
- Focusing on depth in thinking. What complexities are inherent in this issue?
- Focusing on justification in thinking. Is the purpose justified or is it unfair, self-contradictory, or self-defeating given the facts*?*

Context

Introduction to Chemical, Food, and Environmental Engineering Design is a 3 credit required course for CE, FE, and EE. Course content and classroom activities are divided into two, 75-minute sessions (Concepts, and Laboratory) per week. Students have three different facilitators (an instructor and two teaching assistants).

Course main goal is to introduce students to the Engineering Method, this is accomplished by focusing on six course objectives: self-regulation, communication, working cooperatively and collaboratively, problem solving, modeling, and quality. *Introduction to Chemical, Food, and Environmental Engineering Design* uses active, collaborative and cooperative learning techniques; course structure is displayed in Figure 2.

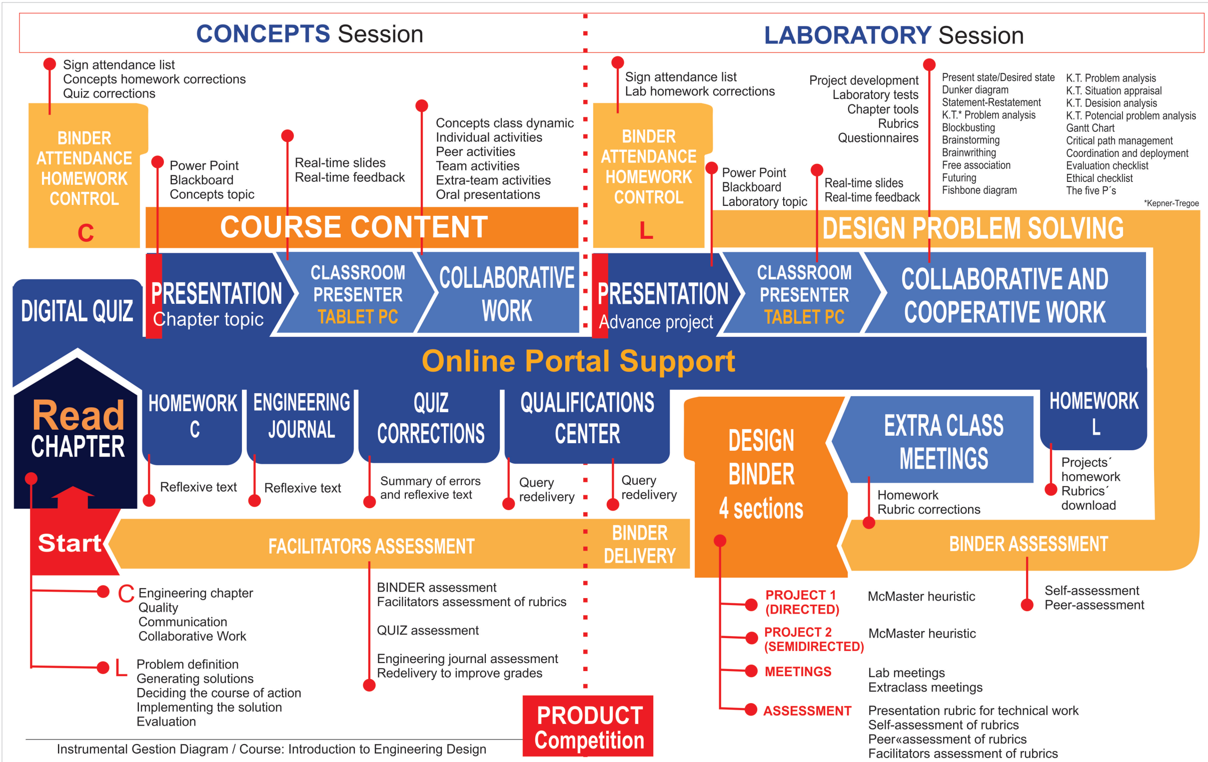

Figure 2. *Introduction to Chemical, Food, and Environmental Engineering Design* course structure

“Concepts” introduce students to the engineering design process, problem-solving techniques, working in teams, engineering as a profession, and planning for success that students then apply in “Laboratory” on two actual design projects. Students were organized into multidisciplinary teams of three to four members; the group had a total of thirty-eight students (15 male).

The “Concepts” section uses quizzes given in nearly every session to ascertain whether students have understood the material in their pre-class reading assignments. In addition, we encourage students to write brief reflective journal entries to further solidify and reinforce their own understanding, as well as demonstrate that improved understanding for an improved quiz grade. *Universidad de las Américas Puebla*’s Chemical, Environmental, and Food engineering students have in the study course a great opportunity for a multidisciplinary collaborative experience.

It is important to note, that students were formally trained to think critically as needed in the various elements of the reasoning described in this paper in the first-semester required language (Spanish I in our case) course. Students were taking the second-semester required language course (Spanish II, in which they applied their previous semester knowledge and abilities to projects related to their specific disciplines) concurrently with the studied course.

Introduction to Chemical, Food, and Environmental Engineering Design **two major projects**

First project (thermodynamics and heat transfer): Save the Penguins

At the University of Virginia, Larry Richards and his colleagues have undertaken a major challenge to design, implement, test and distribute Engineering Teaching Kits (ETKs). In particular, the *Save the Penguins* ETK is a design-based science curriculum, in which students are challenged to create a dwelling that reduces heat transfer in order to keep a penguin-shaped ice cube from melting.[19] This curriculum was originally developed by engineering students and faculty at the University of Virginia as part of the *Virginia Middle School Engineering Education Initiative*, but was subsequently revised and re-written by Schnittka[6] after pilot testing.

The *Save the Penguins* ETK is designed to address student alternative conceptions about heat, heat transfer, and temperature, increase student interest in science, and give students the opportunity to learn more about engineering through the engineering design process. The *Save the Penguins* ETK is described in detail elsewhere.[19, 20]

In our case, the entire ETK took six class blocks to complete. In brief, it began with the teacher performing some engaging demonstrations about heat transfer. In these demonstrations, the teacher modeled the experimental methods as the "more knowledgeable other," and students were shown how to undertake these methods on their own in teams.[19] The teacher then elicited discussions and reflections on the discrepant events students witness as s/he and the students "talked science." The teacher described how experiments are conducted with controls and a variable, and got students to identify the independent and dependent variables and the controls. The teacher introduced the concept of heat by first finding out what students thought about it. Then presented the concepts of conduction, convection, and radiation, and performed additional demonstrations illustrating the three methods of heat transfer.[21] These demonstrations are designed to provide discrepant events, challenging students' conceptions of heat transfer. The seven demonstrations are designed to consume one class period out of the six class periods. Students were then presented with the design challenge: to build a structure that will keep a penguin-shaped ice cube from melting.

They were given several materials (with different costs), and instructed to perform experiments to test these different materials before using them, designing, and building the dwelling for their ice penguin. Students worked in teams of 3 or 4 students each to test materials, design the dwelling, test the dwelling, and create a design binder explicating their progress, design decisions, materials used, and final design. Teams tested their first iteration of the design and shared their results, their conception of what worked well and what did not, with the class. Students used the ideas and suggestions from their peers to re-design their structure with the goal of improving its performance. They had multiple opportunities to construct, test, and revise their work. The team that constructed the dwelling of lesser cost that kept the most of the ice penguin mass won the competition.

Students learned about heat, temperature, controls and variables in experimental methodology, insulators and conductors, and other material properties as they assembled the dwelling for their penguin ice cube.[19] The final design challenge (competition) took place on the sixth and last day of the unit. After having the opportunity to redesign their dwelling, each team again started with a 10 g ice penguin. After 20 minutes in the test, students once again removed their ice penguin and found the mass of their remaining ice. They then finalized the design binder they have been working on, so that it completely described the design process for the entire activity. The class as a whole discussed how they think certain materials may have contributed to or hindered heat transfer, how much ice melted during the two challenges, and how modifications to their design may have affected the final outcomes. The class discussed why some designs were more successful than others in preventing heat transfer.

Second project (packaging design and strength of materials): Potato Chip Challenge

The Potato Chip Challenge[22] from Wondergy is an engineering challenge that has students designing a package to protect a potato chip being sent through the mail. In order to win, the crunchy snack food must arrive at its destination intact and undamaged. Single regular-type potato chips are mailed by teams that create a potato chip package for mailing. Another team receives the chip and scores their received chip based on standard criteria. In our case, instead of mailing the package, it was subjected to three standard tests for food packaging. The *Potato Chip Challenge* is described in detail elsewhere.[22, 23]

No substance could be applied to the chip, or the chip altered in any way. The chip had to be recoverable and edible (though they weren't eaten) when received by the evaluating team. Students worked in teams on the design, building and testing of this project package. No pre-made packages could be used (such as a Pringles can or a pre-molded plastic container). Packages were limited in size to 3″ x 5″. In our case, the entire Potato Chip Challenge took five class blocks to complete. The final design challenge (testing of packages with single chips) took place on the last day of the unit. They then finalized the design binder they have been working on, so that it completely described the design process for the entire activity. The team that constructed the packaging of smallest mass that kept the chip most intact won the competition.

Critical thinking assessment

Critical thinking assessment was grounded on the *Consensual Assessment Technique*[24], which is based on the idea that the best measure of critical thinking regardless of what is being evaluated, is the assessment by experts in that field.

Course two major projects were presented to a group of twenty experts in the field (chemical, food, and environmental engineering professors that teach engineering design capstone courses and alumni with such expertise) that assessed students' critical thinking by means of a specialized rubric[3] (Appendix A). Possible performance levels were from *exemplary* (value of 4, skilled, marked by excellence in clarity, accuracy, precision, relevance, depth, breadth, logicality, and fairness) to *unsatisfactory* (value of 1, unskilled and insufficient, marked by imprecision, lack of clarity, superficiality, illogicality, inaccuracy, and unfairness).

Instructor, peer-, and self-assessments were also performed throughout the course on several assignments (formative) as well as on two major projects (summative).

Results and discussion

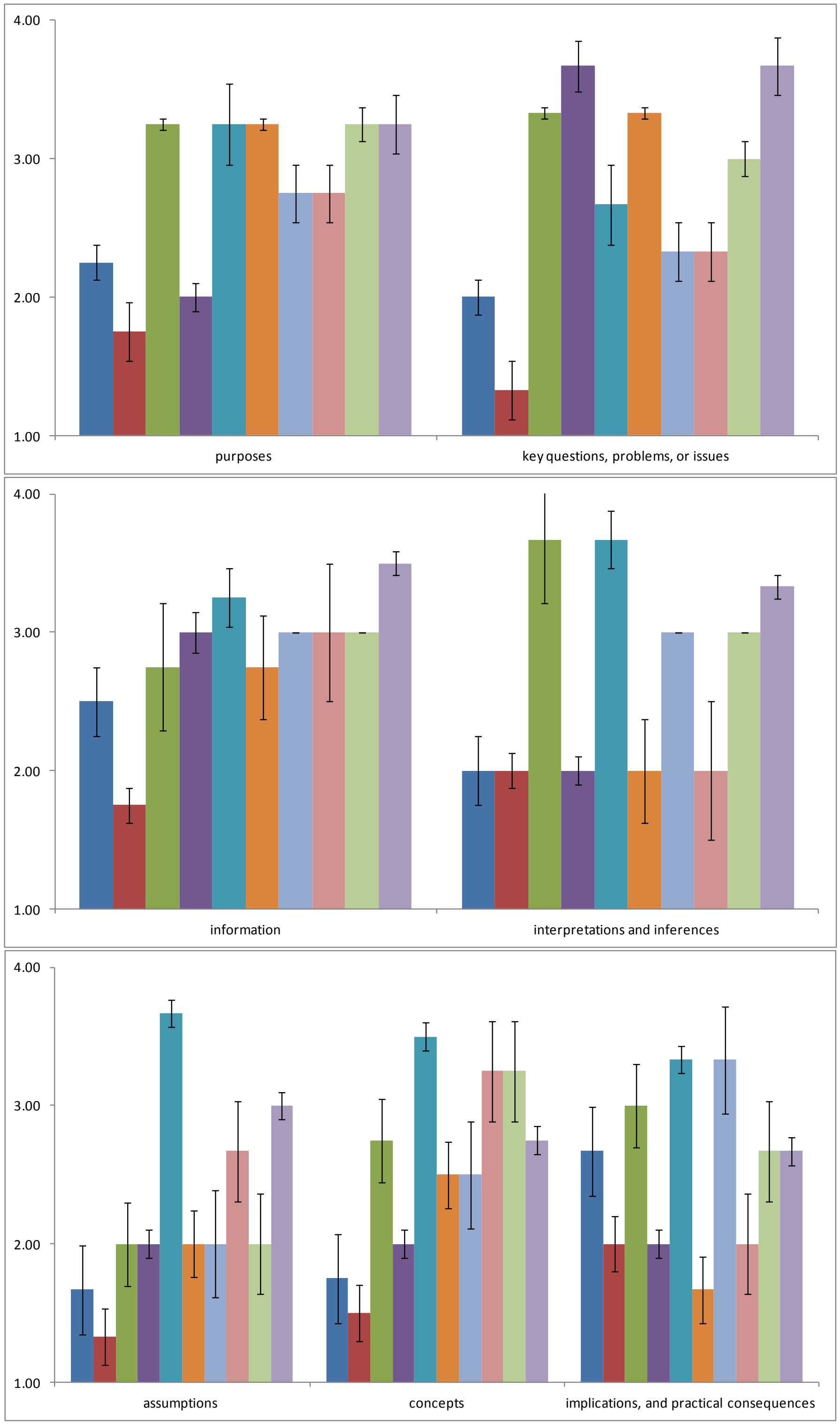

Figure 3. Critical thinking specific team (each bar represents a different team) average scores and standard deviations (error bars) assessed by means of the *Critical Thinking Grid*[3].
Performance level from *exemplary*: 4 to *unsatisfactory*: 1.

Critical thinking assessment results for the ten team projects (average of both projects) are presented in Figure 3. It can be observed that the evaluated aspects differ between teams, and also some teams performed better in some aspects than in others and vice-versa. The majority of the teams were evaluated above a value of 2 in most aspects. Team 2 (red bars in Figure 3) is a special case, where the team did not work appropriately and it's clearly reflected in the obtained scores.

Mean values from *Critical Thinking Grid*[3] assessment of two major projects were 2.78 ± 0.58 for *purposes* (meaning that in average, students demonstrated an understanding of the assignment's purpose), 2.77 ± 0.77 for *key questions, problems, or issues* (students defined the issue; identified the core issues, but may not fully explored their depth and breadth), 2.85 ± 0.47 for *information* (students gathered sufficient, credible, and relevant information, included some information from opposing views, and distinguish between information and inferences drawn from it), 2.67 ± 0.74 for *interpretations and inferences* (students followed some evidence to conclusions, but inferences are more often than not unclear, illogical, inconsistent, and/or superficial), 2.23 ± 0.69 for *assumptions* (students are failing to identify assumptions, or failing to explain them, or the assumptions identified are irrelevant, not clearly stated, and/or invalid), 2.58 ± 0.67 for *concepts* (students identified some key concepts, but use of concepts was superficial and inaccurate at times), 2.53 ± 0.59 for *implications, and practical consequences* (meaning that in average, students are having trouble identifying significant implications and consequences and/or identifying improbable implications).

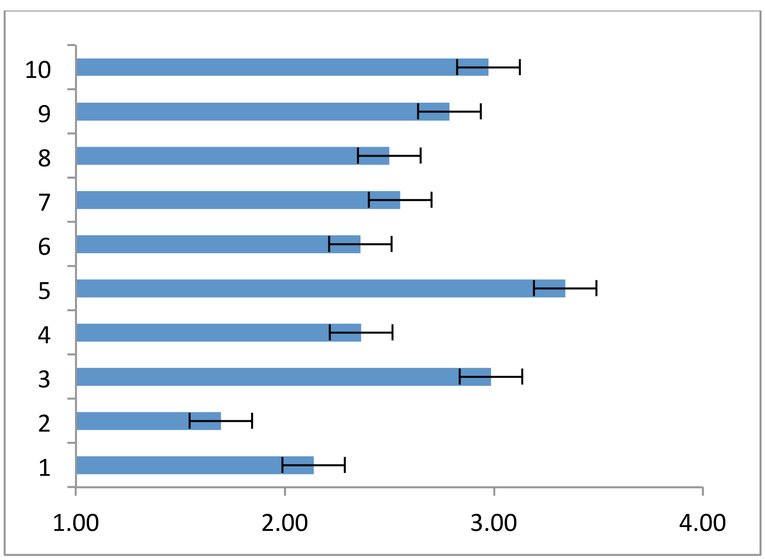

Figure 4. Critical thinking team (each bar represents a different team) average scores and standard deviations (error bars) assessed by means of the *Critical Thinking Grid*[3].
Performance level from *exemplary*: 4 to *unsatisfactory*: 1.

The vast majority of students attained projects' expected critical thinking outcomes between the level of competent, effective, accurate and clear, but lacks the exemplary depth, precision, and insight, and the level of inconsistent, ineffective thinking; showing a lack of consistent competence: often unclear, imprecise, inaccurate, and superficial (Figure 4). Therefore, it is suggested to further integrate critical thinking in subsequent courses in order to foster its meaningful development in Chemical, Food, and Environmental Engineering students[4].

Future Actions

The results achieved by students in the course *Introduction to Chemical, Food, and Environmental Engineering Design* demonstrate that critical thinking assessment is not an easy task, but the applied rubric allowed us to evaluate not only the final product (summatively on two studied projects) of a design process, but several important aspects of critical thinking processes (formatively during the semester) during the studied design processes. We are assessing how improving critical thinking skills in the studied course is impacting student performance in subsequent "pillar" courses.

Assessed rubrics allowed the identification of several opportunity areas to improve the studied engineering cornerstone course while identifying the advantages and disadvantages of selected course pedagogical interventions. Next course offering is nowadays in place, and several changes were implemented as a result of detecting these opportunity areas. Thus, we are gathering additional data on how these course modifications improve (or not) student critical thinking performance.

Another group of future actions that are important to point out are related to the need of setting the stage for faculty development programs targeted at improving critical thinking pedagogy within engineering classrooms. We also need to promote the importance of developing and assessing critical thinking in several engineering courses at our programs, so that the studied cornerstone course will neither be the first nor the last course in which students further learn and practice their critical thinking skills. Students need to be knowledgeable, learn and adapt to think critically as needed in the various elements of the reasoning described in this paper before being successful with them. We cannot expect students to be critical thinkers the very first time they encounter this approach in an engineering course. Thus we are planning to continue fostering the development of critical thinking in the subsequent five "pillar" courses of our programs.

Acknowledgments

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Appendix A
Critical Thinking Grid*

	4 - Exemplary If applicable, consistently does all or almost all of the following	**3 - Satisfactory** If applicable, consistently does most or many of the following	**2- Below Satisfactory** If applicable, consistently does most or many of the following	**1 - Unsatisfactory** If applicable, consistently does all or almost all of the following
Purpose	--Demonstrates a clear understanding of the assignment's purpose	--Demonstrates an understanding of the assignment's purpose	--Is not completely clear about the purpose of the assignment	--Does not clearly understand the purpose of the assignment
Key Question, Problem, or Issue	--Clearly defines the issue or problem; accurately identifies the core issues --Appreciates depth and breadth of problem --Demonstrates fair-mindedness toward problem	--Defines the issue; identifies the core issues, but may not fully explore their depth and breadth --Demonstrates fair-mindedness	--Defines the issue, but poorly (superficially, narrowly); may overlook some core issues --Has trouble maintaining a fair-minded approach toward the problem	--Fails to clearly define the issue or problem; does not recognize the core issues --Fails to maintain a fair-minded approach toward the problem
Point of View	--Identifies and evaluates relevant significant points of view --Is empathetic, fair in examining all relevant points of view	--Identifies and evaluates relevant points of view --Is fair in examining those views	--May identify other points of view but struggles with maintaining fair-mindedness; may focus on irrelevant or insignificant points of view	--Ignores or superficially evaluates alternate points of view --Cannot separate own vested interests and feelings when evaluating other points of view
Information	--Gathers sufficient, credible, relevant information: observations, statements, logic, data, facts, questions, graphs, themes, assertions, descriptions, etc. --Includes information that opposes as well as supports the argued position --Distinguishes between information and inferences drawn from that information	--Gathers sufficient, credible, and relevant information --Includes some information from opposing views --Distinguishes between information and inferences drawn from it	--Gathers some credible information, but not enough; some information may be irrelevant --Omits significant information, including some strong counter-arguments --Sometimes confuses information and the inferences drawn from it	--Relies on insufficient, irrelevant, or unreliable information --Fails to identify or hastily dismisses strong, relevant counter-arguments --Confuses information and inferences drawn from that information
Concepts	--Identifies and accurately explains/uses the relevant key concepts	--Identifies and accurately explains and uses the key concepts, but not with the depth and precision of a "4"	--Identifies some (not all) key concepts, but use of concepts is superficial and inaccurate at times	--Misunderstands key concepts or ignores relevant key concepts altogether
Assumptions	--Accurately identifies assumptions (things taken for granted) --Makes assumptions that are consistent, reasonable, valid	--Identifies assumptions --Makes valid assumptions	--Fails to identify assumptions, or fails to explain them, or the assumptions identified are irrelevant, not clearly stated, and/or invalid	--Fails to identify assumptions --Makes invalid assumptions
Interpretations, Inferences	--Follows where evidence and reason lead in order to obtain defensible, thoughtful, logical conclusions or solutions --Makes deep rather than	--Follows where evidence and reason lead to obtain justifiable, logical conclusions --Makes valid	--Does follow some evidence to conclusions, but inferences are more often than not unclear, illogical, inconsistent,	--Uses superficial, simplistic, or irrelevant reasons and unjustifiable claims --Makes illogical, inconsistent inferences

	superficial inferences --Makes inferences that are consistent with one another	inferences, but not with the same depth and as a "4"	and/or superficial	--Exhibits closed-mindedness or hostility to reason; regardless of the evidence, maintains or defends views based on self-interest
Implications, Consequences	--Identifies the most significant implications and consequences of the reasoning (whether positive and/or negative) --Distinguishes probable from improbable implications	--Identifies significant implications and consequences and distinguishes probable from improbable implications, but not with the same insight and precision as a "4"	--Has trouble identifying significant implications and consequences; identifies improbable implications	--Ignores significant implications and consequences of reasoning

4 = Thinking is exemplary, skilled, marked by excellence in clarity, accuracy, precision, relevance, depth, breadth, logicality, and fairness
3 = Thinking is competent, effective, accurate and clear, but lacks the exemplary depth, precision, and insight of a 4
2 = Thinking is inconsistent, ineffective; shows a lack of consistent competence: is often unclear, imprecise, inaccurate, and superficial
1 = Thinking is unskilled and insufficient, marked by imprecision, lack of clarity, superficiality, illogicality, and inaccuracy, and unfairness

* Foundation for Critical Thinking. 2013. *Critical Thinking Grid*. Tomales, CA: Foundation for Critical Thinking Press.[3]

Critical Thinking Worksheet*

Overall Score ________

If applicable, score the element (1-4)	Element of Reasoning	Comments
	Purpose: Does the student demonstrate a clear understanding of the assignment's purpose?	
	Key Question, Problem, or Issue: Does the student clearly define the issue or problem, accurately identify the core issues, and appreciate their depth and breadth?	
	Point of View: Does the student identify and evaluate relevant significant points of view? Does the student demonstrate fair-mindedness toward the problem?	
	Information: Does the student gather sufficient, credible, relevant information (statements, logic, data, facts, questions, graphs, assertions, observations, etc.)? Does the student include information that opposes as well as supports the argued position? Does the student distinguish between information and inferences drawn from that information?	
	Concepts: Does the student identify and accurately explain/use the relevant key concepts?	
	Assumptions: Does the student accurately identify assumptions (things taken for granted)? Does the student make assumptions that are consistent, reasonable, and valid?	
	Interpretations, Inferences: Does the student follow where evidence and reason lead in order to obtain defensible, thoughtful, logical conclusions or solutions? Does the student make deep (rather than superficial) inferences? Are the inferences consistent?	
	Implications, Consequences: Does the student identify the most significant implications and consequences? Does the student distinguish probable from improbable implications?	

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