Food Engineering Students' Creative Experiences in a Capstone Course

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Food Engineering Students' Creative Experiences in a Capstone Course

Abstract

This paper describes several creative experiences (and corresponding assessments) in a Food Product Development capstone course for Food Engineering students at *Universidad de las Américas Puebla* (UDLAP). This course was designed in order for them to experience a real work environment, where they have the opportunity to think and act as experts in the field do, and included several problem-solving learning environments (PSLEs)[1]. Course main goal is that students design and develop a new food product involving idea generation, formulation, process selection, nutritional facts and label, shelf-life estimation, costs, sensory evaluation, among many others aspects of its development. Students were organized into teams of two members; the group had a total of eight students (3 male). Course activities were designed for student teams to work independently in the required labs depending on their product selection; however, several course sessions and meetings with the course instructor were planned in order to promote creativity including lessons and selected exercises that provided a number of techniques to help them generate innovative solutions to the correctly defined problem. These techniques include brainstorming, vertical and lateral thinking, analogies, TRIZ (Russian acronym for *Resheniya Teoriya Izobretatelskikh Zadach*, that translated literally is "theory of the resolution of invention-related tasks"), and SCAMPER (acronym for Substitute, Combine, Adapt, Modify, Put to another use, Eliminate, and Reverse) [2].

In this context, a creativity test at the beginning and end of the semester was applied. The test is a self-assessment that consists of 16 questions that are grouped into 5 categories of analysis that are related to the five steps that are part of the effective creative process proposed by Csikszentmihalyi[3]: 1) Finding problems (preparation), 2) Gathering and reflecting on information (incubation), 3) Problem exploration (insight), 4) Generating and evaluating ideas (evaluation), and 5) Implementation (elaboration). Furthermore, a group of experts in the field were invited to evaluate final projects and developed food products by means of the *Creative Thinking VALUE Rubric*, which is made up of a set of attributes that are common to creative thinking across disciplines[4]. Instructor-, peer-, and self-assessments were also performed throughout the course and on final project. Additionally, a *Specific Course Rubric* that included technical aspects regarding food product development as well as abilities of the team to present their product and answering questions raised during oral and poster presentations as well as during tasting of developed food products was utilized[5].

An increase in the scores for every category of the creativity test[3] applied at the beginning and end of the semester was observed. However, according to Csikszentmihalyi an effective creative process should follow the five steps in the mentioned order[3]. Students' results followed a

different order; performed analysis reflected a creative thinking process that resembles the engineering method[6]. *Creative Thinking VALUE Rubric* mean results (out of 4) for final projects and presentations were 2.58 for *Acquiring Competencies*, 2.38 for *Taking Risks*, 2.54 for *Solving Problems*, 2.83 for *Embracing Contradictions*, 2.46 for *Innovative Thinking*, and 2.67 for *Connecting, Synthesizing, and Transforming*. Regarding the *Specific Course Rubric* three out of four teams' projects received scores higher than 2.8, which correspond also to an *intermediate level* performance.

At last, in order to identify the students' perceptions with regards to the course and in particular to studied creative experiences a final survey was carried out. Students considered that studied course's learning outcomes are very important and felt very confident with their progress in achieving each assessed course outcome. Every student believed that this course helped them make the transition from being a student to being a food engineer, as well as allowed them to make mistakes and learn from these. Additionally, students expressed pride regarding their achievements.

Introduction

Food Engineering is the discipline in which the engineering, chemical, biological, and physical sciences are utilized to study the nature of foods, their causes of deterioration, the principles on which can perform their processing, machinery design and industrial plant processing, packaging and distribution, in order to ensure the manufacture of safe, nutritious, and healthy foods. Thus, the main task of a food engineer is to design and operate processes to transform raw materials into final products, particularly with the aim to control, prevent, or delay spoilage caused by chemical reactions, physical effects, and/or biological activity[7]. Food engineering students from *Universidad de las Américas Puebla* (UDLAP) apply their knowledge and skills required to function in the different fields of food engineering at the capstone course entitled *Design and Development of Food Products and Processes*. A food-engineering student must have a solid grounding in the disciplinary strategies and domain skills in order to make connections and synthesize in the development of an original food product throughout the course. On the other hand, a creative thinker while demonstrating a solid knowledge of the parameters of the domain in the highest levels of performance, pushes him or herself beyond those limits by means of new, unique or atypical combinations; discovering or critically perceiving new synthesis, and using or recognizing risk taking to achieve a creative solution.

Creativity is the ability to innovatively create and think creatively, consequently, ensues the development of new ideas and concepts. It is the ability to form new combinations of ideas to fill a need. Therefore, the result or product of creative thinking tends to be original. Creative thinking can be understood as the acquisition of knowledge in a particular mode of cognitive approach that has characteristics of originality, flexibility, plasticity and fluidity, and works as a strategy or cognitive tool in the design, building and solving problematic situations in a particular learning context, resulting in the appropriation of knowledge. Thus, creative thinking can only be expressed productively within a particular domain[4]. Creative thinking includes the capacity to combine or synthesize existing ideas, images, or expertise in original ways and the experience of thinking, reacting, and working in an imaginative way characterized by a high degree of innovation, divergent thinking, and risk taking[4, 5]. Creativity, developed in a social, cultural and contextual insight, is not only an internal process as conceived in 1950 by Guilford[8] whom included fluency, flexibility, elaboration, originality, and redefinition; but a multidimensional construct mediated by various factors. In the investment theory (Sternberg and Lubart[9, 10]), creativity requires a confluence of six distinct but interrelated resources (Table 1): intellectual abilities, knowledge, styles of thinking, personality, motivation, and environment.

Table 1. Resources for creativity from the investment theory[9, 10]

Intellectual skills	Three intellectual skills are particularly important: (a) the synthetic skill to see problems in new ways and to escape the bounds of conventional thinking, (b) the analytic skill to recognize which of one's ideas are worth pursuing and which are not, and (c) the practical–contextual skill to know how to persuade others of (to sell other people on) the value of one's ideas. The confluence of these three skills is very important.
Knowledge	One needs to know enough about a field to move it forward. One cannot move beyond where a field is if one does not know where it is. On the other hand, knowledge about a field can result in a closed and entrenched perspective, resulting in a person's not moving beyond the way in which he or she has seen problems in the past. Knowledge thus can help, or it can hinder creativity.
Thinking styles	Thinking styles are preferred ways of using one's skills. In essence, they are decisions about how to deploy the skills available to a person. With regard to thinking styles, a legislative style is particularly important for creativity, that is, a preference for thinking and a decision to think in new ways. It also helps to become a major creative thinker, if one is able to think globally as well as locally, distinguishing the forest from the trees and thereby recognizing which questions are important and which ones are not.
Motivation	Intrinsic, task-focused motivation is also essential to creativity. The research of Amabile[11-13] and others has shown the importance of such motivation for creative work and has suggested that people rarely do truly creative work in an area unless they really love what they are doing and focus on the work rather than the potential rewards.
Personality	The importance of certain personality attributes for creative functioning. These attributes include, but are not limited to, willingness to overcome obstacles, willingness to take sensible risks, willingness to tolerate ambiguity, and self-efficacy. Often creative people seek opposition; that is, they decide to think in ways that countervail how others think. Note that none of the attributes of creative thinking is fixed. One can decide to overcome obstacles, take sensible risks, and so forth.
Environment	One needs an environment that is supportive and rewarding of creative ideas. One could have all of the internal resources needed to think creatively, but without some environmental support (such as a forum for proposing those ideas), the creativity that a person has within him or her might never be displayed.

Although levels of resources shown in Table 1 are sources of individual differences, often the decision to use a resource is a more important source of individual differences. Creativity involves the application of these six resources to specific tasks. Sternberg and Lubart[9, 10] claim that when combined interactively, they can stimulate creativity beyond their individual limits.

Course learning outcomes include that students will be able to: a) Identify consumer and commercial factors that should be considered when designing a new product, b) Describe the product to be developed, c) Develop and evaluate potential product formulations, d) Propose the manufacturing process for the product to be developed, e) Choose the most suitable packaging for the product, f) Evaluate the shelf-life of the product, g) Locate and describe the laws applicable to the ingredients used to ensure the safety of the developed product, h) Develop a nutritional label for the product, h) Identify critical control points and limits of the proposed process, and i) Estimate operating costs and investment required to start the production line[5]. Consequently, at the end of the course students will be able to understand and apply the methodology for the design of food products and processes, integrating the knowledge acquired in previous courses regarding food science, technology, and engineering. They could implement procedures to obtain a high quality food product that could compete successfully on the market of processed foods, which will allow students to develop a new product and its corresponding processing, in order to demonstrate their learning.

The course learning environment is designed to present the problem, simulating the conditions in order for them to experience a real work environment, where students have the opportunity to think and act as experts in the field. Course topics and activities are divided into several categories (Table 2), being the first one "product design" that was enforced during several weeks (course sessions) incorporating selected creative tools and activities in order to generate an "original" idea. Students were organized into teams of two members; the group had a total of eight students (3 male). Course activities (Table 2) were carried out in a classroom during the first stage (product design) while the next three stages are designed for student teams to work independently in the required labs, depending on their product[4].

Product design

This stage focuses on the information sources and related complementary analogies. Students at this stage were sensitized to the problem, for which they were engaged by means of selected videos, text documents, as well as some support documents regarding techniques for creative and analytical performance. Decisions taken during the design process require analytical and creative thinking processes to synthesize. To strengthen the creative output of students, four sessions were performed to enhance the quantity and quality of ideas generated. The use of these techniques enhanced students' creative performance. Creativity techniques[2] that were presented in this course section are included in Table 3. These sessions and meetings with the course' instructor were planned in order to promote creativity and included lessons and selected exercises that provided a number of techniques to help students generate solutions (ideas) to the correctly defined problem (Phase 1). The applied tools and methods vary in their focus, specificity, and usability[17].

Table 2. Structure, course activities, and learning outcomes for the studied course *Design and Development of Food Products and Processes*

	Topics	*Expected course learning outcomes*
Product design	Research Problem insight Idea generation Feasibility Analysis Idea selection Prototypes production and evaluation	Identify consumer and commercial factors that should be considered when designing a new product Describe the product to be developed Develop and evaluate potential product formulations
Product description and evaluation	Sensory analysis Formulation Ingredients' functionality Shelf-life Packaging Cost Nutritional labeling	Choose the most suitable packaging for the product Evaluate the shelf-life of the product Develop a nutritional label for the product
Processing description and evaluation	Processing flow diagram Critical control points Processing limits Operation costs Financial Analysis	Propose the manufacturing process for the product to be developed Identify critical control points and limits of the proposed process Estimate operating costs and investment required to start the production line
Safety	Legislation – additives use Good manufacturing practices Use and safety for the consumer	Locate and describe the laws applicable to the ingredients used to ensure the safety of the developed product

Table 3. Creativity phases and techniques applied in the studied course *Design and Development of Food Products and Processes*

Creativity phases	Tools, techniques and methods applied
Phase 1. Idea generation	Prior unblocking exercise Classical Brainstorming Analog Brain-writing Vertical and lateral thinking Analogy TRIZ SCAMPER
Phase 2. Decision analysis	Dunker Diagram Kepner-Tregoe Decision Analysis
Phase 3. Feasibility analysis	Matrix Analysis that includes a plurality of grounds for discrimination was used to analyze the feasibility of the idea; this matrix was developed as a collaborative classroom activity, where every student was involved

Brainstorming is aimed at ideation starting (without any initial concepts), it provides general guidelines: suggest as many ideas as possible, do not evaluate while generating them, and build off of others' ideas. SCAMPER offers more specific guidelines (Substitute, Combine, Adapt, Modify, Put to another use, Eliminate, and Reverse) and was useful after a two sessions of brainstorming and brain-writing. Later, TRIZ (according to five patterns that successfully were directed to new food product design and development: Subtraction, Multiplication, Division, Attribute Dependency, and Task Unification) was applied since it focuses on refinements of engineering and design mechanisms that start in the implementation phase of the design process[17]. This stage ended when the students had a clear idea of the product that they aspired to develop. In the next stage they began the process of preparing to turn this idea into a valuable, appropriate, and original product.

Description and evaluation of the product and processing

In these stages, teams were given required freedom, since the process was performed in the laboratories; they were free to use required tools and equipment while given full autonomy to start its development. Decisions taken during the design process required creative and analytical thinking, so the whole process was considered a creative act[18]. These stages facilitate the use of cognitive tools; students started with their product description, although this description will be modified during the design process. This description focused on the design and functionality of each of the ingredients that contains their product, its shelf-life, determined the cost and chose the right type of packaging for their product while initiated the development of product nutritional label.

Also, students continued with documentation of their processes, they made the processing flow chart for their developed product, identified critical control points, processing limits, and operating costs that were included in their reports. They already made their first prototype, and a first sensory evaluation test to evaluate their proposed food products was performed. During these stages, each team regularly met with the course' instructor in order to find possible solutions to the identified problems either during prototype development or sensory evaluation. The instructor only guided the team to further search for relevant information on new formulations, additives, equipment, etc.; with this new information and prototype, the team once again prepared samples for quality and sensory evaluation.

At the end of the course, students were encouraged to make alternate creative efforts, since they produced a visual image for their product, which included logo design, package label, audiovisual materials and a poster for formal presentation (a group of experts was invited to their final presentations), also integrated their final reports that included applicable laws of the use of product' ingredients, good manufacturing practices, use and safety for the consumer. Finally, they prepared final products for tasting as part of their final presentations.

Creativity assessment

A creativity test at the beginning and end of the semester was applied. The test is a self-assessment that consists of 16 questions that are grouped into 5 categories of analysis that are related to the five steps that are part of the effective creative process proposed by Csikszentmihalyi[5]: 1) Finding problems (preparation), 2) Gathering and reflecting on information (incubation), 3) Problem exploration (insight), 4) Generating and evaluating ideas (evaluation), and 5) Implementation (elaboration).

Creativity assessment was also based on the *Consensual Assessment Technique*[9] (CAT), which is constructed on the idea that the best measure of creativity regardless of what is being evaluated, is the assessment by experts in that field. Therefore, a group of twenty experts in *Food Science, Technology, and Engineering* fields were invited to evaluate capstone course final projects and developed food products by means of the *Creative Thinking VALUE Rubric*[4], which is made up of a set of attributes that are common to creative thinking across disciplines[4, 19] that can be appreciated in Appendix A. Possible performance levels were entitled *capstone* or *exemplar* (value of 4), *milestones* (values of 3 or 2), and *benchmark* (value of 1). Final presentations were performed in two steps, first audiovisual presentations of projects, then poster presentations and tasting of food products. Additionally, a *Specific Course Rubric* (Appendix B) that included technical aspects regarding food product development (four stages of the course) and its relation to the creative product characterization proposed by Sternberg and Lubart[10], as well as abilities of the team to present their product and answering questions raised during oral and poster presentations, and during tasting of developed food products. For this specific rubric, the scale varied from 1 (*novice*) to 4 (*expert*). Evaluators achieved 85 and 79 percent inter-rater reliability in using the *Creative Thinking VALUE Rubric*[4] and the *Specific Course Rubric*, respectively. Instructor-, peer-, and self-assessments were also performed throughout the course as well as on the final project. The experts in the field included chemical and food engineering professors that teach engineering design capstone courses and food engineering alumni with such expertise.

Results and discussion

Table 4 presents the results of creativity test applied at the beginning and end of the semester. In the evaluated categories, students performed better after the activities completed throughout the course. They expressed that felt more confident about the decisions they made during product idea generation and design. The initial scores (pre-test) were around 50 that correspond to "creativity is a *work in progress*". They need to share their ideas and perspectives, and embrace a collaborative approach (ask how others view and solve problems), and work more actively with others. After the course, students' scores were in average higher than 54 that means, "creativity is *strengthening*". Specifically, students gained experience for creating a plan to implement the solution, and following through (elaboration)[5]. These results imply that there is plenty room for improvement; therefore a lot of work to do in order to enhance students' achievement of course outcomes. However, students felt that the course gave them the opportunity to be creative, situation that did not happened in a lot of the courses they have taken throughout their undergraduate studies.

Table 4. Creativity test results at the beginning and end of the semester for the studied course *Design and Development of Food Products and Processes*

Categories	Maximum score	Pre-test average score	Post-test average score	Difference
Finding Problems (Preparation)	25	15.7	15.9	0.2
Gathering and Reflecting on Information (Incubation)	10	6.6	6.8	0.2
Problem Exploration (Insight)	15	11.2	12.3	1.1
Generating and Evaluating Ideas (Evaluation)	15	8.0	9.0	1.0
Implementation (Elaboration)	15	8.9	10.3	1.4
Total	80	50.3	54.3	4.0

Students' perceptions were captured in the applied final survey, they answers to the question: When technical and design issues are discussed with the instructor, he/her most often: 38% answered the instructor suggested options but did not try to influence my decisions, 50% the instructor helped you generate your own list of options, and 13% the instructor listened, you generated your options and made the decisions on your own. They answer to the question: Which of the following statements most accurately describes the learning environment in the course design? 38% the instructor defined overall goals, and we had to reach (achieve) them, and 62% we define our overall goals and we had to reach (achieve) them under the guidance of the instructor. Selected quotes when student were asked about their experiences regarding food product design, they express the following:

- *I have developed a prototype of a product that could be marketed, based on the knowledge learned in this course and other courses*
- *I have accomplished to have a product (physically) as was imagined and with good flavor. It was not only in the imagination, we could do it*
- *We could work together. It was our responsibility to achieve the objectives of the class having to organize our time to do so. We apply different knowledge seen along the courses*
- *The product came out as we imagine it and it gave us the opportunity to innovate, even when there were errors*
- *Despite our product turned out to be what we initially thought, tried several things and tried various ingredients. I'm not so proud of not having tried a different technique*
- *The facts pose a product, its nutritional label, shelf life, etc. because it is part of the complement to be an engineer. Being able to handle formulations is also something that we as food engineers*
- *I am proud that despite problems continue with the project and generate a new product*

Figure 1 presents the average scores obtained by the four teams of students enrolled in the course regarding the *Specific Course Rubric*. Some teams performed better than others in selected aspects, probably due to the content and explanations given during presentations of their products. For the product design category, three out of four teams' projects received scores higher than 2.8, which correspond to an *intermediate* level performance. Product design category in the *Specific Course Rubric* evaluates the originality of the idea, and three teams obtained higher scores than in our previous report[5], since this work presents results from its second implementation in the studied course.

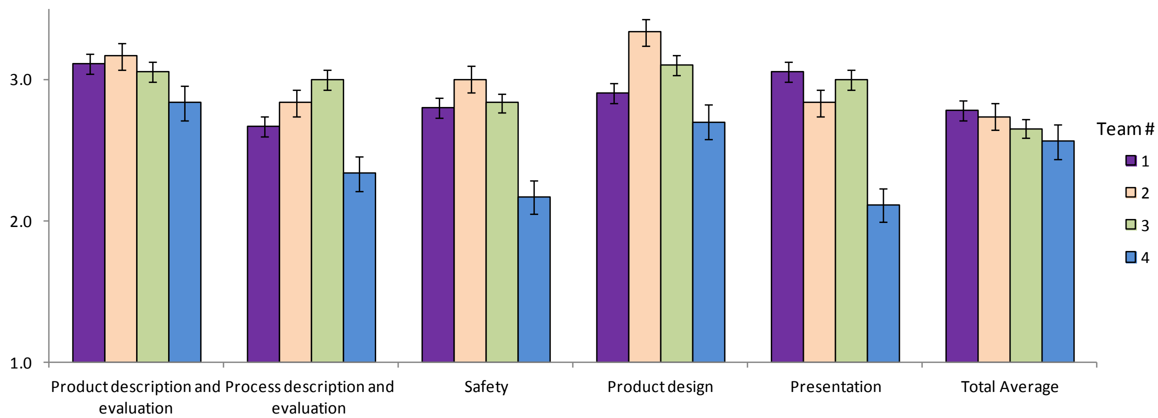

Figure 1. Team average scores and standard deviations (error bars) assessed by means of the *Specific Course Rubric,* (scale varies from 1: *novice* to 4: *expert*).

Figure 2 exhibits the average scores obtained by the four teams of students enrolled in the course regarding the *Creative Thinking VALUE Rubric*[4, 19]. Mean values from rubric assessment of final projects were 2.58 for *Acquiring Competencies* (attaining strategies and skills within a particular domain), 2.38 for *Taking Risks* (may include personal risk, fear of embarrassment or rejection, or risk of failure in successfully completing assignment, i.e. going beyond original parameters of assignment, introducing new materials and forms, tackling controversial topics, advocating unpopular ideas or solutions), 2.54 for *Solving Problems*, 2.83 for *Embracing Contradictions*, 2.46 for *Innovative Thinking* (novelty or uniqueness of idea, claim, question, form, etc.), and 2.67 for *Connecting*, *Synthesizing*, and *Transforming*. In general the average scores obtained were higher than those obtained in our previous report[5].

None of the invited experts believed that food products and corresponding presentations of team projects did not meet the minimal expectations. Students' creative thinking was at an intermediate level in both the capacity to combine or synthesize existing ideas or expertise in original ways and the experience of thinking, reacting, and working in an imaginative way.

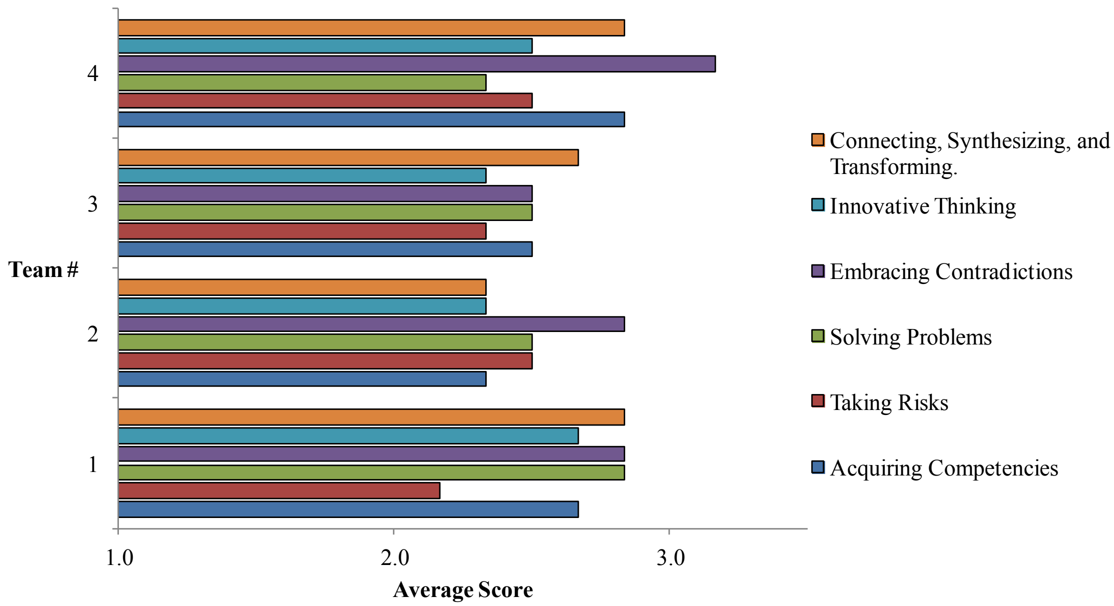

Figure 2. Team average scores assessed by means of the *Creative Thinking VALUE Rubric*[4, 19], (scale varies from *exemplar*: value of 4, *milestones*: values of 3 or 2, to *benchmark*: value of 1).

Finally, in order to identify the students' perception on the importance and the progress achieved by them for each studied course' learning outcome, an exit survey was carried out. Importance that students assigned to the course learning outcomes was assessed in a scale from 1: "none" to 5: "a lot", while the progress achieved by them regarding course learning outcomes was assessed in a scale from 1: "none" to 5: "a lot") according to their own perception. Students consider that studied course's learning outcomes are very important (mean of 4.93) and felt very confident with their progress in achieving assessed course outcomes (mean of 4.31).

Final remarks

Tested creative experiences and course final projects allowed enhancement of creativity in food engineering students; however, it is necessary to implement many more of such experiences throughout the curriculum because as expressed by the students they had little opportunities to make their creativity visible (for themselves, their peers, and instructors) and apply their creative thinking[20] in most of their food engineering previous courses. Our results demonstrate that creativity assessment is not an easy task, but the applied rubrics and tests allowed us to evaluate not only the final product of a creative process, but several important aspects during this creative process.

Assessed rubrics and tests allowed the identification of several opportunity areas to improve the studied food engineering capstone course. The activities performed during the course enhanced students' creative thinking, but other didactic interventions are needed to make the food product design and development processes more efficient, as well as to overall improve the creative experience for students in this capstone course in order to enhance student achievement of course learning outcomes.

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References

1. Jonassen, D. H. 2011. *Learning to Solve Problems: A Handbook for Designing Problem-Solving Learning Environments*. New York: Routledge.
2. Fogler, H. S., LeBlanc, S. E., and Rizzo, B. 2014. *Strategies for Creative Problem Solving*. 3rd ed. Upper Saddle River, NJ: Prentice Hall.
3. Csikszentmihalyi, M. 2015. *The Systems Model of Creativity: The Collected Works of Mihaly Csikszentmihalyi*. New York: Springer.
4. AACU. 2013. *Association of American Colleges and Universities (AACU) Value Rubrics*. Available (January 28, 2016) at: http://www.aacu.org/value/rubrics?CFID=27703138&CFTOKEN=51989935.
5. Husted, S., Ramirez-Corona, N., López-Malo, A., and Palou, E. 2014. Creativity and its assessment in a design and development of food products and processes course. *Proceedings of the 2014 American Society for Engineering Education Annual Conference and Exposition*, Indianapolis, IN, June 15-18. Available (January 28, 2016) at: https://peer.asee.org
6. Koen, B. V. 2003. *Discussion of the Method: Conducting the Engineer's Approach to Problem Solving*. New York: Oxford University Press.
7. Ramírez Apud, T., Gutierrez Cuba, J. V., Ramirez-Corona, N., López-Malo, A., and Palou, E. 2015. Arguing to solve food engineering problems. *Proceedings of the 2015 American Society for Engineering Education Annual Conference and Exposition*, Seattle, WA, June 14-17. Available (January 28, 2016) at: https://peer.asee.org
8. Guilford, J. P. 1950. Creativity. *American Psychologist*, 5: 444-454.
9. Amabile, T. M. 1982. Social Psychology of Creativity: A Consensual Assessment Technique, *Journal of Personality and Social Psychology*, 43(5): 997-1013.
10. Sternberg, R. and Lubart, T. 1997. *La Creatividad en una Cultura Conformista. Un Desafío a las Masas*. Madrid, Spain: Editorial Paidós.
11. Amabile, T. M. 1982. Social Psychology of Creativity: A Consensual Assessment Technique. *Journal of Personality and Social Psychology*, 43(5): 997-1013.
12. Amabile, T. M. 1983. *The Social Psychology of Creativity*. New York: Springer.

13. Amabile, T. M. 1993. Motivational Synergy: Toward new conceptualizations of intrinsic and extrinsic motivation in the workplace. *Human Resource Management Review*, 3:185-201.
14. Jonassen, D. H. 2000. *El Diseño de Entornos Constructivistas de Aprendizaje. In C. Reigeluth (Ed.), Diseño de la Instrucción. Teoría y Modelos*. Madrid, Spain: Santillana.
15. Jonassen, D. H. 2010. Assembling and Analyzing the Building Blocks of Problem-Based Learning Environments. In K. H. Silber and W. R. Foshay (Eds.), *Handbook of Improving Performance in the Workplace, Volume One: Instructional Design and Training Delivery*. Hoboken, NJ: John Wiley & Sons.
16. Jonassen, D. H. 2011. *Learning to Solve Problems: A Handbook for Designing Problem-Solving Learning Environments*. New York: Routledge.
17. Daly, S. R., Yilmaz, S., Christian, J. L., Seifert, C. M., & Gonzalez, R. 2012. Design heuristics in engineering concept generation. *Journal of Engineering Education*, 101(4), 601-629.
18. Guilford, J. P. 1956. The structure of intellect*.* *Psychological Bulletin*, 53: 267-293.
19. Rhodes, T. (Ed.). 2010. *Assessing Outcomes and Improving Achievement: Tips and Tools for Using Rubrics*. Washington, DC: Association of American Colleges and Universities.
20. Sternberg, R. J., Lubart, T. I., Kaufman, J. C. and Prelz, J. E. 2005. Creativity. In K. J. Holyoak and R. G. Morrison (Eds.) *The Cambridge Handbook of Thinking and Reasoning* (pp. 351-369). New York: Cambridge University Press.

Appendix A

CREATIVE THINKING VALUE RUBRIC*

for more information, please contact value@aacu.org

Association of American Colleges and Universities

The VALUE rubrics were developed by teams of faculty experts representing colleges and universities across the United States through a process that examined many existing campus rubrics and related documents for each learning outcome and incorporated additional feedback from faculty. The rubrics articulate fundamental criteria for each learning outcome, with performance descriptors demonstrating progressively more sophisticated levels of attainment. The rubrics are intended for institutional-level use in evaluating and discussing student learning, not for grading. The core expectations articulated in all 15 of the VALUE rubrics can and should be translated into the language of individual campuses, disciplines, and even courses. The utility of the VALUE rubrics is to position learning at all undergraduate levels within a basic framework of expectations such that evidence of learning can by shared nationally through a common dialog and understanding of student success.

Definition

Creative thinking is both the capacity to combine or synthesize existing ideas, images, or expertise in original ways and the experience of thinking, reacting, and working in an imaginative way characterized by a high degree of innovation, divergent thinking, and risk taking.

Framing Language

Creative thinking, as it is fostered within higher education, must be distinguished from less focused types of creativity such as, for example, the creativity exhibited by a small child's drawing, which stems not from an understanding of connections, but from an ignorance of boundaries. Creative thinking in higher education can only be expressed productively within a particular domain. The student must have a strong foundation in the strategies and skills of the domain in order to make connections and synthesize. While demonstrating solid knowledge of the domain's parameters, the creative thinker, at the highest levels of performance, pushes beyond those boundaries in new, unique, or atypical recombinations, uncovering or critically perceiving new syntheses and using or recognizing creative risk-taking to achieve a solution.

The Creative Thinking VALUE Rubric is intended to help faculty assess creative thinking in a broad range of transdisciplinary or interdisciplinary work samples or collections of work. The rubric is made up of a set of attributes that are common to creative thinking across disciplines. Examples of work samples or collections of work that could be assessed for creative thinking may include research papers, lab reports, musical compositions, a mathematical equation that solves a problem, a prototype design, a reflective piece about the final product of an assignment, or other academic works. The work samples or collections of work may be completed by an individual student or a group of students.

Glossary

The definitions that follow were developed to clarify terms and concepts used in this rubric only.

- Exemplar: A model or pattern to be copied or imitated (quoted from www.dictionary.reference.com/browse/exemplar).
- Domain: Field of study or activity and a sphere of knowledge and influence.

* AACU. 2013. Association of American Colleges and Universities (AACU) Value Rubrics. Available at: http://www.aacu.org/value/rubrics/index_p.cfm?CFID=27703138&CFTOKEN=51989935; accessed January 28, 2016.[4]

Rhodes, T. (Ed.). 2010. Assessing Outcomes and Improving Achievement: Tips and Tools for Using Rubrics. Washington, DC: Association of American Colleges and Universities.[19]

CREATIVE THINKING VALUE RUBRIC*

for more information, please contact value@aacu.org

Association of American Colleges and Universities

Definition

Creative thinking is both the capacity to combine or synthesize existing ideas, images, or expertise in original ways and the experience of thinking, reacting, and working in an imaginative way characterized by a high degree of innovation, divergent thinking, and risk taking.

Evaluators are encouraged to assign a zero to any work sample or collection of work that does not meet benchmark (cell one) level performance.

	Capstone	**Milestones**		**Benchmark**
	4	3	2	1
Acquiring Competencies *This step refers to acquiring strategies and skills within a particular domain.*	Reflect: Evaluates creative process and product using domain-appropriate criteria.	Create: Creates an entirely new object, solution or idea that is appropriate to the domain.	Adapt: Successfully adapts an appropriate exemplar to his/her own specifications.	Model: Successfully reproduces an appropriate exemplar.
Taking Risks *May include personal risk (fear of embarrassment or rejection) or risk of failure in successfully completing assignment, i.e. going beyond original parameters of assignment, introducing new materials and forms, tackling controversial topics, advocating unpopular ideas or solutions.*	Actively seeks out and follows through on untested and potentially risky directions or approaches to the assignment in the final product.	Incorporates new directions or approaches to the assignment in the final product.	Considers new directions or approaches without going beyond the guidelines of the assignment.	Stays strictly within the guidelines of the assignment.
Solving Problems	Not only develops a logical, consistent plan to solve problem, but recognizes consequences of solution and can articulate reason for choosing solution.	Having selected from among alternatives, develops a logical, consistent plan to solve the problem.	Considers and rejects less acceptable approaches to solving problem.	Only a single approach is considered and is used to solve the problem.
Embracing Contradictions	Integrates alternate, divergent, or contradictory perspectives or ideas fully.	Incorporates alternate, divergent, or contradictory perspectives or ideas in a exploratory way.	Includes (recognizes the value of) alternate, divergent, or contradictory perspectives or ideas in a small way.	Acknowledges (mentions in passing) alternate, divergent, or contradictory perspectives or ideas.
Innovative Thinking *Novelty or uniqueness (of idea, claim, question, form, etc.)*	Extends a novel or unique idea, question, format, or product to create new knowledge or knowledge that crosses boundaries.	Creates a novel or unique idea, question, format, or product.	Experiments with creating a novel or unique idea, question, format, or product.	Reformulates a collection of available ideas.
Connecting, Synthesizing, Transforming	Transforms ideas or solutions into entirely new forms.	Synthesizes ideas or solutions into a coherent whole.	Connects ideas or solutions in novel ways.	Recognizes existing connections among ideas or solutions.

* AACU. 2013. Association of American Colleges and Universities (AACU) Value Rubrics. Available at: http://www.aacu.org/value/rubrics/index_p.cfm?CFID=27703138&CFTOKEN=51989935; accessed January 28, 2016.[4]

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Appendix B
Specific Course Rubric

<u>Design and Development of Products and Processes</u>

Spring 2015

Reviewer: ____________________________ Date: _____________

Please evaluate using the scale (1 = novice, 2 or 3 intermediate (*in progress*), and 4 = expert) each of the items listed below:

Team #		
Product description	Score	Comments
Description - uses of the product Formulation - Ingredients, Potential market, Competitors, etc.		
Packaging, presentation		
Nutritional label		
Tasting/appearance (Sensory evaluation)		
Process description		
Security - regulations		
Assessment / Safety (formulation, process) use (home / end-user)		
Bonuses		
Originality		
Feasibility		
Presentation		
Clarity of presentation, use of visual aids, knowledge of the problem, etc.		

Additional comments: