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A theoretical framework for integrating creativity development into curriculum: the case of a Korean engineering school

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Abstract Existing approaches to developing creativity rely on the sporadic teaching of creative thinking techniques or the engagement of learners in a creativity-promoting environment. Such methods cannot develop students' creativity as fully as a multilateral approach that integrates creativity throughout a curriculum. The purpose of this study was to formulate a theoretical framework for a curriculum that fosters creativity. Based on the analysis of documents from accreditation organizations and engineering programs, the researchers synthesized the essential abilities and knowledge of creative engineers and formulated an initial theoretical framework for an engineering curriculum designed to integrate creativity development. To validate this initial framework, in-depth faculty interviews were conducted. The results pointed to an optimal curriculum containing four course groups centered on design, domain knowledge, interdisciplinary knowledge, and creative leadership. In addition, the findings revealed an optimal structure and sequence for the courses by grade level. The discussion includes implications of the resulting framework, along with contextual and institutional issues and recommendations for future study.

Keywords Creativity development · Restructuring curriculum · Design course group · Domain knowledge course group · Creative leadership course group · Interdisciplinary course group

Introduction and background

The dramatic changes taking place worldwide are evidence of the importance of creativity in driving history's most innovative breakthroughs (Sawyer 2012; Sternberg and Lubart 1996). For decades, researchers and educators in many disciplines have sought to identify the factors and methods best used to foster creativity. While psychological research has focused mainly on individual creativity and the personality traits and cognitive capabilities of creative individuals (e.g., Boden 1991; Piirto 1992; Runco 2007; Sternberg 1999), socio-cultural research has approached creativity more as a social and environmental process (George 2007; Sawyer 2007; Zhou and Shalley 2003). In fact, recent trends have involved an integrated, interdisciplinary approach to creativity that takes into account *both* individualist and socio-cultural perspectives in order to encompass the increasing complexities of human realities. In other words, being creative increasingly is seen as being a creative individual with creative potentials *and* being a member of a creative group for creative products in a social context. In this sense, creativity represents the interplay between individual ability and social processes that lead to outcomes recognized as novel and useful within a certain social context (Kaufman and Plucker 2011). Nevertheless, the question of how to nurture and enhance creative potential has remained a challenging issue.

Dominant educational approaches to developing creativity include either teaching creative thinking techniques or engaging learners in a creativity-promoting environment. The former approach regards creative thinking as

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crucial to innovation and discovery and assumes that creativity can be trained and supported (Maiden and Robertson 2005). Based on this domain-general perspective, processes and methods such as the theory of inventive problem-solving or TRIZ (*Teoriya Resheniya Izobreatatelskiah Zadach* in Russian), creative problem-solving (CPS), and Synetics have been widely explored and implemented (e.g., Lim et al. 2009; Puccio et al. 2010; Treffinger et al. 2000; Zhou 2012). The Synetics approach, in particular, suggests that creative potential can be developed by providing opportunities for students to constructively demonstrate their creative performance. This is the approach most commonly adopted in engineering education, which requires college students to design and produce projects using their engineering knowledge (Warr and O'Neill 2005). Several researchers have studied and proposed the kinds of content, activities, and assessment that should constitute design courses based on this domain-specific perspective (e.g., Cropley and Cropley 2000; Evans 1991; Russell and Oliva 2004).

Although both methods—training creative thinking skills and exposing learners to design opportunities—have resulted in empirically documented positive effects on creativity, many studies have pointed to the need for a more integrated and systematic approach to developing creativity (e.g., Sternberg 2005). The increasingly complex problems in the world require creative solutions that acknowledge and address a multitude of societal and human concerns (Grimson 2002). One or two courses on creative thinking skills or design tasks cannot fully develop the potential creativity in students (Cropley and Cropley 2000; Helson 1999), leading some researchers to address the need for creativity education at the macro (curriculum)-level rather than just the micro (course)-level (Borrego and Cutler 2010; Crawley et al. 2011). Coincidentally, a movement to reform curricula by integrating creativity has emerged, especially in the field of university engineering education (e.g., Badran 2007; Durgin and Parrish 1998). Such a multilateral approach to integrating creative development throughout a curriculum is thought to result in more profound and long-lasting changes than brief training in a few courses (Mills and Treagust 2003).

Studies on the development of creativity throughout the curriculum have identified salient courses and organized them into groups. Most of these studies are in the field of engineering, where the emphasis on creativity is greater because it is seen as an essential capability for success (Cropley and Cropley 2000; Zhou 2012). In addition, studies on key features of engineering practice have addressed the increasing complexity of engineering systems, supporting the need for an integrated approach to creativity in curriculum development so as to produce creative engineers who can generate new knowledge and demonstrate innovative problem-solving and technological and design abilities (Zhou 2012). Chen et al. (2005), for example, formulated a conceptual framework for reforming an engineering curriculum to maximize creativity development. The courses in their framework were grouped into *knowledge*, *skills*, or *ability* domains. The knowledge domain included general knowledge courses in math or science; the skill domain included professional courses, such as production control or quality management; and the ability domain included courses on communication, CPS or scientific research methodology. Crawley et al. (2011) proposed four groups of courses for an engineering creativity curriculum: *disciplinary knowledge and reasoning*; *personal and professional skills and attributes*; *interpersonal skills*; and *design skills in the enterprise*, *societal, and environmental context.* Badran (2007) proposed a five-pronged engineering program to enhance creativity that encompassed curricular, co-curricular, and extracurricular programs: *core scientific knowledge*; *co-curricular creativity-related workshops*, *seminars*, *or competitions*; *projects*; *exposure to entrepreneurial experts or experiences*; and *interaction with industry.* In addition, he provided a brief set of principles for curriculum design that primarily involved instructional methods.

More generally, Shneiderman (2000) described three perspectives on creativity: the *inspirationalist*, *structuralist*, and *situationalist*, each of which requires certain knowledge or skills. The inspirationalist view suggests that creativity originates at an unconscious level and, aided by insight, suddenly illuminates the mind. Although it is not yet known how such insight is triggered, *interdisciplinary infusion* may facilitate it. The structuralist view proposes that creativity requires rational and systematic evaluation and decision-making to develop more complete solutions; this process requires domain knowledge and effective thinking skills (Kazerounian and Foley 2007). The situationalist view emphasizes that creativity is a collaborative process that requires *communication skills within teams*. Besides the higher education level, creativity-enhancing primary and secondary curricula have been proposed to help young learners develop greater creativity in many subject areas using various instructional methods and design principles (Duffy 2009; Thomson et al. 2012).

Although existing studies on creativity development at the curriculum level have provided a valuable foundation and meaningful insights, they are limited in several ways. At the higher education level in particular, the groupings of courses may not have been comprehensive, that is, all courses may not be grouped, nor may be grouped according to their function in enhancing creativity in the specific field, perhaps because the abilities required for creativity were not closely examined due to the curriculum development method used. Second, the relationships between courses or sequence of courses may have not have been described. A college curriculum is designed as a 4- or 5-year plan, and courses should be offered within this framework while still allowing a certain range of flexibility. If a creativity-enhancing curriculum is to be practical, the course sequence and structure should suggest a broad plan for nurturing creativity, yet the current literature does not afford such guidance. Lastly, any existing curriculum frameworks for enhancing creativity have not been verified by field practitioners like instructors, professors, instructional designers, or teaching assistants, an important step in identifying practical concerns that could arise in implementation.

The primary purpose of this study was to formulate a domain-specific theoretical framework for an engineering curriculum that comprehensively incorporates creativity development. This framework would include the component structure of the courses and their structural and sequential relationships, thereby promoting an integrated and systematic approach to developing creativity that would inform both micro-level course design and macro-level curriculum design. A secondary purpose of the study was to provide a starting point for a domain-general theoretical framework for developing creativity-enhancing curricula at the higher education level. The specific research questions posed in this study were: (1) what is the component structure of courses constituting an effective creativity curriculum, and (2) what is overall sequential structure of the courses that would constitute an effective creativity curriculum?

This paper is structured as follows. First, using the case of an engineering curriculum at a university in South Korea, we describe our formulation of an initial theoretical framework that synthesizes the key abilities and knowledge required of creative engineers. Next, we describe our revisions to the framework based on feedback from engineering faculty members. Finally, we discuss the implications of the resulting framework and other contextual issues and recommendations that emerged as a result of the study.

Methods

The method for this study was based primarily on the methodology for curriculum development proposed by Grayson (1978), who offered a simplified curriculum development method for engineering education. Rooted in Tyler's (1949) classic methodology for general curriculum development, Grayson's approach contains three phases of curriculum development (see Fig. 1). These phases include: (1) problem definition derived from the mission statements of departments and industry, or based on societal or professional needs; (2) structuring the curriculum based on the output of Phase 1, that is, the list of domain knowledge required for successful graduates as well as overall and detailed sequences within the list that reflect students' characteristics, accreditation criteria, available resources, and teaching and learning methods; and (3) implementation and evaluation through feedback from multiple related parties.

Following Grayson's model, we first collected documents from the engineering programs of selected universities and engineering accreditation organizations in order to analyze their mission statements and statements identifying engineering needs in industry, society, and the profession. In the next phase, we set out to group of knowledge identified in Phase 1 into domains and then structured and sequenced these knowledge domains based on interview data with faculty members, who were asked to consider the roles, weights, relationships, and constraints (resources and learner characteristics) of the domains. Though Grayson (1978) suggested both macro-design and detailed course design, we chose to focus on a macro-level curriculum design in Phase 2. For the final implementation and evaluation phase, we executed a hypothetical implementation of the devised curriculum by interviewing faculty members. We asked questions designed to help us determine the validity and viability of proposed curriculum for the desired outcomes, since a full evaluation process of the curriculum in actual operation would have taken years.

Data collection

Documents

The documents we analyzed in the initial stage of data analysis were gathered from four engineering accreditation organizations and prominent higher education engineering programs, six in the USA and one in Korea. The curricula of the programs whose mission statements we analyzed also were used for purposes of formative evaluation following our content analysis.

Interviews

Interviews were conducted at two different points in the study. The first set of interviews was intended to provide information about the courses and course groups we identified through the document analysis, and the second set was used for preliminary validation of the proposed curriculum framework for creativity enhancement. We used purposeful sampling to choose a set of interview participants whose expertise matched the intent of our study. Eight engineering faculty members, each with more than 10 years of teaching experience, were recommended

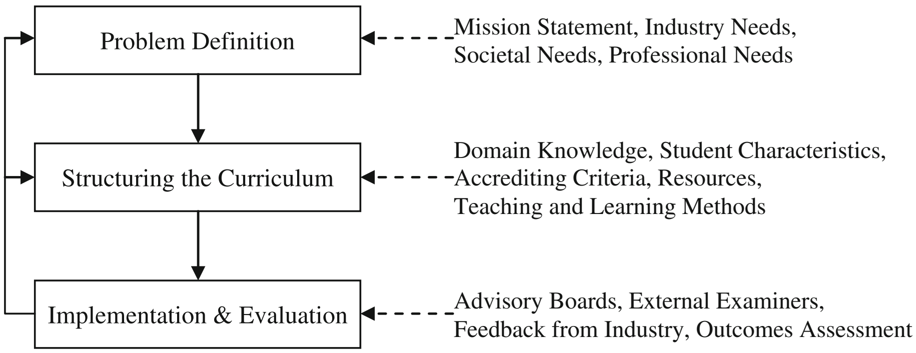

Fig. 1 A methodology for curriculum development (Grayson 1978)

Table 1 Interview participant information

Purpose	Participant	Department	Self-identified discipline	Years of teaching	Validation
To identify relationships and sequences among the course groups ($n = 8$)	A	Mechanical and Aerospace Engineering	Precision manufacturing	10–15	Yes
	B	Industrial Engineering	Product engineering	10–15	Yes
	C	Naval Architecture and Ocean Engineering	Mechanical engineering	5–10	
To validate the framework ($n = 5$)	D	Computer Science and Engineering	Database, e-business technology	15–20	Yes
	E	Industrial Engineering	Ergonomics	5–10	
	F	Mechanical and Aerospace Engineering	Fuel cell	10–15	Yes
	G	Civil and Environmental Engineering	Geo-environmental engineering	15–20	Yes
	H	Architecture and Architectural Engineering	Architectural history, theory, and design	5–10	

by the vice-dean of A engineering school. These participants were recommended because of their deep concern for the curriculum structure and because they had initiated curricular innovations to enhance creativity in their students.[1] In the first set of interviews, conducted between September and December 2012, questions concerned the needs, relationships, roles, weights, and sequences associated with the five sets of domain knowledge and abilities identified in the Phase 1 (e.g., *What knowledge or abilities would the graduating creative engineers possess? Do you think design ability significant for creative engineers? What role the design ability play in relation to other abilities? When and how do you think the ability should be assign and design within the curriculum? What do you take account regarding learners' characteristics*, *available resources*, *or instructional methods?*). The second set of interviews was conducted between December 2012 and January 2013. These interviews contained questions related to the implementation/evaluation of the proposed curriculum (e.g., *Do you think this curriculum can be successfully implemented in practice? Do you think this curriculum can produce creative engineers as intended? Do you think this curriculum corresponds to the missions of engineering education that nurtures creative engineers? Do you think the graduates of this curriculum would act more capable creative engineers in industry?*).

The interviews ranged from 43 to 95 min in duration and were recorded, transcribed, and analyzed. Following the analysis and construction of the proposed curriculum, we conducted member-checking via email in order to confirm the original meaning from an *emic* perspective. Table 1 summarizes interview participant information for both phases of interviews.

Data analysis

The data analysis process followed Grayson's method for curriculum development. Using documents from

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[1] The faculty members interviewed were all deeply involved in creativity initiative of the institution. They have engaged in either launching the creativity center and building a creativity practice space called C-Cube (creativity–convergence–collaboration) (B, C, D, E, G), or they have actively involved in initiating, designing, running, and reforming creativity courses by themselves (A, C, E, F, G, H).

engineering accreditation organizations and engineering curricula from several prominent engineering programs, and later, data from interviews with selected engineering faculty, we adhered to Grayson's three phases of *problem definition*, *structuring the curriculum*, and *implementation/evaluation.* Through a systematic process, we sought to establish a theoretical framework that would provide a structure for component courses in the curriculum and a description of their structural and sequential relationships.

Phase 1: Problem definition

In the problem definition phase, each of the three researchers conducted an analysis of documents containing the criteria of four relevant engineering accreditation organizations[2] and the mission statements of seven engineering schools.[3] Our goal was to identify what industry, society, and professional communities saw as the essential knowledge and skills of engineers. In a process informed by Wolcott's (1994) thematic approach to qualitative data analysis, each of the three researchers separately identified themes in the documents and developed categories of essential knowledge and skills. Next, we compared our results. Through an iterative process, then, we refined our categories of essential knowledge and skills until we reached consensus. In this way, we obtained a preliminary picture of the essential educational objectives and outcomes of a curricular structure for engineering programs, resulting in five rough categories of knowledge and skills.

Phase 2: Structuring the curriculum elements

In this phase, we sought to identify a broad compositional and sequential structure of the curriculum elements. Accordingly, our analysis involved two related steps: identifying the functional relationships among the course groups, i.e., the categories of courses, and devising their sequence in the 4-year program. We used the five categories of knowledge and skills that we identified in Phase 1 to group the 468 undergraduate courses in the curricula taught during the 2012 spring and fall semesters at A engineering school. This task served as a kind of formative evaluation, that is, an attempt to ascertain whether our grouping and classification of courses were feasible in practice based on the status quo. Second, through intense interviews with eight faculty members involved in curriculum reform in the A engineering school, we arrived at a new 4-year course sequence. In this way, we integrated the practical perspectives of the interviewees into an initial framework for a creativity curriculum in engineering by explicating the relationships between and sequences of the course groups.

Phase 3: Implementation/evaluation

Since it was not possible to obtain data on the actual implementation of our proposed creativity curriculum, in line with the Grayson (1978) model we conducted in-depth, semi-structured interviews with five engineering faculty members who were chosen because of their expertise in the curriculum innovation for nurturing creative engineers. We developed a semi-structured interview protocol to obtain valuable feedback on the validity and viability of the draft curricular framework (Merriam 1998; Schwandt 2001). Based on this information, we revised our initial framework and generated a final version. The data collection and analysis process are summarized in Table 2.

Results

Phase 1: Key knowledge and abilities for developing creativity

The documents we analyzed from the accreditation organizations and engineering schools explicitly and implicitly emphasized the importance of creativity and innovative thinking among engineers (Crawley et al. 2011). In Phase 1 of our analysis, we were able to and roughly classify five groups of essential knowledge/abilities creative engineers would possess: creative design abilities, leadership, global abilities, interdisciplinary knowledge, and ethics, as shown in Table 3.

The category of creative design abilities is comprised of both domain knowledge and design ability. Domain knowledge in engineering would include basic math, science, and engineering coursework that provides a foundation for creative ideas and performance. A frequently occurring theme in the curricula and accreditation documents analyzed in Phase 1 was the notion that imparting domain knowledge is essential to nurturing creative engineers. Not just this domain knowledge was valued, however, but also design ability, which encompassed five subabilities based on the design thinking process: creative thinking ability and problem-solving in the conceptualization stage; drafting and visualization skills (which allows students to represent the ideas generated in the previous stage); experimentation skills (the ability to plan, implement, analyze, and explain); implementation skills (the ability to implement products into engineering practices);

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[2] Engineering Criteria (EC) 2000/2006, Accreditation Board for Engineering and Technology (ABET), Accreditation Board for Engineering Education of Korea (ABEEK), and Washington Accord Member Universities.

[3] Georgia Tech, MIT, Stanford, University of California at Berkley, University of Texas, University of Washington, and Seoul National University (SNU).

Table 2 Data collection and analysis throughout the curriculum development process

Phases	Data/data collection	Data analysis
Phase 1	Mission statements of four relevant accreditation organizations and seven engineering schools	Thematic analysis for preliminary grouping
Problem definition		
Industry/societal/professional needs		
School mission statements		
Phase 2	2012 spring and fall course list (468 undergraduate courses at A engineering school)	Classification of the each course into a preliminary grouping for more elaborated grouping
Structuring the curriculum	Interviews with eight faculty members on relationships, roles, weights, and constraints (student characteristics, resources, or teaching and learning methods)	Thematic analysis for explicating the relationships among and sequences of the course groups
Domain knowledge		
Accreditation criteria, student characteristics, resources, teaching, and learning methods		
Phase 3		
Implementation/evaluation	Interviews with five engineering faculty members on hypothetical implementation and anticipated outcomes	Thematic analysis for determining the validity and viability of the draft framework
Feedback from industry advisory boards, or external examiners		
Outcomes assessment		

and quality improvement skills (the ability to improve the quality of the implemented product during the field application).

The analysis of the mission statements of engineering schools revealed that most had a stated mission of producing leaders who would take the initiative in innovation and entrepreneurship and would be highly motivated, curious, and persistent. Thus, the second type of knowledge that was seen as essential for creative engineers was related to leadership. Most of the accreditation organizations valued collective creativity, that is, the ability to join with others in producing creative outcome. Collective creativity, then, requires the critical leadership abilities of communication, teamwork, and self-management. A third type of essential knowledge that emerged from the analysis was global ability, or the ability to understand global culture and global cooperation and actively pioneer global markets. Finally, a fourth type was interdisciplinary ability, that is, knowledge of diverse fields, such as art, the humanities, business, economics, administration, and law. Interdisciplinary knowledge was particularly emphasized by the accreditation boards, a recognition of the positive influence that a diversified perspective has on creativity.

Finally, documents from both accrediting organizations and engineering schools indicated that engineers must gain knowledge of engineering ethics. More specifically, creative engineers must become involved in public service and understand their ethical responsibilities when involved in creative engineering practices.

Phase 2: Initial framework—structure, relationship, and sequence of courses

The course group structure

In Phase 2, the five key knowledge and abilities identified in Phase 1 were assigned to four groups of courses, based on an analysis of the current curriculum. A total of 468 undergraduate courses were categorized accordingly. Of these courses, 68 % (319 courses) were assigned to the domain knowledge group, 22 % (103 courses) to the design practice group, 7 % (32 courses) to the interdisciplinary group, and 3 % (14 courses) to the leadership group.

The domain knowledge course group (KCG) covers both basic courses (math and science) and domain-specific courses (engineering theory and design theory). Basic

Table 3 Key knowledge and abilities for creativity curriculum in engineering

Key knowledge	Sub-knowledge	Contributors
Creative design ability	Domain knowledge	
	Math/science knowledge	EC2000/2006, ABEEK, ABET Stanford, MIT, U of Texas, UC Berkeley, SNU
	Engineering knowledge	
	Design ability	
	Creative thinking ability	EC2000/2006, ABEEK, ABET U of Texas, SNU
	Problem-solving ability	
	Drafting and visualization ability	
	Experimental ability (plan, implement, analyze, explain)	ABEEK, ABET
	Ability to implement engineering practices (needs specification, …)	EC2000/2006
	Quality improvement ability	EC2000/2006, ABET MIT
	Field application ability	EC2000/2006, ABET
Leadership	Self-management	
	Self-development/life-long learning	EC2000/2006, ABEEK, ABET Georgia Tech, U of Texas, SNU
	Communication	
	Presentation ability	
	Writing technical reports ability	EC2000/2006, ABET, SNU
	Mediating discussions ability	
	Teamwork	
	Teamwork	
	Project management	EC2000/2006, SNU Georgia Tech
	Plan and execution ability	
	Innovation challenge	
	Achievement motivation	Stanford, MIT, Georgia Tech, UC Berkeley, U of Washington
	Active exploration/curiosity	
	Task persistence	
	Initiative	Stanford, MIT, SNU
	Entrepreneurship	
Global ability	Global culture and global cooperation	EC2000/2006, SNU
	Global market pioneering	EC2000/2006, ABEEK
Interdisciplinary ability	Artistic knowledge	ABEEK, ABET
	Humanities knowledge	ABEEK, ABET
	Socio-economic knowledge (business, economics, administration, law)	ABEEK, ABET, SNU
Ethics	Public service	EC2000/2006, Stanford, U of Texas, UC Berkeley, U of Washington
	Ethical responsibility	EC2000/2006, ABEEK, ABET, SNU

courses are typically offered for sophomores (54 %), while most domain-specific courses are designed for juniors (44 %). The design practice course group includes courses on planning (visualization and creative thinking) and production (engineering practice and field application); these are typically offered for seniors (53 %). The interdisciplinary course group (ICG) includes classes on the humanities and social sciences, economics and business, art, and law, which are commonly offered for seniors (56 %). The leadership course group (LCG) covers teamwork and communication, innovation, and ethics. While courses on teamwork and communication are usually offered for underclassmen and are typically integrated into design courses, innovation and ethics courses are open to seniors. Table 4 shows the refined course group list, course title examples, and ratios to the total number of classes offered.

Relationship and sequence among course groups

Based on the interviews with eight faculty members and examination of the current engineering curriculum at the

Table 4 Course groups in creativity curriculum

	Course group	Course example	Ratio ($n = 486$)
Basic and domain knowledge	Basic (math/science)	Engineering mathematics	68 % ($n = 319$)
	Domain-specific (engineering theory/design theory)	Aerospace sensor systems	
Design	Planning (visualization/creative thinking)	Creative engineering design	22 % ($n = 103$)
	Production (engineering practice and field application)	Integrated mechanical design and analysis	
Interdisciplinary	Humanities and social sciences	Management for engineers	7 % ($n = 32$)
	Economics and business	Radiation technology for industrial and medical applications	
	Art	Activity and space	
	Law	Nuclear energy laws and society	
Leadership	Teamwork and communication	Engineering project management	3 % ($n = 14$)
	Innovation (global cooperation, entrepreneurship)	Analysis of international energy markets, IT venture creation	
	Ethics	Engineering ethics and leadership	

university, an initial curricular framework was developed to capture the optimal structural and sequential relationships among the courses that would provide the essential knowledge or abilities of creative engineers. The structure and sequence of the curriculum can be described in terms of four course groups and their overarching functions: (1) the basic and domain KCG, the grounding component; (2) the design course group (DCG), the central component; (3) the ICG, the creativity impetus component; and (4) the creative LCG, the collective creativity facilitator component.

The KCG as the grounding component Three of the faculty members interviewed repeatedly mentioned that basic and domain knowledge (KCG) was a fundamental resource for creativity. In engineering education, lecture-based engineering math, science, and engineering courses represented this course group. Most of the engineering faculty members believed that the goal of the engineering curriculum was to provide a strong foundation of engineering knowledge. Most of them expressed discomfort with the low ratio of classes in this course group as compared to other course groups:

> Creativity begins with knowing the resources that you already have inside of you. For instance, your knowledge—whether it is basic knowledge or domain knowledge or interdisciplinary knowledge—could be that resource. Based on that, you are able to connect and synthesize your knowledge into creative solutions. (Faculty D)

> Basic and domain knowledge is quite important when it comes to innovative thinking. It can't be replaced or neglected. If you try to innovate ideas without knowledge, it could lead you the wrong way. Steve Jobs and Bill Gates became successful because they had rich background knowledge, even though they quit school… most people do not know this. (Faculty E)

The optimal sequence for the basic and advanced domain knowledge courses would be one in which the ratio of basic knowledge courses is gradually reduced until the junior year. Simultaneously, the ratio of domain knowledge courses should gradually increase until the junior year. The ratio of courses from these two groups should be balance in the senior year:

> To account for the realities of the institution, such as the credit system, time, space, etc., it is important to weight the course groups by grade. For example, freshmen need a general and basic understanding of the engineering field. For the sophomore and junior, gradually deepening one's professional understanding of the field is recommended. Finally, for the senior, actual application of the knowledge in real practice should be pursued. (Faculty B)

The DCG as the central component Most of the interviewees agreed that the DCG should be the focus and center of the curriculum. Therefore, engaging students in the design process should provide them with critical opportunities for CPS, from planning to production. Faculty A compared the DCG to a driving test:

> The design course group should be the key course group of the engineering curriculum. I will say that to have no design course is similar to letting inexperienced drivers on the road immediately after they pass

> their written test. If you want to learn how to drive, you need real experiences on the road. I think that road practice is to driving as design practice is to engineering. (Faculty A)

Some faculty members pointed out that the current DCG does not provide sufficient design experiences with systematically planned sequences and connections by grade and by major, resulting in repetitive, misplaced, and omitted courses. Because the current DCG courses are offered according to individual professors' availability, professors rarely share or communicate course information with other professors who teach related courses. One faculty member suggested a solution:

> Even though I think there is no golden rule for every course, some basic standard that each department can modify is still needed. For example, the design thinking process—ideation, research, prototyping, and implementation/testing—could be the framework of the course sequences. (Faculty A)

A faculty member proposed that the DCG sequence can be modeled on the design thinking process (Herbert 1969) and modified according to the practical constraints of the engineering school. For the freshmen, design courses include easier tasks that have more constraints and focus on the ideation step and visualization skills. Sophomore courses include fewer constraints and emphasize the research step and creative thinking skills. At the junior and senior levels, the constraints become minimal and should closely resemble reality. These courses focus on prototyping and implementation/testing in the field. In this sequence, the planning and production jobs increase by grade.

> As the design thinking process moves from ideation to implementation, the assigned design tasks lose constrains. It means it is getting closer to reality. More constraints mean laboratory setting. But… realities… fields have numerous possibilities! The difficulties also increase. Freshmen only raise ideas in a restricted situation. Then sophomore do research and try out many creative trials. They produce implementable prototypes based on their research. Finally, they implement, test, and refine the actual product in their senior year! (Faculty A)

The interdisciplinary course group as the creativity impetus component Many of the faculty interviewed agreed that the ICG should be an integral part of creativity education. Humanities and social sciences, economics and business, art, and law courses were suggested as subcomponents of this course group. The art, humanities, and social science courses were thought to provide fresh stimulus for creative insight. The law, economics, and business courses also could provide practical knowledge so that the resulting creative artifacts would be accepted in their social context. The interviewees were all aware that innovative and groundbreaking ideas were unlikely to arise solely from domain knowledge and design practice abilities. They understood that such ideas are fostered by fresh perspectives outside of the domain and are inspired by a broad appreciation of humans and society.

> While breaking out of one's own shell and exploring converging points among conflicting ideas, the harmonizing creativity drawn from art, tradition, the humanities, and management…can inspire innovative creativity. Only if such creativity is reflected and supported by engineering design tasks can innovative and creative output be produced. (Faculty H)

One faculty member suggested that if one wants to determine whether a person is creative or not, one need only examine how diverse are the fields of that individual's friends. Knowledge should not be restricted and static, but should be harmoniously converged with new knowledge and applied in practice to foster creative ability:

> If you want to tell how creative a person is, one of the easiest ways is to see how many people in remote fields of study he/she interacts with. In many cases, a creative person has a wide network of people in diverse areas. My students should also try to explore and make contacts in a variety of fields outside of their own. (Faculty G)

The faculty members suggested that a broad understanding of the humanities, social sciences, economics, and business should be emphasized at the freshman and sophomore levels. At the junior and senior levels, art and law should be studied to introduce students to the variety of factors they might encounter in actual social contexts.

> The views that humanities and social sciences cannot be nurtured at a short period, those should be fostered from freshmen. Business mind also needs to be cultivated at least from sophomore. Specific law related to engineering practice can provide a set of restrictions, which may be learned in senior. Artistic infusion… it is important for creativity… but it depends on engineering disciplines. Normally… it can be integrated in the curriculum around junior so that it can give direct implications (Faculty G)

The creative LCG as the collective creativity facilitator component The interviewees suggested that the creative LCG should be integrated into the curriculum as a collective creativity facilitator, that is, the group of courses that can facilitate fostering collective creativity. The LCG subgroups included teamwork, communication, global cooperation and entrepreneurship, and ethics. One faculty member critiqued students' poor communication skills and inability to effectively express their ideas. Such skills are crucial when working in industry, where it is necessary to give oral presentations or write technical reports. In the current curriculum, however, only liberal arts courses address this need, though students need preparation in order to meet domain-specific demands.

Several interviewees also recommended that leadership skills and teamwork be integrated into the curriculum. The interviewees indicated that most of the design courses primarily consist of team projects. Because this group work often leads to interpersonal conflicts, interviewees suggested that group social skills should be taught. These skills are even more critical when leading a multi-background team communicating and collaborating with team members after graduation:

> There aren't many people who make decisions on their own. That is how society works. I hear a lot of stories about high performers who have problems with team building or communication skills. (Faculty F)

> Collective creativity should be required in engineering school because projects are performed by groups or teams to solve authentic problems. For successful collective creativity, leadership, communication skills, teamwork, and ability to network with colleagues, professors, or experts are essential capabilities. (Faculty C)

In our recommended LCG sequence, teamwork, communication, and ethics courses are integrated into the DCG in all grades. For the lower grades, a global cooperation course should be emphasized as important, and for the upper grades, an entrepreneurship course should be offered:

> Freshmen and sophomores need to receive a basic education in the liberal arts, targeting a broad understanding of diverse fields like writing, presentation skills, and global cooperation. As they move to their junior and senior years, they need to concentrate on entrepreneurship. Most of all, communication skills, teamwork, and networking should be fostered throughout all the grades to improve collective creativity. (Faculty F)

Phase 3: Final framework

Though we could not evaluate an actual implementation of the proposed creativity curriculum, we conducted a preliminary validation through interviews with five faculty members. The results of these interviews contained mostly positive comments about the curriculum. The dominant themes in these comments are summarized as follows:

> The framework can function as a mediating vehicle that provokes discussion and communication about the whole curriculum from the perspective of each department.

> The framework facilitates a flexible approach to the curriculum's content and structure. Preferences can vary by department or professor. We can adopt the suggested conceptual structure and sequence, and the details can be determined by the individual department or instructor.

> It graphically represents the role of each course in the curriculum and how the courses are connected and sequenced.

> In the DCG, the terms should be generalized. The term "production" pertains only to some of the majors, such as mechanical or aerospace engineering. Revise *production* to *implementation, integration,* or *application*.

> It is difficult to identify each course's mode. We can develop creativity in stand-alone courses or integrated courses. Please elaborate the framework by classifying the courses into one of these two modes.

Based on the interviewees' comments, the framework was revised and finalized, as shown in Figs. 2 and 3.

Figure 2 depicts the structure and relationships between the course groups. The DCG, which includes courses for planning and implementation of design, is located in the center. The KCG, with its basic math and science courses and domain-specific engineering and design theory courses, is found under the DCG. The ICG of humanities, social sciences, economics, business, art, and law supports the DCG in stimulating creativity. Finally, the LCG on teamwork, communication, innovation, and ethics also props up the DCG.

Figure 3 represents the proposed sequence of each of the course groups throughout the 4 years of an engineering curriculum. Within the ICG, humanities and social science should be broadly infused throughout the 4 years, economics and business should be introduced around the sophomore year, and art and law should be cultivated at the junior and senior levels. The DCG follows the design thinking process of ideate–research–prototype–implement/test.

As the grade level increases, the tasks should get closer to real-world design tasks and thus contain less constraint. In other words, at the freshmen level, students should receive more ideation tasks in a simulated design situation,

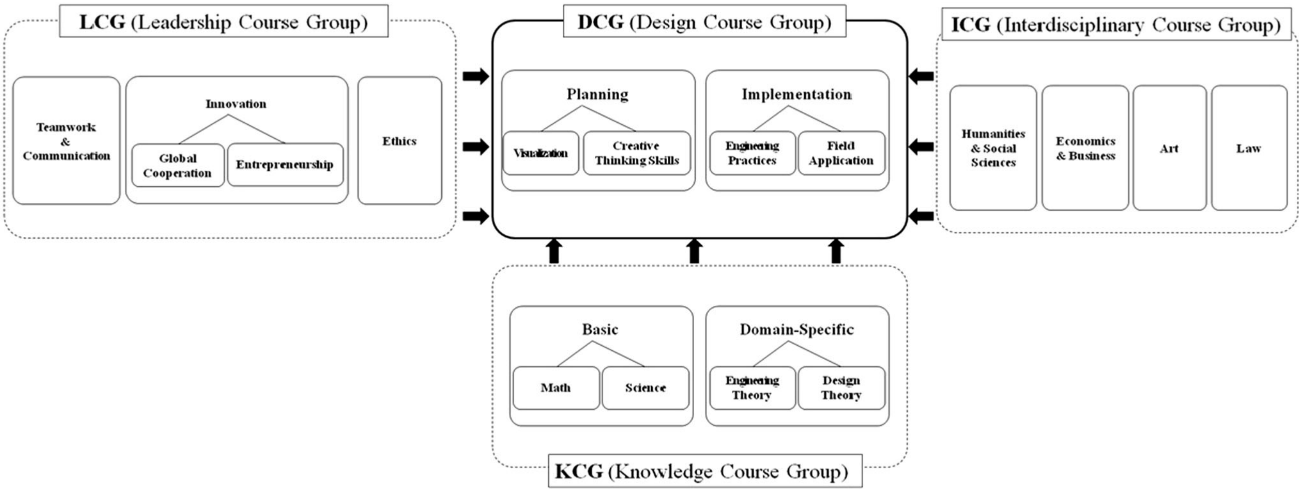

Fig. 2 The final framework: structure and relationship of the course groups

while at the sophomore level, more elaborated research skills need to be nurtured to help students support or select the ideas planned. At the junior level, students should produce prototypes to be virtually implemented in practice, and finally, at the senior level, the products should be implemented and tested in the field. The scale and weight of both the planning and production get enlarged as the students move to the closer to graduation. Courses in the KCG should proceed in such a way that basic courses decrease as the student moves toward the junior year, and domain-specific courses should increase. In the senior year, both basic courses and domain-specific courses should interact and blend for applied purposes. The courses in the LCG should be distributed throughout the 4 years and should especially focus on teamwork, communication, and ethics. Courses on innovation which include global cooperation and entrepreneurship are designed with broad focus on global cooperation throughout the 4 year and special emphasis on entrepreneurship in the upper grade levels.

Discussion

Organization of the curriculum framework

The analysis of documents and faculty interviews conducted for this study led to a curriculum composed of four course groups with different but equally important creativity-fostering functions. In the proposed curricular structure, the DCG provided a central focus for creativity, the basic and domain KCG offered grounding for creativity, the ICG served as an impetus to creativity, and the LCG facilitated the exercise of collective creativity in group contexts.

This final framework, then, describes a holistic curricular approach to developing creativity that stands in contrast with most previous approaches, which have focused solely on design ability in design tasks or creative thinking skills at the course level. As such, this approach integrates both domain-general and domain-specific perspectives offers an alternative to isolated and disconnected opportunities to enhance creativity within a curriculum. The studies that have taken a curricular approach to developing creativity in engineering education, reviewed earlier in this paper, are compared with the results of this study in Table 5.

This study hopes to be a valuable addition to studies of developing creativity curriculum in that the creativity curriculum we developed comprehensively covers the four areas that previous studies only partially developed. In Chen et al.'s (2005) ability–knowledge–skills categorization scheme, for example, "knowledge" corresponds to our basic knowledge and "skills" to domain knowledge, both in our KCG, while "ability" can be found in both our design and LCGs. In the study by Crawley et al. (2011), "design skills" and "disciplinary knowledge and reasoning" correspond to our design and KCGs, respectively, and the "personal and professional skills and attributes" and "interpersonal skills" elements correspond to our LCG. Badran's (2007) package resembles the design, knowledge, and LCGs we identified, and Shneiderman's (2000) approach—structuralist, inspirationalist, and situationalist—corresponds to our knowledge, interdisciplinary, and LCGs, respectively. None of these studies, however, comprehensively covered the four course groups we derived from all the courses in the engineering curricula we reviewed.

The nature of design tasks is intimately related to the nature of creativity. Therefore, the DCG is at the center of

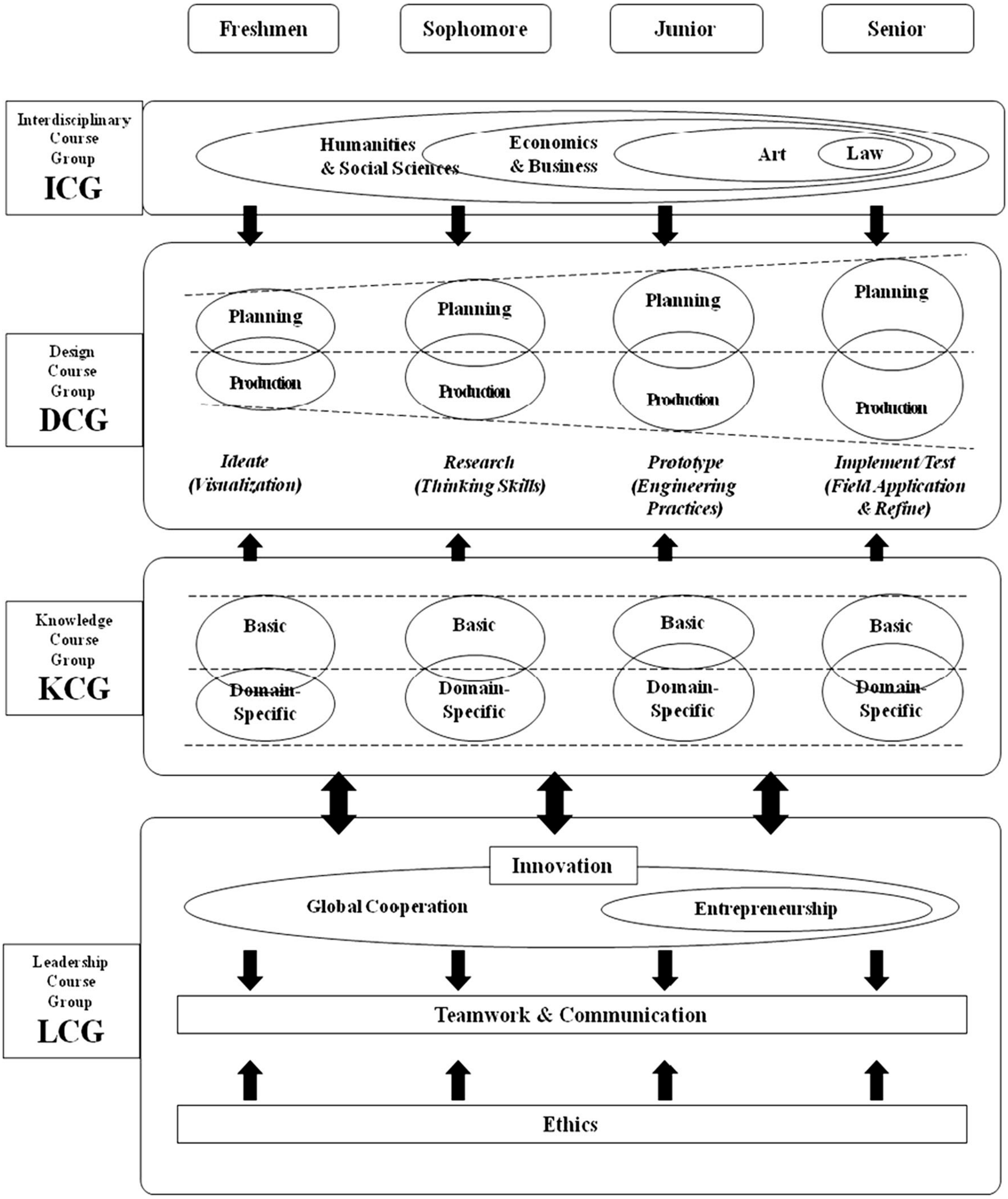

Fig. 3 The final framework: course group sequences

the proposed curricular framework, and the KCG, which represents a general approach to creativity education, acts as a grounding component (Gardner 1993; Ericsson et al. 1993; Mumford et al. 1996; Simonton 1988). The term "design" has been used in many relevant studies, potentially confirming the structure we proposed for a creativity curriculum. Similarly, many scholars have defined "design" as an evidence-based problem-solving and decision-making process (Archer 1965; Lewis et al. 2006). In this case, the evidence comes from object knowledge, that is, domain-specific or domain-general knowledge (Daly et al. 2012), implying that successful design requires grounding knowledge to assure the validity of solutions or decisions.

The purpose of the ICG is to stimulate creative design. Its sub-components include courses in the humanities and social sciences, economics and business, art, and law. Many classic definitions of design suggest that design involves careful consideration of the use of artifacts, their context, people in the users' environment, other variables,

Table 5 Curriculum components of related studies

Chen et al. (2005)	Crawley et al. (2011)	Badran (2007)	Shneiderman (2000)	This study
Ability (problem-solving, research methodology)	Design skills	Co-curricular creativity-related workshops, seminars, or competitions Projects at different levels		Design Course group
Knowledge (math, science) Skills (production control, quality management)	Disciplinary knowledge and reasoning	Core scientific knowledge	Structuralist (knowledge of math, sciences, and effective thinking skills)	Knowledge Course group
			Inspirationalist (multidisciplinary infusion)	Interdisciplinary Course group
Ability (communication)	Personal and professional skills and attributes Interpersonal skills	Exposure to entrepreneurial experts or experiences Interaction with industry	Situationalist (communication skills within teams)	Leadership Course group

and the complex relationships among these variables. In other words, to design is to consider a wide variety of factors, a process that requires diverse perspectives and approaches. Exposing students to such diverse perspectives, then, should foster creativity (Csikszentmihalyi 1996; Hennessey and Amabile 2010; Sternberg 2005).

Lastly, the LCG is intended to facilitate collective creativity. Design has been defined as a social and collaborative process (Warr and O'Neill 2005), and has often been said to represent the synthesizing of crucial design components through collaboration (Cross 1982; Herbert 1969). Although some support an individual approach to creativity, it is difficult to produce a physical creative artifact solely from the imagination and inspiration of a single individual. Nguyen and Shanks (2009) defined creativity as "a result of collective effort and subject to the collective judgment of a team, organization, community, or society" (p.656), which resembles Sosa and Gero's (2003) concept of situated creativity, that is, the collaborative production of creative artifacts and their adoption and diffusion within the social and environmental context of use. Creativity, then, relies on a range of social functions, as suggested by the LCG sub-components of teamwork, communication, and ethics.

Sequence of the course groups

Our analysis also suggested a 4-year sequence for the four course groups. In the DCG, freshman design courses should focus on the ideation step and visualization skills, and design projects should be guided by a number of constraints: The sophomore design courses should emphasize the research step and creative thinking skills and apply looser constraints. The junior and senior level courses should focus on prototyping and implementation/testing in the field and apply the fewest constraints to approximate reality.

In the KCG, basic knowledge courses should be gradually reduced until the junior level; domain knowledge courses should gradually increase until the junior level. These two groups should be balanced and converge at the senior level. In the freshman and sophomore level ICG, courses providing a broad understanding of the humanities, social sciences, economics, and business should be emphasized. At the junior and senior levels, art and law should be emphasized to familiarize students with the diverse factors they may encounter in actual social contexts.

In the LCG, teamwork, communication, and ethics courses should be integrated into the DCG at each grade level via regular courses and special courses offered during academic vacations. Courses in the LCG should emphasize global cooperation in the lower grades, and an entrepreneurship course should be offered to upperclassmen.

Few studies have established a sequence or weight for the courses in their creativity curricula. The recommended sequences of each course group are based on how closely the content and tasks resemble reality. For example, in the DCG, the course difficulty should increase by grade as constraints are loosened and students transition from laboratory tasks to tasks approaching real projects. At the senior level, the knowledge, interdisciplinary, and LCGs also should be sequenced to prepare students to apply their knowledge and skills in realistic situations.

Institutional and contextual issues that influence creativity education

The implementation of the proposed curriculum framework will encounter a variety of contextual issues in practice. The faculty interviewees raised these issues and suggested possible solutions that have multiple implications at the course and institutional level. One of the most contentious issues is offering courses in a standalone versus integrated manner in order to maximize the development of creativity in students. Offering new standalone courses might have a stronger impact but could cause complicated problems because existing courses may need to be eliminated or substituted. Some faculty members recommended creating independent courses for the interdisciplinary and LCGs, while others preferred integrated courses for the LCG. Most of the faculty members interviewed believed that social skills, such as leadership, communication, and teamwork, could be taught through team project experiences and that independent courses for these skills may not be necessary. One faculty member reported that when a project management course was offered, few students registered for it. Students did not seem to realize the significance of focused, independent training in that skill. Although many studies and accreditation criteria claim that leadership and social skills are crucial to developing group and organizational creativity, it is assumed that these interpersonal skills are acquired informally through experience rather than through a set of formal courses. This assumption is inconsistent with existing studies indicating the need for intensive leadership training in creativity development (Kahai et al. 2003). Such findings should have meaningful implications for design curricula.

Researchers have proposed several possible solutions for resolving the conflict between standalone and integrated course approaches. Advocates of the standalone approach propose technology adoption as an attractive answer. One faculty member we interviewed suggested that some lecture-based courses in the KCG could be replaced by open course ware (OCW), massive online open courses (MOOCS), flipped classrooms, or any other technology-based course that is currently not counted for regular credit in the curriculum. If the future of higher education does not lie in the impartment of knowledge (Laurillard 2002), and if students still need to learn basic and domain knowledge to develop creativity, individual students can master this knowledge individually through informal technology-based courses rather than in formal college courses. Then, curriculum in higher education could focus on achieving higher-order missions. To the contrary, integrated approach advocates believe that intense effort should be exerted to reform existing courses. Integrating more than two groups of courses requires a novel curriculum design, however. The LCG in our formulation, for example, could be integrated as an instructional method or as learning activities, and the ICG could be incorporated through course materials, media, or assignments. Such a course design endeavor could generate space for more critical standalone courses within the curriculum.

In conjunction with course issues, several institutional issues were addressed in the interviews conducted for this study: consensus and communication about the curriculum framework, institutional support (i.e., financial and human resources), and a more flexible system for evaluating student performance. Interviewees indicated that these three issues influence creativity education. Most importantly, in whatever form the proposed curriculum framework is actualized, it will require consensus and communication among the faculty members. Students' creativity is inspired just as much by the way in which professors implement a course as by the course or curriculum design. Faculty, then, should implement each course with a clear vision of its role in enhancing creativity within the curriculum. Further, different courses may be offered under the same course title, and redundant courses may be offered while significant courses are omitted. One solution proposed was to clearly notate a course's group and sequence in the course title so that both faculty members and students are aware of the position and role of each course within the curriculum.

Another critical issue concerns evaluating student performance. The current grading system, which is based on norm- or criterion-referenced evaluation to produce a grade point average (GPA), may not encourage students to creatively challenge themselves; rather, it can motivate students to passively digest domain knowledge (Lee and Lee 2012). To allow students free creative expression, more flexible assessment, such as pass/fail grading, was recommended by one faculty member. Even if this issue brings into conflict various educational perspectives toward learning and knowledge, and is heavily affected by sociocultural factors (Amabile 1996; Li 2003; Simonton 1988), by assessing students more flexibly, the development of creativity can become the ultimate goal of coursework rather than the single achievement of a high GPA.

The institutional issue that could have the greatest impact on the successful implementation of a creativity curriculum framework like the one we proposed is institutional support in the form of financial and human resources. Implementing a creativity curriculum will require additional effort from the faculty and assistance from staff members. Developing a new course or reforming an existing course, for example, can be a demanding task that may not relate to a faculty member's expertise. In addition, offering more design courses will require more teaching assistants. A supportive institutional atmosphere in which the necessary support and incentives are provided could accelerate the successful implementation of a creativity-driven curriculum.

Conclusion

The primary goal of this study was to take a holistic approach to creativity development by integrating it throughout an engineering curriculum rather than by developing a few isolated courses. Dismissing the individualistic view of creativity, this approach treated creativity as an ability fundamental to creative problem-solving that can be enhanced by a knowledge of design practices, by communicating and collaborating in a social context, by basic and domain knowledge, and by an interdisciplinary perspective. That is, creativity encompasses the characteristics of socially successful organizations, not the isolated features of creative solutions or products. This study, therefore, argues that creativity should be fostered throughout the curriculum by a set of systematically linked composite course groups, that each course group should be assigned a clearly defined role, and that together the course groups should achieve the ultimate educational goal.

This study was limited to the educational activities within an engineering curriculum. Additionally, the collection of interview data was limited to purposefully selected participants from an engineering program in higher education. The resulting curriculum structure, then, will require actual implementation and further empirical validation to prove its validity and practical effectiveness. Nevertheless, it is our hope that this research provides a useful starting point for the development of domain-specific theoretical frameworks for incorporating creativity development throughout the curriculum, whether in engineering or other disciplines.

Realistically, the reform of a preexisting curriculum involves discontinuing some existing courses and raising administrative and political issues. Extra- or co-curricular activities for students, such as short-term workshops, seminars, internships, contests, volunteer work, or club activities, can also contribute to developing creativity. Such activities could relieve the faculty of the burden of delivering lectures outside of their field of expertise and would help to professionalize students and give them the opportunity to meet people in diverse fields. Relevant research can provide practical guidance to extra-/co-curriculum developers (Badran 2007). In addition, faculty should review studies on creativity-promoting instructional methods so that innovative instructional methods can be implemented in existing courses. Such a methodological approach can easily and flexibly be integrated on a micro-scale, i.e., at the course level, allowing individual faculty members to choose which strategies to adopt. Finally, it is our hope that this study's holistic approach to creativity development through a systematically redesign of an entire curriculum will advance learning in the field of creativity education.

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References

Amabile, T. M. (1996). *Creativity in context*. Boulder, CO: Westview Press.

Archer, L. (1965). *Systematic method for designers*. London: Council of Industrial Design.

Badran, I. (2007). Enhancing creativity and innovation in engineering education. *European Journal of Engineering Education, 32*(5), 573–585.

Boden, M. A. (1991). *The creative mind: Myths and mechanisms*. New York, NY: Basic Books.

Borrego, M., & Cutler, S. (2010). Constructive alignment of interdisciplinary graduate curriculum in engineering and science: An analysis of successful IGERT proposals. *Journal of Engineering Education, 99*(4), 355–369.

Chen, C., Jiang, B. C., & Hsu, K. (2005). An empirical study of industrial engineering and management curriculum reform in fostering students' creativity. *European Journal of Engineering Education, 30*(2), 191–202.

Crawley, E., Malmqvist, J., Licas, W., & Brodeur, D. (2011). The CDIO syllabus v2.0, an updated statement of goals for engineering education. In *Paper presented at the 7th international conceive-design-implement-operate conference*, Copenhagen, Denmark.

Cropley, D., & Cropley, A. (2000). Fostering creativity in engineering undergraduates. *High Ability Studies, 11*(2), 207–219.

Cross, N. (1982). Designerly ways of knowing. *Design Studies, 3*(4), 221–227.

Csikszentmihalyi, M. (1996). *Creativity: Flow and the psychology of discovery and invention*. New York, NY: Harper Collins.

Daly, S. R., Adams, R. S., & Bodner, G. M. (2012). What does it mean to design? A qualitative investigation of design professionals' experiences. *Journal of Engineering Education, 101*(2), 187–219.

Duffy, B. (2009). Creativity across the curriculum. In C. Cable, L. Miller, & G. Goodliff (Eds.), *Working with children in the early years* (pp. 139–152). New York, NY: Routledge.

Durgin, W., & Parrish, E. (1998). Redesigning engineering education. In *Paper presented at the realizing new paradigm for engineering education* (pp. 62–65), ECI, Baltimore, ML.

Ericsson, K., Kramper, R., & Tesch-Romer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100*(3), 363–406.

Evans, J. (1991). *Creative thinking in the decision and management sciences*. Cincinnati, OH: South-Western.

Gardner, H. (1993). *Multiple intelligences: The theory in practice*. New York, NY: Basic Books.

George, J. (2007). Creativity in organizations. *The Academy of Management Annals, 1*(1), 439–477.

Grayson, L. (1978). On a methodology for curriculum design. *Engineering Education, 69*, 285–295.

Grimson, J. (2002). Re-engineering the curriculum for the 21st century. *European Journal of Engineering Education, 27*(1), 31–37.

Helson, R. (1999). A longitudinal study of creative personality in women. *Creative Research Journal, 12*(2), 89–101.

Hennessey, B., & Amabile, T. (2010). Creativity. *Annual Review of Psychology, 61*, 569–598.

Herbert, S. (1969). *The sciences of the artificial*. Cambridge: MIT Press.

Kahai, S., Sosik, S., & Avolio, B. (2003). Effects of leadership style, anonymity, and rewards on creativity-relevant processes and outcomes in an electronic meeting system context. *The Leadership Quarterly, 14*(4–5), 499–524.

Kaufman, J. C., & Plucker, J. (2011). Creativity and intelligence. In R. J. Sternberg & S. B. Kaufman (Eds.), *The Cambridge handbook of intelligence* (pp. 771–783). Cambridge: New York, NY.

Kazerounian, K., & Foley, S. (2007). Barriers to creativity in engineering education: A study on instructors and students perceptions. *Journal of Mechanical Design, 129*(7), 761–768.

Laurillard, D. (2002). *Rethinking university teaching* (2nd ed.). London, UK: Routledge Falmer.

Lee, H., & Lee, J. (2012). Who gets the best grades at top universities? An exploratory analysis of institution-wide interviews with the highest achievers at a top Korean University. *Asia Pacific Education Review, 13*(4), 665–676.

Lewis, K. E., Chen, W., & Schimidt, L. C. (2006). *Decision making in engineering design*. New York, NY: ASME.

Li, J. (2003). US and Chinese cultural beliefs about learning. *Journal of Educational Psychology, 95*(2), 258–267.

Lim, C., Yoon, S., Park, K., & Hong, M. (2009). A study of an integrated instructional model in a collegiate course for creative problem solving with online support system. *Korean Journal of Educational Technology, 25*(1), 171–203.

Maiden, N., & Robertson, S. (2005). Integrating creativity into requirements engineering process: Experiences with an air traffic management system. In Paper *presented at the 13th IEEE international conference on requirements engineering*, Paris, France.

Merriam, S. (1998). *Qualitative research and case study applications in education*. San Francisco: Jossey-Bass.

Mills, S., & Treagust, D. (2003). Engineering education: Is problem-based or project-based learning the answer? *Australasian Journal of Engineering Education*, 2–16. Retrieved from http://www.aaee.com.au/journal/2003/mills_treagust03.pdf.

Mumford, M. D., Baughman, W. A., Supinski, E. P., & Maher, M. A. (1996). Process-based measure of creative problem solving skills: Information encoding. *Creativity Research Journal, 9*(1), 77–88.

Nguyen, L., & Shanks, G. (2009). A framework for understanding creativity in requirements engineering. *Information and Software Technology, 51*(3), 655–662.

Piirto, J. (1992). *Understanding those who create*. Dayton, OH: Psychology Press.

Puccio, G. J., Mance, M., & Murdock, M. C. (2010). *Creative leadership: Skills that drive change*. Thousand Oaks, CA: SAGE.

Runco, M. (2007). *Creativity: Theories, themes, practice*. Philadelphia, CA: Academic Press.

Russell, J. S., Oliva, M. G. (2004). Making the strange familiar: Creativity and the future of engineering education. In *Paper presented at the 2004 American Society for Engineering Education annual conference*, American Society for Engineering Education, Salt Lake City, UT.

Sawyer, R. K. (2007). *Group genius: The creative power of collaboration*. NY: Basic Books.

Sawyer, R. K. (2012). *Explaining creativity: The science of human innovation*. New York, NY: Oxford University Press.

Schwandt, T. (2001). *Dictionary of qualitative inquiry* (2nd ed.). Thousand Oaks, CA: Sage.

Shneiderman, B. (2000). Creating creativity: User interfaces for supporting innovation. *ACM Transactions on Computer–Human Interaction, 7*(1), 114–138.

Simonton, D. K. (1988). Creativity, leadership, and chance. In R. J. Sternberg (Ed.), *The nature of creativity* (pp. 386–426). New York, NY: Cambridge University Press.

Sosa, R., & Gero, J. (2003). Design and change: A model of situated creativity. In *Paper presented at the third workshop on creative systems: Approaches to creativity in artificial intelligence and cognitive science,* Aucapulco, Mexico.

Sternberg, R. J. (1999). A dialectical basis for understanding the study of cognition. In R. J. Sternberg (Ed.), *The nature of cognition*. Cambridge, MA: MIT Press.

Sternberg, R. J. (2005). Creativity or creativities? *International Journal of Human–Computer Studies, 63*(4–5), 370–382.

Sternberg, R. J., & Lubart, T. I. (1996). Investing in creativity. *American Psychologist, 51*(7), 677–688.

Thomson, P., Hall, C., & Jones, K. (2012). Creativity and cross-curriculum strategies in England: Tales of doing, forgetting and not knowing. *International Journal of Educational Research, 55*, 6–15.

Treffinger, D. J., Isaksen, S. G., & Dorval, K. B. (2000). *Creative problem solving: An introduction* (3rd ed.). Waco, TX: Prufrock Press.

Tyler, R. W. (1949). *Basic principles of curriculum and instruction*. Chicago, IL: University of Chicago Press.

Warr, A., & O'Neill, E. (2005). Understanding design as a social creative process. In *Paper presented at the 5th conference on creativity and cognition*, ACM, London, UK.

Wolcott, H. F. (1994). *Transforming qualitative data: Description, analysis, and interpretation*. Thousand Oaks, CA: Sage.

Zhou, C. (2012). Fostering creative engineers: A key to face the complexity of engineering practice. *European Journal of Engineering Education*, *37*(4), 343–353.

Zhou, J., & Shalley, C. (2003). Research on employee creativity: A critical review and directions for future research. In J. J. Martocchio & G. R. Ferris (Eds.), *Research in personnel and human resources management* (pp. 165–217). Oxford, UK: Elsevier Science.