Pan-mentoring in creative engineering design – the coordination of individual and team creativity

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Abstract - Pan-mentoring is an approach to creative engineering design education establishing a close relationship with and within design teams of students. This paper focuses on the role of the pan-mentor in creative engineering design as a coordinator of individual creativity and team creativity. Globalization and fast changing technologies require that engineering design education prepare students to become flexible, innovative, and resourceful engineers. This translates into an emphasis on creativity in a wider sense than is currently practiced. Such an approach involves: analyzing individual learning types; providing engineering design tools, such as hand sketches; and introducing evolutionary design. This also involves exploring the notion of team creativity, including gender and ethnicity issues. In this context the role of the pan-mentor consists of: helping students to effectively tap their creativity as individuals and as teams; guiding them through the design process at both the individual and team level; and encouraging self-reflection and assessment. This paper will show that the coordination of individual and team creativity under the guidance of a pan-mentor can enhance engineering design education and help to prepare students for a fast changing future.

Index Terms - creativity, engineering design, individual, team, pan-mentoring.

INTRODUCTION

The teaching of creative engineering design has a reputation for being both complex and challenging [1-3], but also for being underestimated [4]. The vagueness and open-endedness of the design process and the high level of creativity involved presents challenges for both students and instructor and require further research and improvement [4-10]. Globalization and fast changing technologies require that engineering design education prepare students to become flexible, innovative, and resourceful engineers [6, 9]. Klukken et al. [9], reacting to increasing concern in industry about traditional engineering education, argue that ‘autonomy and support’ are significant contributors to creative engineering. This translates into an emphasis on creativity in a wider sense than is currently practiced [11]. Such an approach involves: analyzing individual learning types; providing engineering design tools, such as hand sketches; and introducing evolutionary design. This also involves exploring the notion of team creativity, including gender and ethnicity issues [12].

This paper looks at the role of the pan-mentor (from the Greek πας meaning all, to indicate a mentoring relationship with a team of students) as a coordinator of individual and team creativity. The term “pan-mentor” was coined by Ekwaro-Osire [2] in the context of capstone design course, presenting the concept of a close relationship with teams (3-5 students) of students to compensate for the special challenges of creative engineering design. Individual creativity here relates to the process of generating ideas on the basis of learning types and brainstorming techniques. Team creativity relates to the additional creativity, which is generated through synergy and team dynamics. Carkett [12] also distinguishes between aspects of creativity as a process to generate creative thought, creativity as relating to personality traits, and creativity of environment. The focus of this paper is the coordination of these different aspects, individual and team creativity, under the guidance of the pan-mentor into a synergetic outcome.

Pan-mentoring requires experience in design research, experience in industrial design (including team dynamics), and experience in pedagogics of engineering design education. The functions of a pan-mentor are: the creation of a design conducive environment; the provision of additional information; the encouragement of autonomy and individual learning styles; and psychological support of the students [2]. In the context of creativity, the role of the pan-mentor is particularly important, as it consists of: helping students to effectively tap their creativity as individuals and as teams; guiding them through the design process at both the individual and team level; and encouraging self-reflection and assessment. The coordination of individual and team creativity under the guidance of a pan-mentor can enhance engineering design education and help students to use their creativity in the design process efficiently.

THE PAN-MENTOR

I. Characteristics of the Pan-Mentor

Pan-mentoring in the sense of establishing a close relationship with students without imposing methods, views, or solutions, can compensate for the special challenges of creative engineering design education [2]. The vagueness inherent in the design process poses a challenge for students and can even
A major characteristic of the pan-mentor is his or her accessibility. Communicating one’s willingness to help can be as simple as promptly answering the students’ email queries or regularly requesting feedback from the students. Gall et al. [13] list a variety of methods to maintain a high level of accessibility, such as establishing an open-door policy, establishing group help sessions, addressing students by their names. They found that these methods enhance the student learning experience. Carkett [12] speaks of creativity to be ‘encouraged and nurtured,’ emphasizing the social aspects of design as an essential aspect of the design process. The pan-mentor pays tribute to the human aspect in creative engineering design.

II. Providing the Tools

Klukken et al. [9] mentioned that the two pillars of creative engineering are knowledge acquisition and deliberate openness. The pan-mentor provides the tools for this, namely, brainstorming techniques, sketching techniques, communication techniques and research techniques. Throughout the design process, the students use these tools increasingly independently.

III. Providing the Environment

The pan-mentor also provides an environment conducive to creative engineering design. In this context, the term ‘environment’ encompasses the composition of teams (psychological and social aspects), access to research information, and communication with the other design stakeholders. Concerning the composition of teams, the pan-mentor needs to be aware of stereotype threats [14] and gender and minority issues [15, 16]. Another consideration is the difference between learning styles [17]. As part of the environment, the pan-mentor also functions as ‘environmental scanner,’ combining experience with information beyond the student design situation [18]. Not to be neglected is the atmosphere of the work environment. Klukken et al. [9] stress the importance of ‘freedom from restrictive management’ – an aspect which is characteristic of pan-mentoring.

IV. Monitoring the Design Project

Apart from providing tools and environment, the pan-mentor’s main task is to monitor the design project, to be on call and be available. Obviously the design process characteristically does not evolve in a linear manner, but should be interrupted by phases of reflection of the work and working. This process, which Schön [19] calls ‘reflection in action,’ is greatly facilitated by the presence of the pan-mentor. Since students tend to react to revisions with a certain frustration, it is up to the pan-mentor to provide reassurance, possible expertise, and encouragement. Based on Schön’s [19] research of the design process, Adams et al. [8] point out the importance of ‘back-talk’ in the sense of a ‘reflective conversation with the materials,’ – a technique that will also be fostered by the pan-mentor. The pan-mentor needs to point out that it is desirable not to solve problems instantly. Exceptionally creative design engineers arrive at solutions by a series of approximations and reflective thinking [12].

INDIVIDUAL CREATIVITY

I. Individual Brainstorming

Ideally, brainstorming taps a person’s creativity in several ways. Often, a designer is most comfortable with a particular brainstorming technique. To increase the creative output, the pan-mentor should present a variety of brainstorming techniques, however. Vidal et al. [11] classify brainstorming into sentential, visual, and objectual. While the objectual variant may be difficult to achieve in a classroom setting, the pan-mentor can still demonstrate this method and leave its use up to the individual student. Sentential and visual brainstorming (such as listing, circling, and sketching) may require as little as paper and pencil and can easily be practiced.

At the early level of brainstorming one should adhere to two basic principles of ‘deferred judgement’ and ‘quantity breeds quality’ [11]. According to Pete [20] it is crucial that during brainstorming, engineers refer to outside interests. This is the reason it is important that brainstorming starts off at the individual level. Keeny [21] proposes stimulating creative design alternatives using customer values. At the initial stage the students should be encouraged to listen to the customer, but they should keep in mind that they should assist the customer in the framing of the problem.

II. Hand Sketches

Even in the age of CAD, hand sketches remain very potent tools in creative engineering design, particularly at the very early stages of design. Both Boeck [22] and Gibiec [23] value the creative potential of the hand sketch as ‘unübertroffen’ (unsurpassed). Boeck points out its stark contrast to CAD systems and writes that even though attempts a being made to bridge the gap between hand sketches and CAD systems, such tools are not yet commercially readily available. Some recent tools on the market include DigiMemo [24] and SketchAR [25]. Rodgers et al. [26] focus on the sketches potential to record transformations, both in the lateral and vertical directions. Sketches can generate and demonstrate a movement to slightly different ideas, or from one idea to its more detailed version. It is the pan-mentor’s task to inspire excitement about and appreciation of such a basic tool, at the conceptual stage of the design process, for students who have grown up relying on the computer as a most efficient tool. The pan-mentor needs to remind the students of the value of hand sketches as information for late use [27]. The potential of the hand sketch as a communication tool will be explored in more detail in the section on team creativity.

III. Evolutionary Design

Evolutionary design can serve as a creativity tool in engineering design education by appealing to student interest, incorporating both individual and teamwork, recognizing the
demands of industry, and demystifying the design process. Evolutionary product design, instead of designing a product from scratch, is often used to improve the product and better fulfill the customers’ expectations, while reducing the development time and cost. Industrial designers as well as design researchers agree that the reuse of design information is much more time- and cost-effective than a re-invention [27]. It has been noted that evolutionary product design methodology can be categorized into: the product information recovery phase, the information management phase, and the information reuse phase [27].

As part of the idea generating activities, especially at the individual level, software systems providing data of previous design histories constitute a useful tool [12]. The students can use this information as starting point for idea spin-offs. Ball et al. [1] also emphasize the importance of analogical reasoning, including the use of information from other episodes of the design process.

TEA M CREATIVITY

I. Team Dynamics

Design in increasingly recognized of a ‘team process’ [4]. While it is also possible to start brainstorming in the team setting, it is often desirable to start out individually and follow up by comparing notes in subsequent team brainstorming. If team members spend some time on individual brainstorming, they can draw on outside interests (as described earlier). The ideas generated then provide the basis for team brainstorming. The succession of the two phases means that now the team brainstorming session can be used to its fullest potential. The comments by Rodgers et al. [26] on the potential of hand sketches to record design transformations on the lateral as well as vertical level, can be expanded to the development of ideas suggested by individual team members. During team brainstorming these ideas can be used as starting points for refinement or for spin-off in a different direction. Thus, a group discussion creates synergy, leading to an increase in quantity and/or quality. During such a session the pan-mentor should ask the students to adhere to the ‘four golden rules’ [11] of brainstorming: quantity is wanted, combination and improvement are sought, freewheeling is welcomed, and criticism is ruled out.

II. Polyphonic Composition of the Team

Concerning the composition of the teams, it is desirable to have a diverse mix of students with different talents and skills. While diversity usually refers to gender and ethnicity other aspects of diversity also distinguish students from each other, such as learning styles, approaches to learning, and intellectual development [17]. Ideally students are to some extent aware of there learning styles. For example they might know if they are more at ease with theory and abstraction or with fact and observation; if they prefer visual or verbal presentation of information. If time permits, the pan-mentor can administer the Myers-Briggs Type Indicator® which classifies people in a way that could be useful to team composition. This psychological indicator distinguishes between extraverts and introverts, between those who are rather practical and those who are rather imaginative, between thinkers and feelers, between those who come to conclusions quickly and those who defer judgment. Just as Felder et al. [28] consider the understanding of learning styles, based on personality types, to be essential for a balanced instruction, such an understanding is also helpful for the composition of a diversified team.

In their examination of team gender composition, Laeser et al. [15] suggest that students may need help to facilitate their working in mixed gender teams. Since this class is process oriented (the students need to learn about the design process) the pan-mentor should encourage the formation of mixed gender teams. A diverse background of the team members seems to be useful, considering the notion that drawing on one’s own frame of reference generates a bigger pool of creative ideas for a team [29].

ASSESSMENT

I. Student Assessment

The students will be assessed using four tools, namely, design notebook, peer evaluation, examinations, and product evaluation. Each student will keep an ongoing record of activities, questions, and comments in a design notebook. The book will have weekly entries depending on how often the groups meet and when assignments are given by the pan-mentor. The students will also enter their reflections on what has been learned or experienced, especially concerning areas of possible improvement. This notebook should contain the entire documentation of the creative engineering design process, from the earliest phases of brainstorming, to minutes of team meetings. It should also contain hand sketches, research information, and thoughts on design improvements to demonstrate individual responsibilities for the team project. The pan-mentor should point out the importance of including date and time spent on each task (e.g., time spent on internet research).

In regard to teamwork as practiced in industry, the team members should also rate each other’s efforts. These peer evaluations should be based on a questionnaire provided by the pan-mentor, which includes ratings of team members’ attendance of meetings and contributions to creative productivity, information gathering, and reflective thinking. Both the pan-mentor and the industrial client will conduct the product evaluation. Examinations should include questions about the creative design process (such as a demonstration of knowledge of the various brainstorming techniques), hand sketching techniques, research techniques and design process documentation and communication.

II. Course Assessment

The pan-mentor, the students, and industrial clients at the end of project will assess the course. For each, the assessment tool will be a questionnaire developed by the pan-mentor. For the industrial clients, the questionnaire will ask for input regarding the relevance of the course to their company, including areas
of improvements, as well as the strong points of the course. Most design projects for example capstone design projects will be industry sponsored.

However, since the course is process oriented, the main contribution will come from the pan-mentor’s introspection and from the students. The student survey will address the students’ attitudes concerning the design process: ‘Did you experience few/many moments of designer blocks?’ ‘Did you feel comfortable with just stepping back and reflecting?’ ‘Do you feel that considerable time spent on problem definition is time well spent?’ Questions like these re-enforce the importance of reflective practice in creative engineering design, both at the individual and team level [8]. When analyzing questionnaires, the pan-mentor needs to be aware of the possible draw back of such tool as listed by Olds et al. [30] (e.g., that the accuracy depends on the honesty of the subject).

III. Pan-Mentor Assessment

Since the pan-mentor is an essential element in the creative design education, answers to the questions mentioned above will already reflect on the pan-mentor. For example, how comfortable a student feels about making revisions, both during individual and teamwork, is influenced strongly by the pan-mentors encouragement and reassurance. Still, the questionnaire could include questions like ‘Did the instructor relieve some of your anxiety?’ ‘Did the instructor give equal attention to all team members?’ Since accessibility is an important characteristic of the pan-mentor, the questionnaire should include a feed back on accessibility [13]. Program objectives and course syllabi are also appropriate documents to give a feed back on the pan-mentor [31].

COORDINATING THE DESIGN PROCESS

I. Introducing Creativity Tools

At the beginning of the course, the pan-mentor should introduce the three creativity tools of brainstorming, hand sketches, and evolutionary design. Many students spend inadequate time on brainstorming and/or have employed so far only one technique, such as Listing. Therefore, the instructor should briefly demonstrate alternative techniques, which students would then practice. The pan-mentor chooses one of several suggestions generated by the class (e.g., a new toy) for the students to brainstorm on; the students should not use the technique they are used to, but rather familiarize themselves with the others.

Next, the pan-mentor focuses on the specific advantages of hand sketches and provides a topic for the students to exercise. Both the hand sketch exercise and the brainstorming exercise should evolve around a topic appealing to the interest of the students, and a relaxed and playful atmosphere should be maintained. At this point it is important to remember the pan-mentor has to ‘sell’ these techniques to possibly rather reluctant students. A topic such as ‘Take ten minutes to sketch a mars vehicle’ sparks interest and can be motivating. Then the students use their hand sketches to communicate their ideas to a partner.

Evolutionary design usually does not meet the same reluctance but tends to be greeted with enthusiasm. Here, the pan-mentor needs to make sure that the students continuously stop to reflect on the decisions the original engineers of their research object took.

II. Coordinating Individual and Team Creativity

After the pan-mentor has initiated team building and assigned projects, the students start to work according to a structure provided by the pan-mentor. An initial phase of individual brainstorming is followed by a comparison of notes and discussion within the team setting, as described earlier. The combination of individual and team creativity should lead to a generous amount of ideas to proceed with. At this point, the pan-mentor should visit extensively with each team to ensure that students spend sufficient time on the definition of the problem, instead of rushing to a premature solution. Here, the role of the pan-mentor is crucial in advising students about the next step. Some teams will be able to envision a possible solution and therefore a work-plan faster than others; they may have decided on these already during the first team brainstorming and discussion. Other teams may need more time and should be advised to go back to another phase of individual brainstorming and problem definition. Thus, the pan-mentor encourages an alternation between individual and teamwork, emphasizing all along the importance of reflective thinking. The pan-mentor should make sure that the students communicate in a professional manner.

III. Completing the Project

After a while, the pan-mentor may be able to identify those students whose personality type leads them to rush to conclusions (and who should accordingly be encouraged to spend more time on exploring alternatives). Others may need to be reassured that their vision is worth being shared by the team. All students need to be reminded and reassured that it is an integral part of the design process to step back and reflect on the decision taken so far. The pan-mentor should encourage student to re-use existing information such as hand sketches. This emphasizes also that hand sketches are useful communication tool. The students also have to be reminded that creative, innovative thinking is not limited to the first phase of brainstorming, but that it continues throughout the entire design process. If students need to abandon the initial solution path, they may feel frustrated or even inadequate. It is up the pan-mentor to help students accept this as a natural part of creative engineering design. The assessment tools discussed in the previous section will be applied at the end of the course.

APPLICATION

For the last three years the concept of pan-mentoring has been practiced by the first author at Texas Tech University, in the context of capstone design course. Its application is currently being explored in freshman engineering at Indiana University-Purdue University Indianapolis. Currently, the assessment questionnaires provided by the university (which show consistently positive student evaluations) does not include
some of the aspects mentioned in the section “Assessment.” However, the authors are confident that the aspects previously outlined will be included in the questionnaires in the near future.

So far, the informal response in oral and written form by students and course alumni now in industry has been very encouraging. Granted that this information is anecdotal, the “student evaluation” has been positive. Written responses from students, who have been working in industry for two to three years, include comments such as: “His teaching philosophy and guidance in design techniques during my undergraduate career gave me the tools I need to excel at the tasks my job requires. His personal attention helped me be confident in my own abilities.” “I learned from Dr. Ekwaro-Osire that the philosophy of good teachers is not to simply give instructions; rather to lead students to ask their own questions and come to their own results … these methods were instrumental in my development into and interest in being a designer.” “I find myself often using some teamwork and leadership skills that I learnt from a senior design project class that he (Dr. Ekwaro-Osire) taught during my last semester there.”

CONCLUSION

In this paper, it has been shown that the pan-mentor plays a critical role in the creative engineering design process as the coordinator of individual and team creativity. This is attributed to the characteristic functions of a pan-mentor, namely, the creation of a design conducive environment; the provision of additional information; the encouragement of autonomy and individual learning styles; and psychological support of the students.

ACKNOWLEDGMENT

The second author would like to acknowledge funding for part of this work, from the Office for Professional Development grant for Special focus Gateway Development and Purdue School of Engineering and Technology both at Indiana University-Purdue University Indianapolis.

REFERENCES