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A Design-Centric Approach for Augmented Reality Collaboration*

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Due to the advances and development in computer technology, it is imperative for teachers to use digital tools to instruct students on subjects that are previously accomplished by traditional media and communication methods. The growth and spread of computer-assisted instructions stimulate design educators to develop pedagogically effective learning environments for traditionally studio-based design education to cope with the demand for interdisciplinary collaboration. The main purpose of this study was to investigate how students interact with augmented reality in interdisciplinary design teams and to evaluate their attitudes toward the system. An augmented reality based design collaboration was proposed to facilitate interdisciplinary design work. The result indicated that design students and engineering students tended to regard the system as more stimulating. However, design students tended to regard the system as unreliable. It is hoped that a design-centric augmented reality collaboration can increase student learning motivation and learning achievements.

Keywords: augmented reality; design education; ARToolKit

1. Introduction

The purpose of design education is to teach design students the essential skills of innovation, aesthetics, communication, expertise and teamwork. It is also to transfer knowledge of solving design problems in such a way as to prepare the students for their development from novices to design experts [1]. After graduation, the students can immediately engage in industrial design, product development and innovation management. Nowadays, computer aided design has become a recognized technique for industrial designers, and is moving from the margin to the centre of the design process. Many software and hardware systems are developed to support different design activities. Such exploding growth means that a variety of approaches can be taken to explore the full potential of computers for design purposes. It is necessary for design students to match up with the development of the design industry and the progress of digital technology by collaborating with other disciplines. Many design courses use computers to integrate multiple media into teaching and learning. However, the success of interdisciplinary collaboration depends on the smoothness of communication among various disciplines. The purpose of this study was to use augmented reality in interdisciplinary design education to facilitate the process of communication among students from different backgrounds. Students' experience accumulated in interdisciplinary communication can help to enhance their involvement in related businesses soon after graduation.

Communication is an important interpersonal activity that helps people to understand each other, to solve problems and to reach an agreement on differences of opinion. However, design communication is becoming more and more complicated with a large increase of information and media streams. The development of interdisciplinary design projects reflects the need for design collaboration and coordination, while the success of interdisciplinary collaboration depends on the smoothness of mutual communication and design presentation. Advances in computer technology provide a wide range of applications that revolutionize the practice of the design industry to cope with increasing global competitive pressure. Businesses and the design industry especially need to embrace technology to deliver cutting edge, usable information that will ultimately add to commercial success. Through the accumulation of experience to create a design-centric framework that supports interdisciplinary communication more efficient, it is hoped that design decision-making can be assisted and design quality can be promoted in an augmented reality environment.

In this study, a design-centric approach was used in an augmented reality system for interdisciplinary product design. The purposes were as follows.

(1) To evaluate the applicability of augmented reality technology for interdisciplinary collaboration.
(2) To implement augmented reality in design education and to explore the process of interdisciplinary communication.

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(3) To reflect students' attitude toward the use of augmented reality for further improvement.

2. Literature review

2.1 Augmented reality

Although traditional communication among designers and team members works sufficiently, design professionals are interested in introducing more productive and effective methods for improving the communication experience during interdisciplinary collaboration. The emergence of technological innovations such as virtual environments provides the potential for such a purpose. Virtual applications can provide the tools to allow users to communicate in a quick and happy mode by playing in virtual environments [2]. One of the most promising technologies that currently exist is augmented reality (AR), which is a variation of virtual reality (VR). VR technology completely immerses a user inside a synthetic environment. While immersed, the user cannot see the surrounding real world. In contrast, AR allows the user to see the real world, with virtual objects superimposed upon or mixed with the real world. Therefore, AR supplements reality, rather than completely replaces it. Ideally, it would appear to the user that the virtual and real objects coexist in the same space [3]. The main advantage of using AR is that users can see and manipulate 3D objects in real time without the knowledge of traditional 3D modelling software. By perceiving and experiencing directly in three dimensions, spatial relationships could be comprehended better and faster than with traditional methods [4].

Previous works [5–8] explored the use of AR in education and its prospect. These works focused on presenting 3D graphical models to students, in order to assist them with solving spatial problems. However, the application of AR in design education was little explored [9]. There were applications for design collaboration, such as the utilization of 'sharing space' for the environment of 3D computer—supported collaborative work (CSCW) that strengthened the reality of designed objects and environments [10]. Augmented reality was used to increase designers' working space to observe their interaction in a virtual environment [11]. Designers were even provided with head-mounted displays to interact with 2D and 3D information [12]. However, portable and stand-alone augmented reality system was also developed with self-tracking and running on an unmodified PDA with a commercial camera [13]. Researchers proposed useful principles for the design of augmented reality from the viewpoint of product design to avoid pitfalls, which included the use of proper visual design techniques and the understanding of the user's experience. They also suggested that industrial designers should participate in the technical development of augmented reality [14]. Therefore, the development and application of augmented reality to design education is not only a technical issue, but also requires a design-centric approach to make it more suitable to students' needs and interests.

2.2 Interdisciplinary design

Interdisciplinary design, which is common in a modern design firm, is often considered to be pivotal in the innovative design process. Today's design problems are often interdisciplinary. Designers from many different domains must cooperate to reach a solution [15]. As a result, design seems to have become even more interdisciplinary than in the past [16]. An interdisciplinary team is an entity that has a structure, a definition, a direction, an identification, and group energy or synergy [17]. Interdisciplinary team functioning is also a process of development and change. However, within the interpersonal team perspective, three factors appear to promote or hinder interdisciplinary activities: goal and role conflict, decision-making, and interpersonal communication [18]. Interdisciplinary design has created challenges in design collaboration due to the difficulty in communicating and coordinating across disciplines [19]. Team members from different disciplines may view and solve the same problem from different perspectives, with their own unique method and language, which may create barriers to information sharing [20]. To improve design communication in interdisciplinary collaboration, information sharing across disciplines needs to be supported.

2.3 Design-centric communication

The central role of design in an engineering curriculum is increasingly recognized at various universities [21, 22]. Design is at the core of engineering. Consequently, other important elements of a strategic engineering design program are technology, business processes and users. Integration of these elements into a design-centric curriculum requires reconceptualization of the current educational paradigm. Hence, scholarship in engineering education is an integral component of the strategic engineering design program [23]. The emphasis on design, collaboration, and team work in the engineer's curriculum gives students skills in information management and 'learning to learn' for the complexity of each new project. The multiple values of a design-centric engineering education are the future of the field. Design-based teaching and project-based learning recognize that the best way for students to learn—and most of all to truly understand—is by doing [24].

Whenever there is a design task that involves interdisciplinary members, understanding and facilitation of communication is important. Design communication appears to have a unique quality that separates it from other forms of communication. By better understanding the demands of design communication, we can better understand the nature of interdisciplinary design and how documentation practices enable specialists to work across boundaries [25]. Team communication plays an important role in interdisciplinary design. Communications that improve interdisciplinary functioning include sharing of self, ideas, knowledge, responsibility, aspirations, and disagreements; feedback that is frank, constructive, and issue oriented rather than personal; and the thoughtful examination and consideration of differences [18]. Each design domain has a unique view of the design problem and will search for a solution that is consistent with this view. For the design solution to be successful though it must be consistent with the views of all the various design domains. One of the greatest barriers to successful interdisciplinary design is the inability of designers from different disciplines to understand and appreciate the different views of other design parties involved in the same project [26]. Communication is often problematic in interdisciplinary teams and therefore the coordinated searching and sharing of information is an important team phenomenon to examine [27]. It was suggested that a structured organization could facilitate design communication and consequently contribute to the success of the design project. Computer supported collaborative work required managing design tasks as well as information flows, and supporting three levels of communication, including individual, group and project [28].

3. Research design

3.1 Interdisciplinary product design

This study investigated interdisciplinary design collaboration by configuring a simple AR environment, and traditional 2D drawings were also used in media presentation. The test subjects were specially chosen to represent interdisciplinary team members in different areas, such as design, management and engineering. Each team included three students from different backgrounds, and there were a total of six teams participating in interdisciplinary design collaboration, as shown in Table 1.

In order to make the experiment run smoothly, the topic of this study and the role of each team member were introduced at the beginning for the students' understanding of their functions in assisting each team to achieve its stated purpose. The procedure of the experiment was described to facilitate the students' preparation and understanding of intended performance. The duration of each team session was 40 minutes by default. Each team was provided with AR media and traditional 2D drawings, and there were two design projects for discussion. During each discussion, a team member with management background controlled the timing for each team. After the discussion of a project, team members were interviewed in a focus group for their experience and preference of using traditional and AR media. The interview time was between 15 to 20 minutes. Each interview was recorded and transcribed, and was checked by interviewees for subsequent analysis.

3.2 The AR system for interdisciplinary design

The system was based on the augmented reality application ARToolKit, which is a tool for developing AR interfaces using computer vision based tracking with square markers. It provides AR tracking, virtual object overlay and simple interaction techniques. It is one of the leading open-source AR programming libraries and runs on Windows, Linux and Mac OSX operating systems. The only hardware required is a computer and a low-cost USB web camera. The requirements for a marker is that it must be square, must have a continuous border and the image inside the border must be asymmetric. The visual marker is detected in a live video stream, extracting the 3D position of the marker and its rotation.

The system utilized augmented reality as a medium for presentation, and used 3D models to facilitate design collaboration. The system included a notebook and a camera for the detection of printed markers. By changing, moving and rotating the markers, 3D models were generated, superimposed and displayed on the screen. The system configuration is illustrated in Fig. 1.

Table 1. Interdisciplinary product design teams

Areas of specialty	Management = 6	Design = 6	Engineering = 6
Gender	Male = 10	Female = 8	
Educational background	Bachelor = 7	Master = 10	PhD = 1

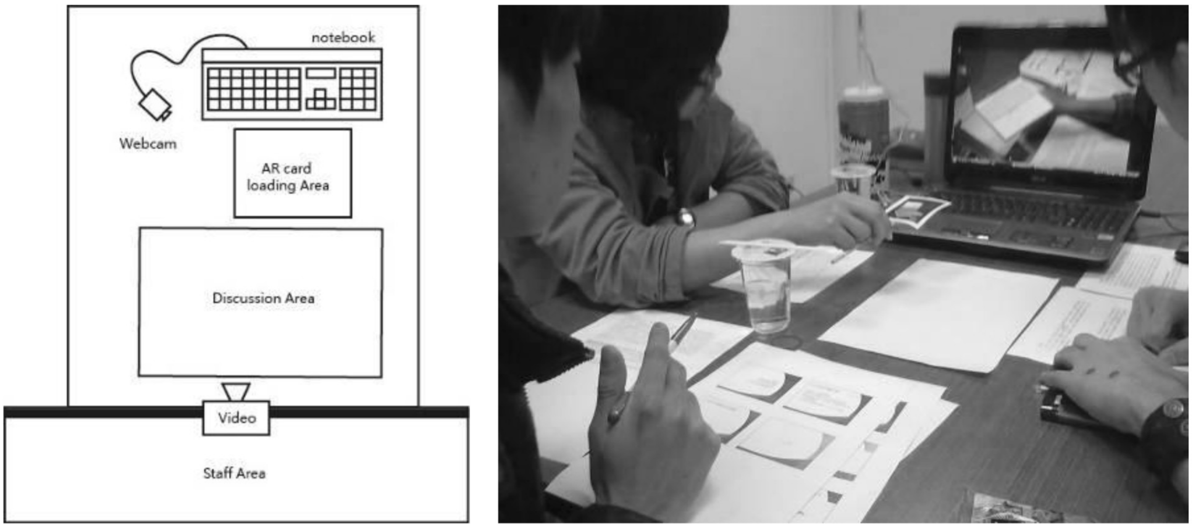

Fig. 1. The collaborative augmented reality system.

4. Results and discussions

The system was evaluated by team members and the questionnaire for user interaction satisfaction (QUIS) was used to measure the quality of user interactions. The overall mean for all questions was a 5.09 on a 1–9 Likert scale. The scale was arranged so that positive adjectives anchored toward 9 and negative toward 1. A one-way ANOVA was used to test for differences among students of three areas of specialty: design, management and engineering. The result is shown in Table 2. There were significant differences in overall reaction to the system (dull/ stimulating) ($p = 0.047$) and system reliability (unreliable/ reliable) ($p = 0.044$).

Further analysis of overall reaction to the system (dull/ stimulating) with a post-hoc LSD-test revealed differences between students as shown in Table 3. There were significant differences between design students and management students ($p = 0.049$), between management students and engineering students ($p = 0.021$). Design and engineering students tended to regard the system as more stimulating.

Further analysis of system reliability (unreliable/ reliable) with a post-hoc LSD-test revealed differences between students as shown in Table 4. There was a significant difference between design students and management students ($p = 0.031$). Design students tended to regard the system as unreliable.

Comments and question ratings on the QUIS indicated areas for interface improvements. The quantitative questionnaire results were investigated further by the focus group and interviews. The results were positive, based on feedback from team members. Students suggested several enhancements such as multitasking and mobility. Some students also indicated that the idea of using augmented reality to identify promising concepts might not be easy for novice users to grasp.

Feedback from the focus group revealed the following advantages of applying augmented reality to interdisciplinary collaboration:

(1) AR-based models are three-dimensional and can be moved in multi-directions conveniently.
(2) AR-based models can be rotated freely.
(3) AR-based models can replace physical rough models.
(4) AR-based models can be manipulated instantaneously to stimulate more design thinking than two-dimensional drawings.
(5) AR-based models increase interactivity in design collaboration.
(6) AR-based models facilitate the understanding of spatial problems.

The system uses AR as a 3D model manipulation tool and the focus is laid on the collaborative aspect of interdisciplinary group discussions. The system can fill in the gap between communication and lack of collaborative support by offering a design-centric way to visualize 3D models that are not only tangible, but also can be interacted with. Interdisciplinary team members can view such models concurrently from different angles on a face-to-face basis. Presenting 3D models in the AR system can stimulate instant and intuitive interactions that encourage exploration of new ideas. Material and colors of models can be changed instantaneously to reduce misunderstanding in communication. Overall, the system brings about joys in designing, the capacity to realize designs, and a sense of accomplishment.

Therefore, AR has the ability to change tradi-

Table 2. One-way ANOVA of the QUIS

No.	QUIS items	P	F test	Mean
Overall Reaction to the System				
1	terrible/ wonderful	0.847	0.168	4.83
2	difficult/ easy	0.451	0.841	5.06
3	frustrating/ satisfying	0.912	0.093	4.78
4	inadequate power/ adequate power	0.596	0.536	4.67
5	dull/ stimulating	0.047*	3.78	4.67
6	rigid/ flexible	0.943	0.059	5.61
Screen				
7	Reading characters on the screen (hard/ easy)	0.847	0.168	5.61
8	Highlighting simplifies task (not at all/ very much)	0.536	0.65	5.39
9	Organization of information (confusing/ very clear)	0.487	0.759	4.39
10	Sequence of screens (confusing/ very clear)	0.809	0.215	4.65
Terminology and System Information				
11	Use of terms throughout system (inconsistent/ consistent)	0.615	0.503	4.47
12	Prompts for input (confusing/ clear)	0.557	0.61	5.12
13	Position of messages on screen (inconsistent/ consistent)	0.905	0.1	4.82
14	Computer informs about its progress (never/ always)	0.849	0.166	5
15	Error messages (unhelpful/ helpful)	0.728	0.325	5.06
Learning				
16	Learning to operate the system (difficult/ easy)	0.113	2.557	5.65
17	Exploring new features by trial and error (difficult/ easy)	0.588	0.552	5.53
18	Performing tasks is straightforward (never/ always)	0.777	0.256	5.65
19	Remembering names and use of commands (difficult/ easy)	0.794	0.235	5.65
System Capabilities				
20	System speed (too slow/ fast enough)	0.865	0.146	5.82
21	System reliability (unreliable/ reliable)	0.044*	3.158	4.88
22	System tends to be (noisy/ quiet)	0.553	0.619	5.18
23	Correcting your mistakes (difficult/ easy)	0.976	0.024	4.76
24	Designed for all levels of users (never/ always)	0.279	1.402	4.88

* $p < a = 0.05$.

Table 3. Post hoc tests of overall reaction to the system (dull/ stimulating).

(I) Specialty	(J) Specialty	Mean Difference (I-J)	Std. Error	Significance	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Design	Management	0.83333*	0.38968	0.049	0.0027	1.6639
	Engineering	–0.16667	0.38968	0.675	–0.9973	0.6639
Management	Design	–0.83333*	0.38968	0.049	–1.6639	–0.0027
	Engineering	–1.00000*	0.38968	0.021	–1.8306	–0.1694
Engineering	Design	0.16667	0.38968	0.675	–0.6639	0.9973
	Management	1.00000*	0.38968	0.021	0.1694	1.8306

* The mean difference is significant at the 0.05 level.

Table 4. Post hoc tests of system reliability (unreliable/reliable)

(I) Specialty	(J) Specialty	Mean Difference (I-J)	Std. Error	Significance	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Design	Management	–1.70000*	0.70789	0.031	–3.2183	–0.1817
	Engineering	–1.36667	0.70789	0.074	–2.8849	0.1516
Management	Design	1.70000*	0.70789	0.031	0.1817	3.2183
	Engineering	0.33333	0.67495	0.629	–1.1143	1.7810
Engineering	Design	1.36667	0.70789	0.074	–0.1516	2.8849
	Management	–0.33333	0.67495	0.629	–1.7810	1.1143

* The mean difference is significant at the 0.05 level.

tional design methods by offering an effective communication platform. It can visualize concepts that lead to an improvement in team members' comprehension. Another import aspect is that interactivity is added to the communication process and is important concerning information sharing for team members. Support for an AR system requires fluent interaction between team members and knowledge in a way that does not impede the process of design collaboration. As the process becomes more interactive, informative and expressive, students can benefit from such an improvement in many areas.

5. Conclusions

The result indicated that the use of augmented reality to support interdisciplinary design collaboration could be beneficial to educational teamwork activities. Design students and engineering students tended to regard the system as more stimulating. However, design students tended to regard the system as unreliable. Therefore, the design of system should be intuitive to use, portable, flexible, and should have much of the functionality of the current design practice, in order to effectively improve design outcomes and to shorten developing time. Intuitiveness is important in the context of both output and input devices. Without intuitiveness, input devices might mislead users and reduce design effect while output devices can not improve design ability simply by digitizing traditional design techniques. Substantiating spatial and abstract concepts in system output is important for computerized design information to successfully increase team members' outcomes in interdisciplinary settings.

The proposed augmented reality system can provide interdisciplinary design teams with necessary information and tools to bring concepts into reality. Such interpretations can broaden the view of traditional computerized systems and pave the way for the development of a multiple digital design environment. Some basic requirements are as follows.

(1) The system can be further incorporated with existing handheld mobile devices to fully exploit the mobility and ubiquity provided by these systems. The time and effort for learning a new system can be reduced.
(2) The system provides a friendly, interactive, relaxed and intuitive environment for team members to explore the full potential of design information.
(3) A group of interdisciplinary members can work together with necessary networking facilities.
(4) The system can help team members to manipulate graphical and textual information, to reveal their insights and inspirations.
(5) The interface has to be psychologically sound as well as ergonomically effective.
(6) Team members can customize the working environment to suit their requirements.
(7) All sorts of feedback are instant and interactive. Team members can get an immediate result from an operation.

Augmented reality can present objects in a more intuitive way that is suitable for developing 3D communication environment for design, and allows students to explore the full potential of design concepts, to evaluate 3D objects before anything is physically built. Students want to be empowered by technology, to apply their knowledge and experience to communicate designs that lead to improved results and greater personal satisfaction. The system can thus build a future in which students will experience competence, clarity, control, comfort, and feelings of mastery and accomplishment.

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References

1. H. Christiaans and K. Venselaar, Creativity in design engineering and the role of knowledge: Modeling the expert, *International Journal of Technology and Design Education*, **15**(3), 2005, pp. 217–236.
2. Z. G. Pan, A. D. Cheok, H. W. Yang, J. Zhu and J. Shi, Virtual reality and mixed reality for virtual learning environments, *Computers & Graphics*, **30**(1), 2006, pp. 20–28.
3. R. Azuma, A survey of augmented reality, *Presence: Teleoperators and Virtual Environments*, **6**(4), 1997, pp. 355–385.
4. H. Kaufmann and D. Schmalstieg, Mathematics and geometry education with collaborative augmented reality, *Computers & Graphics*, **27**(3), 2003, pp. 339–345.
5. F. Liarokapis, P. Petridis, P. F. Lister and M. White, Multimedia augmented reality interface for e-learning (MARIE), *World Transaction on Engineering and Technology Education*, **1**(2), 2002, pp. 173–176.
6. M. Fjeld, P. Juchli and B. M. Voegtli, Chemistry education: A tangible interaction approach, *Proceedings of Human-Computer Interaction INTERACT '03*, Zurich, Switzerland, September 3–5 2003, pp. 287–294.
7. H. Kaufmann, M. Csisinko and A. Totter, Long distance distribution of educational augmented reality applications, *Proceedings of EUROGRAPHICS 2006*, Vienna, Austria, September 4–8, 2006, pp. 23–33.
8. M. Alcañiz, M. Contero, D. C. Pérez-López and M. Ortega, Augmented reality technology for education, *New Achievements in Technology Education and Development*, InTech, Vukovar, Croatia, 2010, pp. 247–256.
9. F. Liarokapis, N. Mourkoussis, P. Petridis, S. Rumsey, P. F. Lister and M. White, An interactive augmented reality system for engineering education, *Proceedings of 3rd Global Congress on Engineering Education*, Melbourne, Australia, June 30–July 5, 2002, pp. 334–337.
10. M. Billinghurst, S. Weghorst and T. Furness, Shared space: An augmented reality approach for computer support collaborative work. *Virtual Reality: Systems, Development and Applications*, **3**(1), 1998, pp. 25–36.
11. G. De Michelis, F. De Paoli, C. Pluchinotta and M. Susani,

Weakly augmented reality: Observing and designing the work-place of creative designers, *Proceedings of DARE 2000 on Designing Augmented Reality Environments*, Elsinore, Denmark, April 12–14, 2000, pp. 81–91.
12. H. T. Regenbrecht and M. T. Wagner, Interaction in a collaborative augmented reality environment, *Extended Abstracts of 2002 Conference on Human Factors in Computing Systems*, Minneapolis, Minnesota, April 20–25, 2002, pp. 504–505.
13. D. Wagner and D. Schmalstieg, First steps toward handheld augmented reality, *Proceedings of 7th IEEE International Symposium on Wearable Computers*, White Plains, NY, October 21–23, 2003, pp. 127–136.
14. J. P. Djajadiningrat, C. J. Overbeeke and S. A. G. Wensveen, Augmenting fun and beauty: A pamphlet, *Proceedings of DARE 2000 on Designing Augmented Reality Environments*, Elsinore, Denmark, April 12–14, 2000, pp. 131–134.
15. C. M. Burns and K. J. Vicente, A framework for describing and understanding interdisciplinary interactions in design, *Proceedings of DIS'95: Designing Interactive Systems: Processes, Practices, Methods, & Techniques*, Ann Arbor, MI, August 23–25, 1995, pp. 97–103.
16. J. Grudin and S. E. Poltrock, User interface design in large corporations: Coordination and communication across disciplines, *Proceedings of ACM CHI'89 Human Factors in Computing Systems Conference*, Austin, TX, April 30–May 4, 1989, pp. 197–203.
17. D. Francis and D. Young, *Improving Work Groups: A Practical Manual for Team Building*, University Associates, San Diego, CA, 1979.
18. C. Mariano, The case for interdisciplinary collaboration, *Nursing Outlook*, **37**(6), 1989, pp. 285–288.
19. B. Curtis, H. Krasner and N. Iscoe, A field study of the software design process for large systems, *Communications of the ACM*, **31**(11), 1988, pp. 1268–1287.
20. A. J. Phuwanartnurak, Exploring the use of Wikis for information sharing in interdisciplinary design, *Proceedings of ACM 2009 International Conference on Supporting Group Work*, Sanibel Island, FL, May 10–13, 2009, pp. 385-386.
21. P. Chang and W. L. Fourney, Design-based course sequence in statics and strength of materials, *International Journal of Engineering Education*, **16**(5), 2000, pp. 430–435.
22. T. M. Regan, J. W. Dally, P. F. Cunniff, G. Zhang and L. Schmidt, Curriculum-integrated engineering design and product realization, *International Journal of Engineering Education*, **17**(4, 5), 2001, pp. 386–390.
23. D. Schaefer, J. H. Panchal, S. K. Choi and F. Mistree, Strategic design of engineering education for the flat world, *International Journal of Engineering Education*, **24**(2), 2008, pp. 274–282.
24. H. Gallegos, The education of an engineer in a holistic age: A Latin American perspective, *Holistic Engineering Education: Beyond technology*, Springer, New York, 2010, pp. 99–111.
25. D. G. Hendry, Communication functions and the adaptation of design representations in interdisciplinary teams, *Proceedings of Designing Interactive Systems (DIS2004)*, Cambridge, MA, August 1–4, 2004, pp. 123–132.
26. K. R. Boff, The Tower of Babel revisited: On cross-disciplinary chokepoints in system design, *System Design: Behavioral Perspectives on Designers, Tools, and Organizations*, North-Holland, New York, 1987, pp. 83–96.
27. S. Poltrock, J. Grudin, S. Dumais, R. Fidel, H. Bruce and A. M. Pejtersen, Information seeking and sharing in design teams, *Proceedings of 2003 International ACM SIGGROUP Conference on Supporting Group Work*, Sanibel Island, FL, November 9–12, 2003, pp. 239–247.
28. M. L. Chiu, An organizational view of design communication in design collaboration, *Design Studies*, **23**(2), 2002, pp. 187–210.

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