Exploring Group' Design Thinking Patterns in a Principe-based Knowledge-Building Environment

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Abstract: This study adopted a principle-based knowledge-building pedagogy to engage groups in four design-thinking modes (i.e., observation, synthesis, ideation and make prototypes) in an online environment. Participants were 38 college students enrolled in an "Introduction to Living Technology" course at a Taiwanese university. They were randomly assigned to eight groups. Each group discussed their design ideas in a computer-supported collaborative knowledge-building environment - called Knowledge Forum (KF) - to collaboratively design a product. Data includes students' design discussion in KF and analysis focused on online knowledge-building activities and groups' design-thinking modes. In general, knowledge-building activities cultivated students in design-thinking modes during the design process as a group. Specifically, the extent to which groups sustained online engagement and the advancement of their group knowledge had a major impact on their design performance. Ways of applying knowledge-building principles to foster effective design processes are discussed.

Introduction

An important strand of research in design education explores how to foster students' design thinking so that they can be effective knowledge workers (Bereiter, & Scardamalia, 2014; Scheer, Noweski, & Meinel, 2012). This includes research on providing more effective and productive online learning environments. To date, current studies have introduced design thinking not only in professional design practices and in different disciplines, but also identified the process to foster design thinking. However, there have been relatively few studies dedicated to improving researchers' and educators' understanding on how to foster students' design skills using online learning environments or the design of pedagogically effective online activities (Taheri, Unterholzer, & Meinel, 2016).

Innovative instruction studies have proved that principle-based knowledge building pedagogy and technology enabled elementary students to engage in collaborative design projects to make visible their invisible design knowledge, in the form of notes written in shared online environment called Knowledge Forum (KF) (Kangas, Seitamaa-Hakkarainen, & Hakkarainen, 2013). These earlier studies have demonstrated the value of KF as a knowledge-building environment in which students can develop their design ideas. Nonetheless, no study has focused on the relationship between groups' collaborative activities and the development of design-thinking modes in online knowledge-building environments (e.g., KF). The current study is designed to adopt principle-based knowledge building pedagogy to guide students' design work in KF. Our research question was brought out: What are the groups' sequential behavior patterns of design thinking in a knowledge-building environment?

Method

Classroom context and participants

Educational reforms in Taiwan are shifting from teacher-guided, outcome-based education to learner-centered, maker-based, technology-integrated education. Based on that, increasing emphasis focused on cultivating students as design-oriented thinkers and knowledge practitioners. Nonetheless, there is a few courses provided to engage students in such innovative and design-oriented learning environment. In the present study, we employed principle-based knowledge-building pedagogy to engage students in online communities to develop design ideas and sustain idea improvement. The participants were 38 undergraduate students aged 18 to 22 years, from a national university in Taiwan. They enrolled in an elective course titled "Introduction to Living Technology" for a semester. At the start of the course, the participants were randomly assigned to eight small groups (G1 to G8) with four or five members each.

Instructional design

The course had two separate parts, one based on lectures given by an instructor and the other on a student-directed design project (for 14 weeks). The groups were allowed to freely choose project topics based on their interests (i.e., shoes, glasses, cotton swab, e-book projector, VR and its application, parking lot, raincoat). The design projects were taken places in an online environment with the goal to help students develop design modes of thinking through knowledge-building activities.

Groups' design work was explicitly guided by two knowledge-building principles: "community knowledge, collective responsibility" and "improvable ideas" (Scardamalia, 2002). The first principle states that participants should work collectively to advance the group's knowledge. The main KF activities, such as notes generated and read, essentially reflect the extent of students' online engagement. The second principle, "improvable ideas", asserts that ideas are improvable and that collective advancement of knowledge depends on sustained, creative work with ideas as a group. Students are encouraged to identify design topics that interest them and then to contribute their initial design ideas in the form of notes in KF. The important point is the production and refinement of ideas (i.e. knowledge advancement activities) that leads to the evolution of group knowledge, and therefore optimizes their design work.

Data collection and analyses

The data of this research was based on groups' design work in an online environment called KF, which is designed on the basis of knowledge building principles so the KF supports the principle-based knowledge building pedagogy.

Analyses of knowledge-building activities

Knowledge building activities include engagement and knowledge advancement. Engagement data was directly retrieved from embedded analytical tool of KF. We summed up number of noted generated and read. In contrast, knowledge advancement in the online community was assessed by counting their built-on (i.e., connected) notes in the KF database and by coding these notes into six levels of cognitive understanding suggested a revised version of Bloom's taxonomy (see Anderson et al., 2001). Using the six cognitive levels from remembering to creating, along with exemplary verbal concepts to indicate knowledge advancing efforts (such as interpreting, designing, etc.), a score of 1 to 6 was assigned. Two researchers independently coded data and Cohen's kappa coefficient computed was 0.87 ($p < 0.001$).

Analyses of design-thinking modes

During the design process, students were introduced to four design-thinking modes (i.e., observation, synthesis, ideation, prototype creation) to help them design products (Plattner, 2010). Groups' design processes were further coded in six categories in our study: (1) discarded idea: the ideas were left without further discussion (e.g., S35: This cannot work, let's abandon the idea.); (2) social talk: they shared an understanding or emotional response toward a thing (e.g., S8: I agree! This is a good way to try.); (3) observation: they "observe" emerging problems in their daily life and then choose a topic that interested them (e.g., S2: Police officers might be well-trained, additional function to their shoes would give them another way of protecting themselves); (4) synthesis: they "synthesized" all the problems in which they were interested into a set of core problems on which they wanted to do further work (e.g., S5: I think that our design could focus on different functions for different duties or tasks, for example…); (5) ideation: they "ideated" every possible solution to the core problems (e.g., S1:I think that the electricity to be used for shocking should be controlled to just cause minor cramp); (6) prototype creation: they summarized and developed a "prototype" (in concept only, due to time constraints) based on promising ideas they had identified (e.g., S30: Our design could include…). Using notes as the unit of analysis, two researchers independently coded data into above mentioned six coding schemes, with Cohen's kappa coefficient computed to be 0.90 ($p < .001$).

Analytical strategies

In order to answer our research question, we calculated KF activity scores using z-scores based on the sum of online engagement activity (including the numbers of notes contributed and read) score and online knowledge advancement score (number of built-on notes and their quality scores). Next, scores for KF activities were calculated using a two-stage cluster analysis with knowledge engagement and advancement as two principal indicators: (1) first using hierarchical clustering analysis to determine the cluster number on the basis of dendrogram; (2) second using k-mean cluster analysis on the identified cluster number. Last, we examined groups' design-thinking performance using behavior sequential analyses to ascertain design patterns (i.e., discarded idea, social talk and four design-thinking modes, i.e., observation, synthesis, idea generation and prototype creation) for each cluster.

Results

Group design-thinking performance in a knowledge-building environment

The online engagement of the 38 participants contributed 399 notes ($M = 10.5$, $SD = 7.16$), read 2728 notes ($M =$

71.79, *SD* = 79.23). The knowledge building advancement counted 181 built-on notes (*M* = 4.76, *SD* = 4.90) and the mean score of built-on notes was 1.69 (*SD* = 0.60). Cluster analysis was employed to measure students' online engagement and knowledge advancement activities (using *z*-scores). The four clusters which emerged according to the online behavior they represented, Cluster 1 (groups 1 and 6), Cluster 2 (groups 2 and 7), Cluster 3 (groups 3 and 4), Cluster 4 (groups 5 and 8).

We conducted the sequential analysis on the six design behaviors - discarded idea, social talk, observation, synthesis, ideation and prototype creation as exhibited by the four clusters of groups. The adjusted residual *z*-score greater than 1.96 indicates that a statistically significance ($p < .05$) of the continuity of specific initial behavior is followed by a subsequent behavior in the design process (Bakeman & Gottman, 1997). As a result, the design behavioral patterns of each cluster is shown in Figure 1.

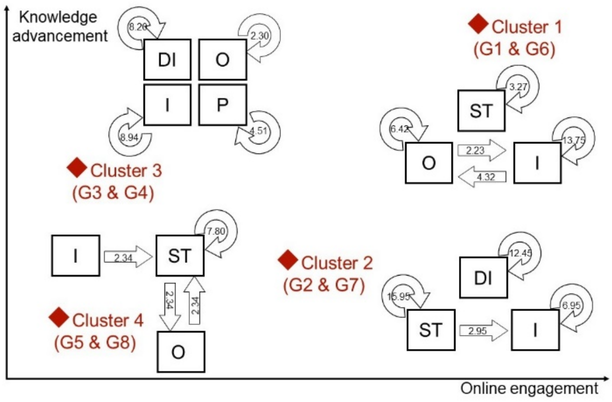

Figure 1. Clusters distribution and design behavioral transition.
Note: DI = discarded idea, ST = social talk, O = observation, I = ideation, P = prototype creation.

The above analyses show an integrating of cluster and sequential analyses of groups' design behavior patterns within the knowledge-building environment. Cluster 1 exhibited high frequencies of online engagement activities and knowledge advancement activities and thus had the best overall design performance as reflected in the sum of their design patterns. Via sequential behavior analysis, we found that groups in Cluster 1 tend to involve in the iterative social talk, observation and ideation. Moreover, they might worked back and forth between observing problems and generating solutions.

Cluster 2 showed that their online activity was dominated by online engagement activities at the expense of knowledge advancement activities and as a result, their design behavioral transition were mainly on iteratively discarding ideas, talking and ideating. As a result, some ideas come after their talking such that group 2 contributed a lot of information, but the information was not being further refined via reflection and elaboration to advance knowledge.

Cluster 3 did better than Cluster 2 at knowledge advancement activities; however, there was relatively little online engagement. This overemphasis on the former is clearly evidenced by the quality of their reflective efforts to advance knowledge through iteratively discarding useless ideas, observing designed problems, proposing possible ideas and making prototype. But their design behavior could not be transited. For example, group 4 worked iteratively on their initial design ideas but did not try to enrich or diversify their initial pool of ideas in order to broaden their ideas solutions.

Lastly, Cluster 4 clearly had the lowest frequencies of online engagement activities and knowledge advancement activities. For example, the groups in Cluster 4 were mainly focus on social talks. As a result, they were not able to decide their design topics. Even though their social talks and observation activities are bi-directionally influencing each other, their social talks were not helpful for observing problems.

Discussion and future directions

The purpose of this study was to investigate whether working in a computer-supported collaborative knowledge-building environment, in this case KF, improves students' design-thinking capability. Students were guided by two knowledge-building principles to encourage them to engage in interactions in an online environment (i.e., "community knowledge, collective responsibility") and advance knowledge (i.e., "improvable ideas"). They involved in design projects to collaborate with group members. To summarize, the findings suggest that the performance of the different clusters would need different, customized guiding principles to further facilitate KF activities and achieve an appropriate balance between them, in order to improve different groups' design performance. For example, we found that many students struggled with particular modes of design thinking and so it might be helpful to design some customized instructional scaffolds to smooth the transitions from one design-thinking mode to another, such as "I observe", "I emphasize", may help novice designers to concretize design ideas and consolidate the complex design process. To facilitate further development of design ideas, it is perhaps necessary to encourage groups to make a fast prototype creation that requires the participants to explain how the prototype would meet users' needs. In addition, setting up more specific and well-defined design goals in each design-thinking mode may be useful.

Moreover, this study showed that groups that demonstrated better knowledge engagement and more knowledge advancement activities also tended to have better and smoother design behavioral transition as indicated by behavioral sequential analyses. In other words, balanced online engagement and knowledge advancement activities in a knowledge-building environment have important effects on students' design-thinking capability.

Instructional implication for future studies should select appropriate pedagogical principles to shape a productive learning environment. This study employed a principle-based knowledge building pedagogy by using two explicit principles and found that providing students with guiding principles helped create an effective knowledge-building environment in which both online engagement and knowledge advancement activities were valued. We found that in an open, collaborative knowledge-building environment that encourages production of ideas and makes it easier to connect ideas to each other, online activities such as contributing, reading and building on notes have to be engaging enough if they are to advance a group's knowledge. For example, groups who find it difficult to move from one design-thinking mode to another might benefit from an additional guiding principle "rise above" (see Scardamalia, 2002, for detail). This principle that highlights group members collectively working towards higher-level understanding of problems, may be useful for guiding the groups to focus on the task at issue, and thus to help enhance group members to enhance their thinking skills. In summary, design thinking is emerging as one of the key thinking competency for the 21st century. To facilitate students' development of design thinking, pedagogical models that with appropriate use of knowledge building principles are urgently needed. Future research into these issues is in progress.

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