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Towards creative reasoning: Scaffolding systems thinking and decision-making

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Abstract: This paper addresses three questions. First, how students can be guided to learn from examples and generate their own ideas without falling into mechanistic substitution from the examples learnt; second, how students can be guided to elaborate on their own ideas; third, how students can be guided to associate concepts in a systemic whole into order to make holistic decisions. Concepts from the learning and decision sciences are applied to address these three questions. Findings indicate positive generation, elaboration, evaluation, reflection and association of concepts culminating in feasible, interesting and systemic decision-making. Three implications to technology-mediated design conclude.

Keywords: Systems thinking, creative reasoning, decision-making, scaffolds

1. Introduction

Making decisions is integral to every aspect of our lives. Hence, it is crucial to train students to reason critically amidst multiple alternatives. However, to create any breakthrough, critical thinking is not sufficient. One needs to reason creatively.

[1] defines creativity as being more than mechanistic substitution of elements, which meet analogical requirements. Instead, creativity requires incremental reflection that facilitates backtracking to consider more alternative search opportunities and consequently elaboration and evaluation of these alternatives in relation to the learning or task goal. To encourage iterative and incremental reflection and the search for alternatives and evaluations of these alternatives, [2, 3] stress that peers or experts who evaluate and determine whether an idea is feasible and worthy of further exploration are crucial.

The underlying factors that contribute towards the need for peer or expert feedback are highlighted by [4, 5]. [4, 5] point out that the building up of schema through the association of concepts and the evaluation and refinement of these associations creates meaning, structure and a basis for further assimilation and accommodation of new concepts. If schema is accurate, then students will be able to draw meaning from what is learnt. However, if schema is inaccurate, reflection and re-evaluation of schematic associations need to be carried out.

The building of schema is characterized by systems thinking. [6] defines a system as "a set of interacting units or elements that form an integrated whole intended to perform some function" (p. 53). In other words, systems thinking aims to help the learner think from a big picture perspective. Thus, to inculcate creativity, [7] suggests that students need to first use systems thinking to identify which and how subsystems contribute to the systemic whole and subsequently reason critically to compare and contrast these information, evaluate the credibility of the information and finally make decisions and solve problems. Hence, scaffolds aimed at inculcating systems thinking should help students to search and reason in a goal-based iteratively deepening manner [8].

1.1 Research objectives

This paper will investigate how to design reflective and evaluative affordance that would increase systems thinking, which would form the basis for creative reasoning in an ill-structured domain, i.e. the business domain. Questions of interest are:

1) How can students be guided to learn from examples and generate their own ideas without falling into mechanistic substitution from the examples learnt?
2) How can students be guided to elaborate on their ideas?
3) How can students be guided to associate concepts in a systemic whole?

The outline of the paper is as follows: Section 2 reviews foundational theories related to creativity. Section 3 presents the research design. Section 4 presents the study outcomes and discussion. Section 5 concludes with implications to technology-mediated design/learning.

2. Related work

2.1 Goals as contextualization and self-regulation scaffold

Goal-based scenarios (GBSs) emphasize on the development of procedural skills as these skills operationalize and enable refinement of schema. Learning of procedural skills occurs within an overriding mission context. The mission context consists of themes that can be adapted into different cover stories (situations, roles and challenges) [9]. These cover stories are woven into interrelated smaller missions structured from easy to difficult situations, roles and challenges.

2.2 Case-based reasoning as adaptation scaffold

Case-based reasoning (CBR) requires students to reflect on their past experiences and to transfer these as heuristics to solve the current problem [10]. Each set of problem-outcome-solution-success/failure and corresponding reasons is a case. Each case is indexed by applicability (situations in which the case can be used) and retrieved based on the learner's current goal and interpretation of what the current problem requires. Hence, the more specific and cohesive the cases (prior problems-solutions) are, the better the quality of emergent solutions. Similarly, the more creative the learner's interpretations of the design/problem requirements, the more optimal the solution will be. However, CBR's value is best seen when students are guided to access and assess information from multiple perspectives, creating cognitive flexibility (CF) [11].

2.3 Summary

The above studies show that meaning is constructed through scientific reasoning and goal-guided reflection. To reason scientifically, students need to learn how to generate alternatives, identify evaluation criteria and the constraints specific to the context, evaluate the strengths and weaknesses of these alternatives and determine possible tradeoffs. To reason creatively, students need to first view creative design/problem-solving as a goal-based iterative design-simulate-test process while working from multiple perspectives. The question remains however, how to use examples as a

launching pad and avoid mechanistic substitution based on these examples, how to guide elaboration and how to guide associations of parts to the whole.

3. Research Design

This paper presents an experiment with creative scaffolding in the business domain. The students involved in this study are 20 groups of students; the population of students taking the course TDS3281 Decision Support Systems. Decision support systems have been presented to them as a response to dynamic business challenges. They have also learnt of processes in decision support as stipulated by [12]: identifying the problem or opportunity, generating intelligence (scanning the environment and reports, making queries and comparisons), designing (creativity, finding alternatives and solutions), making choices (comparing and selecting) and implementing (acting out the solutions).

3.1 Approach

In this paper, to guide students to learn from examples and generate their own ideas without falling into mechanistic substitution from the examples learnt, learning from examples occur only in the first step, i.e. at the generating intelligence stage. Subsequently, to guide students to elaborate on their ideas, students are asked to generate their own ideas using a what-if analysis. Finally, to guide students to develop systemic associations between part and whole, students are asked to rank the opportunities that they have proposed based on feasibility and interestingness, identify possible constraints in their implementation, carry out a drill down analysis to identify means to address these constraints and finally re-evaluate their ranking of proposed solutions/opportunities.

3.2 Methodology

Students are asked to take on the role of chief technological officer for a popular e-card website, i.e., 123greetings.com. Their goal (GBS) is to suggest strategies to increase revenue generated from the website. The mission is structured according to the first three processes of the decision support process. Scaffolds are as follow:

a) Generating intelligence:
   - Scaffold: Compare the technical features in 123greetings.com with 3 competitors (CBR).
   - Activity 1: Mark the features, which exist, as Strengths and those absent, Weaknesses.
   - Activity 2: Identify **O**pportunities and **T**hreats from the above **S**trengths and **W**eaknesses comparison study to complete a **SWOT** analysis.
   - The instructor provides feedback on whether the comparison criteria and comparisons among competitors are accurate.
b) Designing:
   - Scaffold: Traversal between different levels of abstractions to guide systems thinking.
   - Activity 1: Students identify the concept behind each opportunity suggested. For example, the concept behind connecting 123greetings.com to Facebook is social networking. (Asking students to identify these concepts has 2 purposes. First, to

raise the students' reasoning abstraction from technical features to the value that each new opportunity is adding to the business, which contributes to the goal of increasing revenue of the website. Second, to help students generate alternatives at a higher level of abstraction (concept) and not just at the features (opportunity) level.

- Activity 2: Suggest alternatives and solutions from the opportunities that they have identified (what-if analysis). Visualize the alternatives and solutions using a concept map relating each opportunity with how these contribute to the overall goal.
- Activity 3: Evaluate alternatives in terms of feasibility (likelihood to overcome constraints) and interestingness (how much users will be attracted to the new feature) on a scale of 1 to 5. Rank the opportunities based on an average of feasibility and interestingness score for each opportunity and identify the top three ranked opportunities.
- Making choices:
- Activity 1: Identify and elaborate on possible constraints to implementation of the top three ranked opportunities.
- Activity 2: Determine whether it is possible to overcome constraints identified earlier by carrying out a drill-down analysis.
- Activity 3: Based on the outcome of the drill-down analysis, re-evaluate the ranking of opportunities.
- Activity 4: The instructor provides feedback on the coherence of the what-if analysis and drill-down analysis outcomes.

Creative reasoning is evaluated based on the number of new opportunities generated, justification for the proposal, coherence between what-if analysis and drill-down analysis associations and logical outcomes in the students' conclusion.

4. Findings and discussions

As mentioned in Section 1, to *generate* ideas, students did a comparative analysis from existing examples. To *elaborate* on their ideas, students did a what-if analysis, provided justification, and identified the implementation methodology. To encourage *systems thinking*, they ranked their proposals, did a drill-down analysis to identify the constraints to the proposals' implementation and if necessary, reevaluate the ranking of their proposals. The following subsections show examples.

4.1 Designing opportunities/proposals

4.1.1 Number of examples adopted (reused) and number of new opportunities generated

Table 1 shows the number of examples adopted (indicated by the first number) and the number of new opportunities generated per group (indicated by the second number). Due to lack of space, only examples from students with at least three new opportunities generated are shown.

Table 1. Number of adopted examples and new opportunities generated per group

	G1	G2	G3	G4	G5	G6	G7
No. of concepts generated	0, 3	1, 3	1, 5	2, 3	2, 3	2, 3	4, 3

Among the groups, the top 3 groups with the highest ratio of adopted-new opportunities are G1, G2 and G3. The group with the highest number of adopted opportunities is G7, with 4 adopted opportunities and 3 new ideas whereas the group with the highest level of creativity (most number of new proposed opportunities) is G1. Examples from both groups are compared.

G7 Opportunities adopted from other websites:
Online shopping links, related links, photo gallery, mobile e-card

G7 New opportunities:
Create game e-card, relate online shopping links with the E-card to attract the user to see and shop while he/she is sending the card, share e-cards with social websites like Facebook.

G1 New opportunities:
International appeal, integration with social networking sites, integration with video sharing sites

Interviews with both groups of students indicated that they seldom thought of using other websites to generate their own ideas. They also found that marking the presence of a technical feature as strength and the absence of a technical feature as a weakness useful as an evaluation means. Learning this way from examples made sense to them.

4.2 Traversing between different levels of abstraction

G7 students were able to successfully elaborate from the proposed opportunity but were not accurate in identifying the root problem to be addressed for all the new opportunities proposed. For example, for the new opportunity relating online shopping links with the e-card to be sent, the root problem identified was how to attract users to choose another service that is related to the event that he/she wants to send a card for. The next question was what types of services would be attractive. This provided the basis for elaboration. Students identified the need to link to a party/celebration agent who could provide advice what to do and new places to celebrate in.

G1 students were able to identify the root problem without difficulty:
Opportunity: Reach more people internationally

Concept: Diversification through localization (Translating the service into different languages, and hosting some of the service in areas with highest interest) and International advertising online (by using services like AdWords provided by Google the advertising potential for web sites and regions would be maximized).

The ability to go up a higher level of abstraction, to identify the root problem to be addressed, by G1, later resulted in two additional ideas in the what-if analysis (presented in the next subsection). G7 however, did well in elaborating their ideas.

4.3 What-if analysis and ranking of opportunities

The what-if analysis for one of G7's adopted opportunities, i.e., related links, is presented in Fig. 1. The numbers in Fig. 1 refer to the students' ranking of their own proposals. Ranking was carried out on a scale of 1 to 5, with 1 being least feasible/interesting and 5 most feasible/interesting.

Compared with what was proposed initially in Section 4.1, students were able to elaborate on the type of related links (online consultation agent, online traveling agent and event planning agent) as well as what types of services these agents should provide. Hence, self-evaluated what-if analysis did help the students to design, elaborate and concretize their ideas. After evaluating all proposed opportunities, the students decided that the top three opportunities they were going to seriously venture into were photo gallery, online shopping links and provide services and update website.

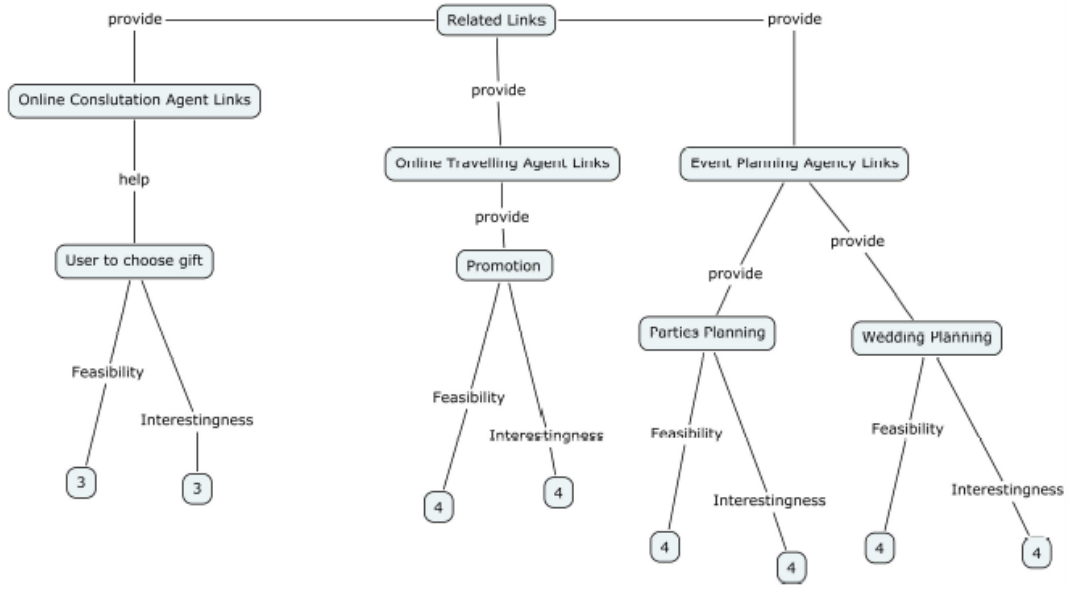

Fig. 1 G7's what-if analysis

As for G1, when asked to do the what-if analysis, they added 2 other new opportunities: personalized cards and printable cards. After self-evaluating each of the 5 opportunities based on feasibility and interestingness and averaging the combined scores, they decided that the top three opportunities that they would venture into are: integration with social networks, integration with video sharing sites and personalized cards.

Reasons for the change in ranking were:

We cannot pursue improvement internationally at the moment due to lack of capital and staff. Although, the most important opportunity from the business point of view, it would not be very interesting to explore since it would involve mainly administration.

Printable cards should not be explored in this time period because they involve entering another field: publishing. Once again, that would involve a lot of paperwork and administration as well as other legal procedures in order to make sure that no intellectual property rights are being violated.

For the sake of contrast it is important to mention the constraints of the opportunities that were not chosen. Firstly, promotion of brand internationally: this would require at least 3 full time persons travelling extensively. The persons would need to be experienced and would need to know what they are doing. This would also require setting up things like a trademark and

registering with various authorities in the region: authorities that may not always be lenient. Secondly, printable cards: first a printer and all the necessary equipment would be needed, then the person who would set all the equipment up, another person who would operate it, and another who would maintain it, in addition to contact with vendors for both the hardware and the materials used.

Based on interviews with the students, having to rate what they proposed in the what-if analysis forced them to really look at what they had proposed and forced them to come up with better ideas to get better grades.

4.4 Drill-down analysis

The drill-down analysis gave them an insight into actual implementation issues. G7 Students were able to identify the constraints for each of the top 3 opportunities mentioned above. For photo gallery, the constraints were the need for big storage space and the cost incurred. On the other hand, for the online shopping links opportunity, constraints identified were attracting vendors to promote their online stores/shopping mall in 123greetings.com, creating a user-friendly user interface to help users navigate through the multiple online shopping links and cost. Finally, for the provide services and update website opportunity, students foresee constraints in terms of getting new ideas, getting developers due to budget constraints, contacting users who often use the website, hiring someone to follow other websites' updates and updating web site security to prevent viruses and hackers as well as to secure customers' privacy.
After considering these constraints, this group of students decided to venture only into the opportunity ranked highest in terms of feasibility and interestingness but lowest in terms of the number of possible constraints, i.e. creating a photo gallery for users. They preferred to leave the other two opportunities to the next phases of development pending new budget outcomes. Hence, drill-down analysis was effective in helping students make choices.
As for G1 students, after self-evaluation, the top three opportunities identified were integration with social networking sites, integration with video sharing sites and finally personalized cards. The main reason for the choice of these three is that there is currently an up-trend in these three opportunities. Constraints identified corresponding to opportunity proposed were lack of capital and staff who are experienced in branding and intellectual property and willing to travel extensively (international branding), lack of expertise and possible violation of intellectual property (printable e-cards). Finally, they decided on the top three new opportunities for the following reasons:

- *Integration with social networking sites: Interesting to make, only cost is time, can be maintained by current staff, social networking is very popular now*
- *Integration with video sharing sites: similar to that of social networking sites*
- *Personalized cards: It's a challenge, would add a personal touch to the site and the cards, it's not currently available everywhere*

The above examples show that drill-down analysis successfully helped students from both groups to associate concepts more holistically, taking into consideration actual implementation issues and subsequently, possible re-evaluation of earlier rankings of proposed solutions. The difference between G7 and G1 however, was the breadth of general knowledge that G1 group members had, which enabled them to think from a broader and deeper perspective.

5. Conclusion

This paper has investigated three research questions. The first question was how students could be guided to learn from examples and subsequently generate their own ideas without falling into mechanistic substitution from the examples learnt. SWOT analysis was used to address the former. As for the latter, generation of new opportunities as opposed to adopted/reuse of other's ideas was emphasized. The second question was how to guide students to elaborate on their own ideas. What-if analysis was used successfully to elaborate on opportunities initially proposed in the gathering intelligence stage. Subsequently, students evaluated their own opportunities, ranked them and identified the top three opportunities in terms of feasibility and interestingness. Finally, the third question investigated how students could be guided to associate concepts in a systemic whole. A drill-down analysis identifying actual constraints that implementers would face during implementation helped students to associate the outcome of the what-if analysis to their company's current resources. The drill-down analysis also helped students to think deeper what they perceived as feasible in concrete operational terms.

Three implications related to technology-mediated design/learning can be derived from this study. First, SWOT analysis was used effectively to help students learn from examples for a website most students are familiar with. However, how can we provide guidance to help students learn from examples in domains which students are not familiar with? Second, technology should help the visualization of what-if analyses. In this study, concept mapping was used. However, how can we scaffold concept mapping more effectively to help students identify root problems? Third, how can we scaffold students who lack general knowledge without incurring information overload? These questions will provide the bases for future investigation.

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