Solving ill-structured problems mediated by online-discussion forums: Mass customisation of learning

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To foster students' learning of critical-thinking skills, we incorporated ill-structured problems in a Human Diseases module for third-year Life Sciences students. Using a problem-solving rubric and working in groups of three, students attempted to solve problems presented to them. We mediated their discussions by asynchronous online discussion forums (AODFs) as part of mass customisation of learning for 40 students where personalised learning was constrained by structure of the module. We examined the quality of students' discussion, focusing on the feedback group members provided to one another, using an interpreted Structure of Observed Learning Outcomes (SOLO) taxonomy to code students' feedback. Our analysis indicated that the students were able to provide uni-structural and multi-structural level in relation to solving an ill-structured problem, even though they are not used to solving ill-structured problems. This indicated that in a mid-size class, while personalised-learning is not always easy, it is possible to mass customise learning for students using common ill-structured problems in a class by mediating problem-solving using student discussions as feedback. However, more can be done to scaffold peer feedback on solving ill-structured problems so that the level of collaborative-learning can be improved in a mass customised model that approaches personalised learning.

Keywords: ill-structured problems; asynchronous online discussion forum; feedback; mass customisation.

Introduction

Real-world problems are often ill-structured problems that have ambiguous information and no standard solutions (Jonassen, 1997). University students, therefore, need opportunities to develop problem-solving skills, apply content knowledge in a rational and relevant manner to solve real-world problems. After graduation, they would be equipped with relevant problem-solving skills that would enable them to contribute productively to society.

However, intentional design of ill-structured problems is not a routine part of curriculum design. In addition, unlike experts, novices such as undergraduates generally do not possess the skills to apply domain-general problem-solving strategies in relation to domain-specific knowledge to solve these problems (Glaser, 1995). Students who are novices at solving such problems can benefit from having a framework (Jonassen, 1997) and support to help them develop problem-solving skills.

In our third-year Molecular Basis of Human Diseases module at NUS, we designed ill-structured problems based on Jonassen's framework (Jonassen, 1997) to provide opportunities for students to learn ill-structured problem-solving skills. The framework describes iterative steps to approach an open-ended problem, beginning with the definition of a problem scope, examining possible solutions based on the evidence available, consider alternative solutions and testing out the solution. Based on previous studies, asynchronous online discussion forums (AODFs) have been found to be effective for students learning in a collaborative manner (Hrastinski, 2009). Accordingly, we organised our students into groups of three to work collaboratively on ill-structured problems at AODFs.

The use of ill-structured problems that are open-ended can form the basis of mass customisation (Schuwer & Kusters, 2014) as an approximation of personalised learning in our curriculum design, where the ill-structured problems posed can be common problems all students have to solve. However, given the open-structure of the problems, there are potentially different solutions. Instructors can leverage peer discussions within groups of students as a means of mass customised learning among students providing feedback to one another. In our conceptualisation of mass customisation, we envisioned that as the discussions among different groups are different, the responses from students among the same group would be focused on group-specific issues and points raised, and hence, provide a customised learning experience for students within each group. In this exploratory study, our research questions in this study revolved around whether students were able to provide feedback to group mates while trying to solve an ill-structured problem collaboratively and if so, what the quality of the feedback was.

Theoretical framework

Problems designed for students to support learning can range from the well-structured ones that mostly test defined concepts within a fixed scenario and a prescribed, perfect solution, to less-structured ones that rely on a range of domain knowledge, have elements of uncertainty about the information available with regard to the problem and have multiple solutions (Jonassen, 2011). Ill-structured problems reflect the characteristics of real scientific issues that scientists deal with in their authentic research work (Aikenhead, 1996; Schwab, 1960) and hence potentially can provide students the opportunity to practise the use of content knowledge and critical-thinking skills within a relevant context.

However, as students might not be equipped to solve open-ended problems, scaffolding needs to be provided. Indeed, from a previous study, we noted that students in our module had difficulties defining the scope of ill-structured problems among other difficulties (Yeong, 2015). Accordingly, we have included scaffolds in subsequent semesters to help students solve ill-structured problems and noted some benefits (Yeong, Foo, & Tan, 2018). Scaffolding refers to appropriate assistance given to novices so that they could solve a problem which is otherwise beyond their means (Wood, Bruner, & Ross, 1976). Previous studies revealed that scaffolds in the form of question prompts could be useful for providing students with the cognitive and metacognitive knowledge that are required to solve ill-structured problems (e.g., see Davis & Linn, 2000; Land, 2000). Of particular relevance is the use of procedural facilitation scaffolds (Guzdial & Turns, 2000) that could help students formulate contributions to the discussion, such as planning the steps of solving a problem. Our scaffolds included the use of questions prompt and message labels on the steps of the ill-structured problem-solving framework (Jonassen, 2011).

Students could further gain from feedback that might help them move from their current state to the desired state (Hattie & Timperley, 2007). In mid- to large-class sizes, prompt feedback provided by instructors might not always be possible. Hence, in addition to merely providing summative feedback from the instructors, we leveraged on group discussions as a form of close to immediate feedback students can receive from their peers. This draws upon the social constructivist theory wherein the ill-structured problem helps create the zone of proximal development (Vygotsky, 1980) and peers provide the scaffolding for student learning so students can develop beyond their initial capabilities. Students as peers working cooperatively together might also have an influence on one another, in terms of the standards expected as well as motivation (Topping, 2005). Moreover, peer as a teacher helping others might have benefits for learning (Whitman, 1988).

As far as personalised learning where learning needs and preferences are tailored to the specific interests of different learners (U.S. Department of Education, Office of Educational Technology, Washington D.C., 2010) is concerned, it was not possible to cater to personalised learning within the constraints of a regular module in our degree programme. Nonetheless, we subscribe to the idea that a continuum exists in the approaches towards tailoring instructional design (Schuwer & Kusters, 2014). In our discussion forums where students attempt to solve ill-structured problems, the open nature of the questions allowed for diverse approaches and solutions (Jonassen, 2011). Other than scaffold and instructor's feedback, comments from groupmates served as immediate feedback for peer learning that would be targeted in response to posts by students themselves. This was conceptualised as the mass customisation of learning (Schuwer & Kusters, 2014).

In this paper, we examined students' posts in AODFs, with a focus on the feedback that students provided for their peers. In particular, we evaluated the quality of students' feedback within a discussion group as a form of mass customisation of learning, given that targeted comment provided by group members served as feedback for members' solutions to the problem and served as an approximation of personalised learning. In our exploratory study described here, we used the SOLO taxonomy (Boulton-Lewis, 1995) to categorise the posts as a proxy for the quality of students' feedback to one another.

The SOLO taxonomy is organised in a hierarchical manner, where students might start at demonstrating little knowledge or competence (pre-structural level) in the subject matter. As students develop, they learn to deal with one relevant aspect (uni-structural level) and subsequently, several relevant aspects (multi-structural level) of the topic. At the more advanced levels, students could demonstrate the ability to integrate different aspects of knowledge into a structure (relational) and even generalise their knowledge to a new domain (extended abstract). The assumption we have made here for our analysis is that the better the ability of the student to provide feedback at the more advanced SOLO levels, the better the quality of the feedback. This is based on evaluating whether the students had been targeting the scope, information or solutions related to the problem posed, as they provided feedback to one another. The feedback could, therefore, range from not connecting their comments to the problem at-hand to extending their comments beyond links to the problem posed to a broader view.

Materials and Method

Module information and recruitment for the study

The elective module was on Molecular Basis of Human Diseases and spanned 13 weeks. The class was made up of 45 undergraduates mostly in their third year of the Life sciences degree programme. An ill-structured problem was incorporated in the end-of-semester summative assessment to assess if students were able to solve the problem on an individual basis. Scaffolds such as question prompts (Ge & Land, 2003) or message labels (Cho & Jonassen, 2002) were used to help students work through two problem-solving assignments. These scaffolds were provided together with the assignments.

One of the ill-structured problem posed was whether students would support the use of gene-editing technologies in embryos. Students were allowed to discuss this topic without any constraints, with issues surrounding techniques of gene editing, as well as ethical, and legal issues were all opened to them. The second problem posed was whether students agreed that a putative tumour suppressor gene was tightly correlated with colon cancer, with limited data set provided and students allowed to select relevant data to support their stand. Depending on the data they selected, students could support or refute the assertion. For each of the problem, students had about 4 weeks to discuss at the AODFs and submit an essay detailing their arguments. The two assignments were run sequentially, with a gap of about four weeks between them.

Coding of students' forum posts

After the semester, we used thematic analysis of students' posts in the AODFs to evaluate students' problem-solving skills and approaches, focusing on the levels of feedback provided by groupmates to one another. At the first level of coding, we used the ill-structured problem-solving framework (Jonassen, 2011) to categorise students' posts into (1) scoping the problem, (2) providing or consolidating relevant information (3) proposing solution and (4) counter-proposing solution (Yeong et al., 2018). Within these steps for solving an ill-structured problem, we also examined feedback among groupmates to understand better about how peers could provide timely and targeted responses to one another's posts. The use of Jonassen's framework was to examine if the learning outcome of solving ill-structured problems was achieved by our students using such an instructional design. As alluded to above, such a problem-solving skill is necessary for our Life Sciences students who might face open-ended problems in their subsequent studies and careers.

We used the SOLO taxonomy (Boulton-Lewis, 1995) to categorise the posts as a proxy for the quality of posts. The feedback fell into categories in the problem-solving steps adapted from (Jonassen, 2011) such as defining the scope of the problem (referred to as "feedback_scope"), information provided surrounding the problem (referred to as "feedback_information") and solution to the problem (referred to as "feedback_solution"). Feedback from both assignments was coded for the SOLO taxonomy and descriptive statistics were generated for a summary of the analyses. We used the SOLO taxonomy to further analyse the quality of students' feedback as these could be rather broad, given that the discussion forums took on different threads from one another. Nonetheless, given that the SOLO taxonomy was based on a hierarchical structure, it provided us a means to focus on the domain competency level of the students from the basic to bringing together different concepts. It also allowed us to examine relevance of students' feedback to the topics under discussion, and also their ability to go beyond concepts and issues discussed in class to implications to the field or a broader societal impact.

Results and Discussion

Students' posts that were categorised as feedback for other group members were coded using the SOLO taxonomy to ascertain the quality of students' comments to one another. We interpreted the SOLO taxonomy in the context of solving an ill-structured problem as shown in Table 1. This allowed us to evaluate the quality of the feedback in relation to how students approach the ill-structured problems. As the students were tasked to provide possible solutions to the problems posed, whether students were able to provide targeted feedback to one another such as directing their feedback to the problem-solving framework was an important criterion. In our observations, we noted that students' feedback ranged from uni-structural to extended abstract as seen in the examples highlighted in Table 1.

In our context, a feedback was judged to be pre-structural if the post failed to make connections directly to the problems posed. These could be short sentences that did not contain information that enabled us to detect any attempts by students to relate their feedback to the problems posed, indicating a limitation in the feedback in terms of being constructive towards solving the problem (Table 1). This was to distinguish the feedback from others that explicitly related at least one issue or topic to the problems.

At other levels of the SOLO taxonomy, the feedback by students demonstrated the ability to make explicit links in their feedback to the ill-structured problem they had to solve. Depending on the number of relevant issues they were able to make connections with, the feedback was classified as uni-structural (typically focussed on a narrow aspect) or relational (more complex feedback with different ideas integrated together that were connected to the problems). There were several examples of feedback that went beyond the problem and were coded as extended abstract. These were those that alluded to more generalised issues that

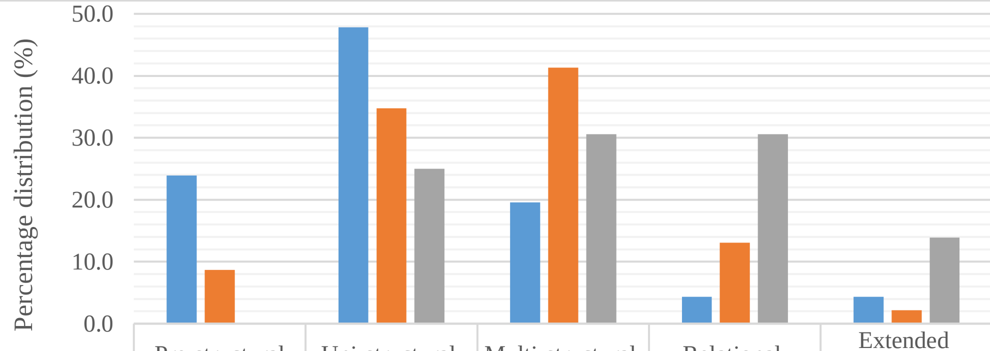
Table 1: Interpreted SOLO taxonomy and samples of students' AODF posts

SOLO taxonomy Levels	Interpreted categories description	Attributes of students' feedback	Examples of students' posts
Pre-structural	At this level, students could not relate to the problem statement at all. The students' feedback failed to connect to the problem statement.	Students forum responses were typically characterized by the general replies without directly addressing the problem question. There was limited information provided and no link to the problem question.	*I think this article is really similar to Article 1, which is great I guess! Forum B3, student #23*
Uni-structural	At the uni-structural level, one aspect of the task was highlighted by the student and the students' understanding was disconnected without obvious connections to the problem statement. Here the students feedback focused on one or a few relevant aspects that have discussed limited concepts about the problem question. Many of the discussions were taken from the articles provided and at the surface level with minimal discussion.	Here the students feedback responses were characterised by information provided with limited or no proper explanation. Students demonstrated a partial understanding of the problem question and one or few aspects were highlighted picked up. Since the discussions were not really complete, the feedback was not completely helpful.	*CHFR & mitotic progression from the article 1* *Dma1p, an orthologue of CHFR, plays a role in regulating mitotic events such as spindle assembly and septum formation. Dma1p and Dma2p have been linked to the positioning of mitotic spindles. There were no clear connections of CHFR functions to the antephase checkpoint, but it is said to delay mitotic entry in cells. Forum B11,student #35*
Multi-structural	At this, students attempted to analyse several aspects related to the problem statement, but their relationships to each other and exact connections were not discussed completely. However, such qualitative Multi-structural discussions included a range of	Here the students' feedback included elaborations on the concepts from various aspects of the problem questions. Not all the student's discussions were connected well to one other. However, most of the students tried to make the connections, but overall there were struggles to understand completely on the true significance of their ideas.	*A study was performed: Among 61 primary colon cancer samples studied, hypermethylation of the MLH1 and CHFR promoter was found in 31% of the tumors. In 68% of all primary cancers with MLH1 promoter hypermethylation, hypermethylation of CHFR promoter was also observed. This suggests there could be*

	discrete facts related to the problem statement. Here the quality of various ideas on the problem statement was increased, but they were alienated from other students' perspectives.		*a direction towards forming a solution targeted at the loss of mismatch repair (MMR) caused by hypermethylation of MLH1 and the loss of CHFR as a mitotic spindle checkpoint. Forum B10, student #13*
Relational	At the relational level, peer discussions were at the deep learning stage, concepts were linked and integrated in order to contribute to a more coherent understanding of the problem statement. At the relational level, peer feedback from the students helped to integrate their ideas into a whole, recognizing relationships and connecting the relevant information to each other. This level was characterized by an adequate understanding of a subject and problem question.	Students at this level could use their understanding to apply their ideas/discussions to new situations. Students argued among each other's discussion, stood on their views and integrated the relevant details to bring the concrete facts together.	*Hence, I would say there is no correlation between chromosomal instability and no / low CHFR expression. As you said, CHFR is perhaps a tumor suppressor gene especially used in the colon. Methylation of the promoter region leads to less CHFR expression and therefore less tumor suppression what cancerous tumors allows to develop easier (there are still physical reactions to stop growth of cancer tissue, i.e. from the immune system). So, the question how to reconcile the CHFR promoter methylation and tumor growth, you have already answered. And because there is no correlation between CIN and no/ low CHFR expression, I'm not able to explain you how to reconcile these 2 components. Forum B11, student #18*
Extended Abstract	At the extended abstract level, the understanding at the relational level was re-thought at another conceptual level, resulting in metacognitive analysis of the problem statement. Students analysed the problem statement in a different view and used it as the basis for prediction, generalization, reflection and creation of new understanding. Students extracted the underlying principles and structures behind the ideas discussed. Multiple possibilities were considered and refined to	Students responses at the extended abstract level went a step further than relational answers, beyond what had been learned from peer discussions. There were indications of reasoning, anticipating possibilities, and multiple connections made. There were instances of generalisation of principles to new situations and considerations beyond the problem statement.	*CHFR hypermethylation can be a benchmark that helps identify patients with high risk of the disease recurrence and have implications for clinical management of colon cancer (following curative surgical resection in their study), and that it may serve as a potential prognostic biomarker. Forum B8, student #24*

	relate to the problem statement.		

The chart in Figure 1 shows the percentage distribution of various categories of feedback among the SOLO taxonomy. Majority of the feedback_scope was at the lower levels of the SOLO taxonomy, with 24% at the pre-structural level and 48% at the uni-structural level. In comparison, for the feedback_information, there was a lower percentage at the pre-structural level (9%) with a majority of them at the multi-structural level (41%). With regards to the feedback_solution that students provided for one another, there were none at the pre-structural level and a fairly-even distribution across uni-structural, multi-structural and relational. Among the different categories of feedback, the feedback on the solution was highest at the extended abstract level (14%).



	Pre-structural	Uni-structural	Multi-structural	Relational	Extended Abstract
Feedback_Scope	23.9	47.8	19.6	4.3	4.3
Feedback_Information	8.7	34.8	41.3	13.0	2.2
Feedback_Solution	0.0	25.0	30.6	30.6	13.9

Figure 1: Percentage distribution of different categories of feedback provided by students to peers according to the SOLO taxonomy

The distribution suggests that the feedback by students in response to group mates' posts on problem scope was less well-developed that feedback on information or solution. This correlated with our previous observations that defining the scope of an ill-structured problem is an issue for students (Yeong, 2015). Consequently, the students might also have problems with helping one another with constructive comments on how to define the scope of the ill-structured problems. Nonetheless, there was at least 20% of the feedback on the scope that was at the multi-structural level, indicating that there were students who were capable of providing useful feedback on the problem scope in attempting to solve the problems.

The better performance of students in providing feedback on information could be due to the fact that the information provided was mostly domain-related and students were able to rely on their knowledge as science students. The link back from information might be less opened than the scope to the problem posed. In providing feedback to solutions proposed by group mates, the more evenly distributed feedback across the across uni-structural, multi-structural and relational could be the fact that different solutions are possible and related to the openness of the problem, students might not all be good at making links to the problems. However, there were no pre-structural feedback and the highest level of extended abstract among the feedback on solutions, suggesting that perhaps with various possible solutions provided, students were likely able to make links to broader issues using prior knowledge.

The observation that 31% of feedback that was multi-structural and 15% relational in nature provided us some confidence that students were able to make relevant comments to one another (Table 2). In relation to customization of learning (Schuwer & Kusters, 2014), students involved at the group level were able at some level, to provide targeted and specific to other members. This fitted our idea of using group-specific discussions to drive the learning of common topics but with scope for students to contribute their own ideas and feedback to one another that might not be possible within the time-frame of an in-class discussion led by on instructor. The peer-feedback by students within groups, therefore, served as a good complement to the feedback provided by instructors, who might be engaged with other modules in parallel and normally provided broader comments for each group without necessarily going into specifics that have already been dealt with by students themselves. The instructor nonetheless catered comments and feedback to the group-specific topics that were raised by the students, again fitting into our aim of customizing learning experiences for students.

SOLO taxonomy	**Percentage Frequency**
Pre-structural	11.7
Uni-structural	36.7
Multi-structural	30.5
Relational	14.8
Extended Abstract	6.3
Total	**100**

Table 2: Percentage distribution of all feedback categories according to the SOLO taxonomy

Conclusions

Given that students are not all experienced in solving ill-structured problems, we anticipated that there might be problems with the level of feedback that students might provide their peers. This is because our scaffolds for solving ill-structured problems were related to steps for solving the problems. However, from the exploratory study, we noted that students were able to provide feedback that included SOLO levels at the uni-structural and multi-structural, with a small percentage of the relational and extended abstract. One reason for this could be that students were still having difficulties with solving ill-structured problems. We could, therefore, strengthen our scaffolding on ill-structured problem-solving skills. Moreover, the observation could indicate that students might not have sufficient skills to provide peer feedback, as this was not part of the instructional design.

Nonetheless, the finding that students were able to provide feedback at more advanced levels of SOLO implied that there could be a way to scaffold students in terms of feedback for peers to improve the proportion of higher-level feedback. For instance, training students to be better at providing constructive feedback (Gielen, Peeters, Dochy, Onghena, & Struyven, 2010) might help improve collaborative-learning. Additionally, there needs to be a continued focus also on defining the knowledge surrounding problem scope as peers who are not familiar with the skill might have difficulties in supporting one another. Additional studies could be conducted such as interviews with students to find out how some students are able to make feedback at the advanced SOLO levels including the relational and extended abstract. Based on this information, we could design ways to support other students so that they might also attain such SOLO categories.

Future studies will focus on the improvements to our problem-solving scaffolds as well as scaffolds to support student collaboration. This should enable us to provide a learning environment that would cater to a more open structure of learning for students at different levels but with the similar outcome of learning about problem-solving skills. In terms of using AODFs as a platform for mediating student discussions as they solve an ill-structured problem, the instructors were able to observe the level and quality of feedback that students provided to one another as students make explicit their problem-solving approaches (Andresen, 2009). Moreover, collaborative-learning among students have been shown to be beneficial to knowledge construction (Schellens & Valcke, 2006). Hence the use of ill-structured problems together with an appropriate technological platform as a mediating tool have afforded us the means to provide mass customization of learning as students work collaboratively on the problem.

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