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Web-based problem solving learning: third-year medical students' participation in end-of-life care Virtual Clinic

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Abstract

This exploratory study examined problem-solving in an on-line problem-based learning environment. Participants included two moderators and 30 medical students in the end-of-life care Virtual Clinic. Using content analysis of transcripts, we analyzed interaction patterns in two groups of students and moderators and students' problem-solving skills as measured by the critical thinking ratio. Moderator in Group 1 posted more connected comments, feedback, and questions than the moderator in Group 2. Students in Group 1 posted more connected comments compared to students in Group 2. However, the disparate interaction patterns yielded little differences in students' critical thinking skills in both groups. We propose the use of critical thinking ratio as an effective outcome measure in assessing problem-solving skills.

Keywords: Problem-solving skills; Computer-mediated conferencing; Moderator facilitation style

1. Introduction

Problem-solving or critical thinking that leads to an effective and accurate medical diagnosis is an essential skill in physicians' patient care. Although interchanged in the literature, problem-solving skills involve logical reasoning and inference that lead to solutions while critical thinking skills involve reasoning about ill-structured problems that lead to a general understanding about a problem and a tolerance for ambiguity (Kamin, O'Sullivan, Younger, & Deterding, 2001).

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Since the 1960s, problem-solving skills have been taught in medical schools primarily through the problem-based learning (PBL) format. Typically, a small group of medical students examine realistic clinical problems under the guidance of a tutor and engage in a series of activities organized into problem-solving stages (Garrison, 1991): (1) problem identification; (2) problem description; (3) problem exploration; (4) applicability; and (5) integration. *Problem identification* involves seeking information necessary for problem solving, such as lab test results or literature; *problem definition* involves clarifying concepts related to the presented problems based on students' knowledge in basic sciences and clinical experiences; *problem exploration* involves linking ideas by posing questions or justifying one's problem-solving approaches; *applicability* involves connecting knowledge gained during learning to on-going practical experiences; and *integration* involves making use of comments of moderators and peer students during problem solving.

The assessment of students' problem-solving skills in medical education often compares the performance of clinical skills in students in the PBL format with students trained in a conventional curricular format (Albanese & Mitchell, 1993; Woodward, 1990). Outcome measures in comparative studies mainly included ratings by faculty of students' skills in history taking, physical exam, problem recognition, and case management during their interactions with standardized patients, who are trained actors simulating conditions of particular illnesses. Few studies have assessed students' problem-solving skills as learning takes place during PBL sessions.

The goal of PBL is to help students construct their knowledge through peer interactions in a small group as students evaluate and clarify their misconceptions with peer input (Dolmans, Wolfhagen, van der Vleuten, & Wijnen, 2001; Frederiksen, 1999). Problem-based learning facilitated in collaborative computer conferencing raises challenges as these interactions are formed and sustained in a virtual environment. Studies have shown that deliberate strategies by moderators produced a higher level of cross referencing to individuals' contributions among students and a higher proportion of students' messages containing feedback, such as agreement, disagreement, and contact statement (e.g. are you there?) (Howell-Richardson & Mellar, 1996; Marttunen, 1998). These findings are important as the quality of collaborative learning is often measured by the number of suggestions, argumentation, and explanations students provide (Marttunen, 1998; Susman, 1998). Some of the specific moderating strategies are summarized: (1) scaffolding students' thinking by providing introduction of new topics and specific discussion topics; (2) using questions to trigger multiple perspectives and to encourage students to justify connections between claim and evidence; (3) modeling how to select, evaluate, and synthesize information from multiple sources; (4) highlighting misconceptions by comparing and contrasting statements; (5) linking individual ideas into generalizable principles; and (6) providing feedback in the form of praise or a direct reference to a student's remark for modeling social interactions and recognizing other students' contributions (Hara, Bonk, & Angeli, 2000; Marttunen, 1998; Mowrer, 1996; Veerman, Andriessen, & Kanselaar, 2000). Compared to traditional PBL format, moderators need to assume an active role for creating an interactive learning environment that promotes conceptual refinement and deeper understanding for overcoming limitations associated with computer conferencing. These limitations encompass lack of social presence, unfamiliarity with peer collaborators, absence of non-verbal cues, and time lags in posting messages (Hron, Hesse, Cress, & Giovis, 2000).

This exploratory study examines medical students' problem-solving skills in an on-line problem-based learning environment where learning is mediated through interactions with faculty moderators and peer students in asynchronous discussion sessions. More specifically, the study focuses on the effects of moderators' facilitation styles on the quality of student learning. We examined the moderators' facilitation style according to their comments that are connected to students' comments as well as frequency of praise, responses, questions provided to students. We also examined student discourse style in terms of students' connected comments and statements including praise, response, and questions. Our research questions include: (1) is there a relationship between moderator facilitation style and student discourse style? and (2) is there a relationship between student discourse style and the quality of their learning as measured by critical thinking ratios? The critical thinking ratios are calculated by categorizing each comment as deep or surface learning and dividing the difference in frequencies between deep and surface learning by their sum, yielding an index between -1 and $+1$.

2. Method

2.1. Setting

The instructional material used in this study is an on-line case learning tool in end-of-life care called, the Virtual Clinic. The Virtual Clinic is designed for third-year medical students who participate in the required family medicine clinical rotations at 24 training sites in five states (Washington, Wyoming, Alaska, Idaho, Montana). Students access via the Web weekly case materials, tasks, and discussion forum where they are required to post three messages per week over a 4-week period. The overall educational objectives of the Virtual Clinic emphasize skills in: (1) solving problems and finding critical information related to pain assessment and management based on the patient's physiological (i.e. type and extent of cancer pain) and psychosocial conditions (i.e. depression); (2) designing a medication regimen that maximally controls the patient's pain with minimum side effects; and (3) devising a pain management plan based on the insurance type held by the patient. The Virtual Clinic is organized into three clinics (red, blue, yellow) during the eight academic terms in a year. Faculty who are family physicians moderate the sessions. Approximately eight students are randomly assigned to one of the three clinics and they use character names from Shakespeare's plays for anonymity purposes.

The instructional materials consist of a cancer patient case along with didactic materials for students' self-directed learning. The didactic contents cover definitions of concepts (e.g. soft tissue pain, bone pain) and interpretation of clinical guidelines provided by health agencies, such as the World Health Organization. At the end of the weekly case presentation, students view the tasks they are required to discuss on-line with their peer students and faculty. Table 1 presents a summary of the case and tasks during the third week.

2.2. Participants

Participants in this study included two faculty moderators and 30 third-year medical students, who participated in the Virtual Clinic sessions conducted during summer and autumn terms of 2001. There were eight students in the Blue and Yellow Clinics, respectively, during the summer term; seven students in the Blue and Yellow Clinics, respectively, during the autumn term. One faculty member moderated the Blue Clinics and the other faculty, Yellow Clinics. Students and faculty in the Blue Clinics were categorized as Group 1 and students and faculty in the Yellow Clinics, as Group 2. In Group 1, 53% of the participants were male compared to 33% in Group 2. When breaking down students' ethnic backgrounds, 67% of the participants in Group 1 were white, followed by Hispanic (20%), Asian (7%), and other (7%). In Group 2, 73% were white, followed by Asian (13%), African-American (7%), and other (7%).

2.3. Procedure

Transcripts from four Clinic sessions were downloaded from the Web server, organized in a chronological order of the discussion within each session, and analyzed by authors (SK, BEK). Each sentence or a paragraph was treated as a textural unit based on the thematic unity represented in the text (Henri, 1992). Therefore, a paragraph may contain multiple codes in some cases. The coding was conducted in

Table 1
Sample case and tasks during week 3

Case: From your assessment, Wendy is pleased to learn that you have a good understanding of what is causing her pain. Your in depth assessment of her pain, clear explanation of why she is having pain, and your commitment to control her pain are reassuring. While she is hopeful, she still is unsure that you will be successful. After all, she has heard this before from multiple physicians and has still suffered 10/10 pain for several months. She now pulls a large magazine advertisement for Vioxx from her purse. Oscar's best friend at the fire station suggested Wendy ask about it several weeks ago. It is described as a once-daily POWER to treat acute pain in adults (among other things). After Dr. Jacobs wrote a prescription several weeks ago, Wendy's pharmacist notified Wendy that the drug was not covered under her new insurance plan. She would have to pay $135 out of pocket for a one month supply of Vioxx.
Task: From the previous session on pain assessment, you determined that Wendy is on the following pharmacologic treatments:
* Percocet (oxycodone 5mg/acetominophen 325 mg) prescribed at two tablets q 4 hrs but she is actually taking 3 tablets q 4hrs; and,
* 25 microgam Duragesic (fentanyl) patch q 3 days.
On this regimen her pain averages 9–10/10 on a verbally reported number scale. Shortly after her three Percocet her pain will lower to the 6–7 range before returning to 9–10 after 2–3 hours. Based on the prior discussion, what pharmacologic pain treatments would you implement to control Wendy's pain?

two separate areas: (1) student and moderator interaction patterns; and (2) students' cognitive and metacognitive skills during problem-solving stages. The inter-rater reliability for coding of interaction patterns was 0.86 and for coding of problem-solving skills, 0.70.

Interaction coding was developed to measure the extent to which the Virtual Clinic was a collaborative activity and how moderator style affected students' patterns of participation. Table 2 presents the coding structure. All textual units were first coded as on- or off-task. On-task comments were directly or indirectly related to the weekly tasks students were required to solve; and off-task comments had no relevance to on-going tasks, such as personal introduction. We included off-task comments since they can be key to developing a sense of community and collaboration. The rest of the coding included the following variables: (1) the extent to which a textual unit was connected or not connected to contents of the moderator's or students' previous comments; (2) the discursive style of a textual unit (i.e. praise, response, question); and (3) the presence or absence of direct address to students or moderator. We sought to measure in the connectedness of comments whether students conceptualized their comments as part of a larger conversation as opposed to a singular contribution about the task. Rafaeli and Sudweeks (1997) characterize interactivity as related to whether an on-line discussion post takes into consideration previous posts. Declarative statements were contrasted with connected, or interactive, posts. This continuum allowed us to examine the extent to which the Virtual Clinic operated as a collaborative problem-based activity. We categorized the discursive styles according to (1) *Praise/Appreciation/Validation*, (2) *Response* (comments that were general contributions), (3) *Question* (direct and indirect questions), and (4) *Other* (technical comments, introductions). Lastly, textual units were coded according to whether they included a specific reference to another person (a: unnamed or b: named) for *Praise/Appreciation/Validation* and *Question* categories,

Table 2
Coding of moderator and student interaction patterns

Task	Level	Connected	Not-connected
On/off-task			
	I	A. Student-to-student comment to one or more students B. Student-to-moderator comment to the moderator C. Moderator-to-student comment to one or more students	D. Student to moderator comment that is unconnected to any previous remark. E. Student-to-student comments that are unconnected to any previous remark. F. Moderator to student comment that is unconnected to any previous remark.
	II	1. Praise/appreciation/validation 2. Response 3. Question 4. Other (technical responses, etc.)	3. Questions 4. Other (technical responses, etc.)
	III	a. Unnamed/implicit b. Named/explicit	a. Unnamed/implicit b. Named/explicit

or whether the units included implicit or explicit references to the comments previously posted for *Response*.

As an example, the code, "A3a" would be associated with a comment, "As to the pharmacology of pain, is there a recipe somewhere to follow or to use as a road map in treating the pain?" A sample moderator's question (code C3a) would be, "Do any of you know how to calculate equalanalgesic doses. It is not clear to me how you are deciding on how to increase Wendy's opioid dose?" A sample off-task comment (A4) would be, "The events of Tuesday [11 September 2001] have left me in a state of disbelief and shock, as they have everyone else."

Using a methodology applied to problem-based learning in a medical school (Kamin et al., 2001), we coded for problem-solving skills based on Garrisons' (1991) five problem-solving stages (identification, description, exploration, applicability and integration). In order to reflect students' comments regarding new areas of learning, we added a category of metacognitive skills to the problem-solving stages. A total of 32 indicators were developed in individual problem-solving categories and labeled as either surface processing (χs) or in-depth processing (χd) (Table 3). There were 16 indicators categorized as deep learning and 16 as surface learning. A family

Table 3
Coding of problem-solving skills

Stage	Surface learning	Deep learning
Problem identification	1. Repeat information already said 2. Complain about unavailable information	1. Identify new problem-related information 2. Ask for information not provided
Problem description	1. Refer to the list of misconceptions without clarification 2. Provide yes/no answer to moderator's request for conceptual clarification	1. Discuss ambiguities to clear them up 2. Identify gaps in knowledge or experience
Problem exploration	1. Repeat information without adding insights 2. Ask closed question 3. Draw on irrelevant personal experience 4. Develop hypothesis without justification 5. Cite literature without interpretation	1. Link facts/data to form new ideas 2. Pose guiding questions 3. Draw on relevant personal experience 4. Draw on previous clinical experience 5. Cite literature with interpretation
Applicability	1. Apply learning to clerkship without elaboration	1. Apply learning to clerkship with elaboration
Integration	1. State agreement without elaboration 2. State disagreement without elaboration	1. State agreement with elaboration 2. State disagreement with elaboration
Metacognitive skills	1. State areas of new learning without examples 2. State areas of non-learning without examples	1. Elaborate areas of new learning with examples 2. Elaborate areas of non-learning with examples

physician faculty reviewed the 32 indicators for validity and relevance to the case materials. Based on the frequency counts of surface and deep learning, a critical thinking ratio was computed by calculating $(\chi d - \chi s) / (\chi d + \chi s)$, where χd = in-depth learning and χs = surface learning. This formula yielded a critical thinking index between −1 and +1.

An exemplar comment under *Problem Exploration* is, "Vioxx is a selective COX-2 inhibitor. It is marketed as a drug that will have less GI irritation than the COX-1 inhibitors because COX-2 has a gastric lining protection component. Wendy's bone pain, because it is mediated by osteoclasts, may benefit from Vioxx" (link facts/data to form new idea, deep learning). An evidence of a student applying learning from Virtual Clinic to his clerkship experience (*Applicability*) would be, "I recently saw an Alzheimer's patient who is now deteriorating more rapidly than before. Many of the same issues [as in end-of-life care] came up: how to best treat her symptoms, what interventions were or were not necessary, how can we support her family and our patient." A *metacognitive* comment would be, "The most valuable lesson that I learned in Virtual Clinic was some therapies for radical pain management. It was very valuable to be able to approach a patient using the analgesic ladder and be able to come up with a specific medicinal treatment based on this evaluation" (deep learning).

3. Results

We examined the following two questions: (1) is there a relationship between moderator facilitation style and student discourse style? and (2) is there a relationship between student discourse style and the quality of their learning as measured by the critical thinking ratio?

3.1. Overall amount of posting

Results from the coding of discourse interaction styles and problem-solving skills are compared between Group 1 (15 students and one moderator in blue clinics in summer and autumn sessions) and Group 2 (15 students and one moderator in yellow clinics in summer and autumn sessions). The participants posted a total of 444 messages to the Virtual Clinic: 175 student and 24 moderator postings in Group 1; and 211 student and 34 moderator postings in Group 2. We coded 710 textual units from the messages and report the results based on these units (355 units in Group 1, 355 units in Group 2).

3.2. Interaction patterns

First, the proportion of on-task and off-task comments was examined by group. Moderators and students largely kept their discussions on task during 4 weeks with an exception of the second week when more than 20% of the participants' comments were of off-task nature for both groups. When breaking down the comments into summer and autumn sessions, we found that most of the off-task comments were related to the 11 September event. When comparing the amount of on- and off-task comments by moderators, there was no statistical significance between the two groups, $\chi^2(1, N=126)=1.78$, $P>0.05$.

Second, we analyzed the connected comments by moderators and students (Fig. 1). The moderator in Group 1 showed a relatively stable and high level of connected comments over the 4-week period (range: 84.8–100%). Connected comments posted by students in Group 1 ranged between 60 and 79.4%. In comparison, the moderator's connected comments in Group 2 fluctuated between 54.5 and 100% and students' comments, between 44.4 and 78.9%. A statistical significance was found between the two groups in the amount of moderator's connected comments, $\chi^2(1, N=126)=7.27$, $P<0.01$, as well as in students' connected comments $\chi^2(1, N=584)=4.74$, $P<0.05$. It is inferred from the data that the high percentage of moderator's connected comments in Group 1 was a factor in maintaining a relatively consistent and high level of connected student comments. Overall, students posted a higher proportion of connected messages during the second and third weeks. Students largely conducted introductions during the first week, and posted evaluative comments during the final week related to the quality of the Virtual Clinic as a learning tool.

Third, the proportion of comments categorized as praise/appreciation/validation and question was examined (Table 4). We highlight these two categories as the literature emphasizes the moderators' role in providing feedback to students and stimulating their learning with the use of questions. On average, the moderator in Group 1 provided a higher proportion of feedback in the form of praise, appreciation, and validation than the moderator in Group 2 (37.4 vs. 32.9%). Almost half of the moderators' comments consisted of feedback during the fourth week in Group 1 and the third week in Group 2. Students in Group 2 provided an equivalent proportion of feedback to students in Group 1 (19.4 vs. 18.6%). No statistical

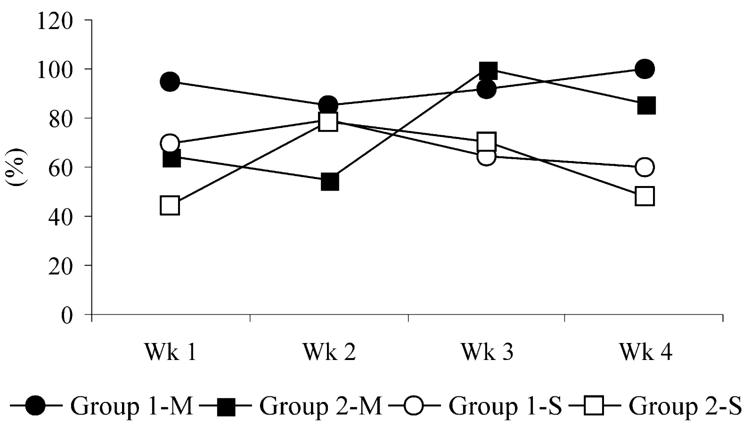

Fig. 1. Proportion (%) of connected comments out of total comments posted by moderators and students by group and by week (M: moderator; S: students).

Table 4
Proportion (%) of praise/appreciation/validation comments and questions out of total comments posted by moderators and students by week

		Week							
		Praise/Appreciation/Validation				Questions			
		1	2	3	4	1	2	3	4
Group 1	Moderator	30.0	36.4	33.3	50.0	45.0	33.3	41.7	14.3
	Student	18.7	16.2	15.5	24.0	5.3	4.4	6.0	6.0
Group 2	Moderator	29.4	27.3	46.2	28.6	11.8	18.2	15.4	28.6
	Student	12.2	23.9	18.4	23.2	2.2	4.2	6.9	0.0

differences were found in the amount of comments made by both the moderator and students. The moderator in Group 1 consistently asked more questions except during the last week compared to the moderator in Group 2, averaging 33.6 vs. 18.5%, $\chi^2(1, N=126)=4.78$, $P<0.05$. Less than 7% of students' postings included questions for both groups.

Lastly, we investigated the extent to which participants directly addressed names of other participants. The moderator's direct comments in Group 1 averaged 28% over 4 weeks compared to 32.5% of direct comments made by the Group 2 moderator. There was no statistical difference in the amount of direct comments made by the moderators. Students in both groups posted a similar amount of direct comments (22.9 vs. 21.5%).

In summary, the moderator in Group 1 posted higher proportions of connected comments, feedback, and questions compared to the moderator in Group 2. The moderator in Group 2 made more number of direct addresses to students compared to Group 1. There was no major difference in moderators' facilitation styles in posting on- and off-task comments. Statistical differences were found in the amount of moderators' connected comments and questions. Students in Group 1 made more connected comments than their peer group and the difference was found to be statistically significant. The moderator's incorporation of feedback and questions did not necessarily translate into students' consistent use of feedback and questions when interacting with their peers.

3.3. Problem-solving skills

We report the critical thinking skill ratios based on the frequency of comments categorized as surface and deep learning. The sub-ratios for individual stages of problem solving and the overall ratio for Group 1 and Group 2 are reported. The ratios were calculated by dividing the difference between deep and surface learning by their sum. The overall critical thinking ratio was higher in Group 1 (0.51) compared to Group 2 (0.48). Group 1 had the highest ratio in *Applicabiltiy* (1.00), followed by *Problem Description* (0.88), *Problem Identification* (0.84), *Integration* (0.51), *Problem Exploration* (0.36), and *Metacognitive skills* (0.22). Group 2 had the highest ratio in *Applicability* (0.81), followed by *Metacognitive Skills* (0.71), *Problem Description* (0.67), *Problem Identification* (0.65), *Integration* (0.49), and *Problem Exploration* (0.38). Overall, the ratios of Group 1 were higher than those of Group 2 in all stages except in *Metacognitive Skills*. The largest difference in the critical thinking ratio between the two groups was observed in *Metacognitive skills* (0.49), followed by *Problem Description* (0.21), *Problem Identification* (0.19), and *Applicability* (0.19).

We further examined the proportion of comments categorized as deep learning in individual problem-solving stages over the 4-week period. The proportions are based on the total comments encompassing all stages in each week. Overall, Group 1 compared to Group 2 made a higher proportion of deep-learning comments in problem identification, description, applicability, and integration. Students in Group 1 consistently posted more integration comments throughout the 4-week period than Group 2. The same pattern is observed in applicability except in Week 1. Students in Group 2 engaged in a higher level of metacognitive reflections during the final week compared to students in Group 1 (63 vs. 34%). When adjusted for multiple tests of comparison, none of the differences in the amount of postings was statistically significant.

4. Discussion

This exploratory study examined medical students' problem-solving skills in an on-line problem-based learning format where learning was largely mediated by interactions with faculty moderators and peer students. The content analysis was guided by the assumption that the discourse during problem-based learning reflects students' problem-solving or critical thinking skills; and in-depth processing or deep learning is important for effective problem solving (Miller, 1992). Although there were differences between the two groups in selected interaction categories, the overall critical thinking ratio was approximately equivalent between the groups (0.51 vs. 0.48). Analyzing the critical thinking ratio by individual problem-solving stages by week pointed to several differences between the two groups. Students in Group 1 whose moderator posted higher proportions of connected comments, feedback, and questions consistently applied their learning from the Virtual Clinic to the on-going clerkship experiences and integrated statements of agreement and disagreement with elaboration of their positions about particular learning issues. Students in Group 2 whose discussions were facilitated by a moderator with more direct addresses to individual students posted more reflective comments regarding areas of learning or non-learning that occurred during Virtual Clinic. None of these differences was found to be statistically significant.

The equivalent level of critical thinking ratio between the two groups makes it difficult to associate differences observed in interaction patterns with students' problem-solving skills. We discuss several limitations in the study as potential confounding factors. First, this study examined the differences in the moderators' facilitation styles and students' participation patterns without specific interventions that differentiated the study groups. Second, we did not control for factors that might have affected group dynamics, such as gender composition, experience with computer-mediated conferencing, or speed of the Internet access. Third, tasks used in the Virtual Clinic were not constructed in a manner that necessitated student collaboration. It is not clear whether a moderator's facilitation style alone can generate collaborative activity in the absence of tasks that deliberately target collaboration.

Our study revealed one area where a moderator's facilitating skills are particularly critical in students' problem-solving skills. When a task called for searching and interpreting of the literature, a significant number of students cut and pasted research studies without offering an analysis of the studies in the context of the on-going learning issues. We conclude that students need training in how to interpret research results and link them with problem-solving tasks. Moderators may have to model how to critically assess the literature and integrate findings in justifying one's problem-solving approaches (Susman, 1998).

We did not demonstrate high levels of students' critical thinking skills as a result of their participation in the Virtual Clinic. However, we propose the use of critical thinking ratio as an effective outcome measure in assessing problem-solving skills. Garrison's (1991) problem-solving stages can be applied to multiple domains where deep and surface learning indicators can be developed for the appropriate learning context and problem-based tasks. We chose to conduct a content analysis of the transcripts collected during problem-based learning sessions and used the deep and surface learning indicators as a coding structure as agreed upon by a content expert. Although coding of transcripts is labor and time intensive, it reveals students' thought processes during their problem solving and provides information to instructors regarding specific areas of misconceptions held by students. The analysis of learning processes as well as outcomes is one area where more research is needed in the problem-solving literature in medical education.

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