STUDENT CRITICAL THINKING IS ENHANCED BY DEVELOPING EXERCISE PRESCRIPTIONS USING ONLINE LEARNING MODULES

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Developing the ability to think critically is an important element of undergraduate physiology education and is influenced by many factors, including the learning environment, the social context of the learning environment, and the instructor’s approach to teaching. In this work, we describe online learning modules (OLM) that were designed to promote higher-order critical thinking skills in students enrolled in an upper-division Exercise Testing and Prescription course. The OLM provided students with an online learning environment in which to review clinical physiological details from authentic patient case data and develop exercise prescriptions (ExRx), by requiring students to critically analyze authentic patient case histories and collaborate on computer-based learning activities. On the basis of assessment data, we conclude that the OLM helped exercise science students develop the critical thinking skills necessary for development of effective exercise prescriptions by requiring them to think critically while concurrently reinforcing lecture-presented exercise science content.

Key words: critical thinking; collaborative group learning; exercise prescription; technology-enhanced learning; learning environment; social context

Development of critical thinking skills in college students is a goal for many college instructors in higher education who seek to prepare their students for postgraduate, real-world situations (7, 8, 26). Despite the importance of these skills, the unfortunate reality is that many college graduates lack the ability to think critically (8, 15, 29, 28), partially owing to 1) large class sizes (33); 2) limited budgets; 3) time constraints that are perceived not to allow for activities that promote critical thinking, such as in-depth inquiry and small group problem solving (11); and 4) external pressure to prepare students to pass standardized college exams that do not require critical thought (30). Furthermore, many instructors were not educated in a manner that supported development of critical thinking skills and thus lack a clear model for how to cultivate these skills in students (20, 31). Online learning modules (OLM) may offer the opportunity to create learning activities that promote critical thinking.

One area of applied physiology that requires significant critical thinking is the development of exercise prescriptions (ExRx). Exercise is commonly used as a preventive and rehabilitative modality in clinical medicine and in corporate fitness programs. Professionals in exercise science, physical therapy, nursing, and other allied health fields are often responsible for
developing such exercise prescriptions. For exercise
to be an effective therapeutic modality, it is necessary
to develop a prescription that is speciﬁc to the indi-
vidual requiring intervention. The effectiveness of an
ExRx is dependent on many physiological and non-
physiological factors. Development of effective exer-
cise prescriptions for different types of subjects re-
quires signiﬁcant content knowledge in areas such as
normal physiology, basic pathophysiology, and phys-
iological responses to exercise stress, as well as con-
sideration of logistical constraints faced by subjects
for whom the prescription is being developed. Eval-
uating and synthesizing the physiological and non-
physiological factors to develop an effective exercise
prescription plan requires signiﬁcant critical thinking.

The concept of critical thinking has numerous deﬁni-
tions (16, 17, 36). Garrison (1992) characterizes crit-
cial thinking as a 5-stage problem-solving process
(17), with each stage characterized by critical reason-
ing skills (23) as shown in Table 1. These problem-
solving stages and critical thinking skills align closely
with the processes that students must work through
to develop effective ExRx. For this reason, Garrison’s
critical thinking model was selected for the present
study, and the instructor-assessed student critical
thinking performance using Garrison’s ﬁve-stage prob-
lem-solving process as the criterion for critical
thinking.

Development of student critical thinking skills is de-
pendent on many variables, including the learning
environment, the social context of learning, and the
teaching style of the instructor (22–26, 30, 32, 33,
35). Learning environments that feature small group
collaborative learning promote critical thinking skill
development in college students (5, 10, 12) through
critical reflection (34). The instructor also plays a
pivotal role in cultivating critical thinking skills, as
well as serving as the domain-speciﬁc content expert.
Effective teachers facilitate student critical thinking
skill development when they implement learning ac-
tivities that have authentic, real-world contexts and
personal relevance to the student (3). Additionally,
well designed, open-ended questions and investiga-
tive activities by the instructor facilitate critical think-
ing (6, 13). Instructors promote critical thinking
when they 1) pose questions that have more than one
correct answer, 2) provide an appropriate length of
time for students to think before responding, and 3)
avoid asking questions that require only a “yes” or
“no” response (6, 22).

The purpose of this study was to determine whether
students enrolled in an upper-division Exercise Testing
and Prescription class engaged in critical thinking while
collaboratively developing exercise prescription plans
using online learning modules designed with attention
to factors known to promote critical thinking.

METHODS

OLM were designed and developed using Active
Server Page (ASP) and JavaScript (computer program-
ing languages), with OLM content generated from a
Microsoft SQL7 database. Developing in these plat-
forms allowed students to reorder, edit, rearrange,
and recall their responses from the database easily.

The instructional design incorporated into the OLM
represented a balance between two important peda-
gogical models: 1) a construct-driven model (31),

<table>
<thead>
<tr>
<th>Garrison’s Problem-Solving Stages</th>
<th>Henri’s Critical Thinking Skills</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem identiﬁcation</td>
<td>Elementary clariﬁcation</td>
<td>Observing or studying a problem, identifying its elements, observing their linkages</td>
</tr>
<tr>
<td>Problem discussion</td>
<td>In-depth clariﬁcation</td>
<td>Analyzing a problem to understand its underlying values, beliefs, assumptions</td>
</tr>
<tr>
<td>Problem exploration</td>
<td>Inference</td>
<td>Admitting or proposing an idea based on links to admittedly true propositions</td>
</tr>
<tr>
<td>Problem applicability</td>
<td>Judgment</td>
<td>Making decisions, evaluations and criticisms</td>
</tr>
<tr>
<td>Problem integration</td>
<td>Strategies</td>
<td>Applying solutions following a choice or decision</td>
</tr>
</tbody>
</table>

Garrison (17) characterizes critical thinking as a 5-stage problem-solving process and provides activities that characterize each stage. Henri (23) cites critical thinking skills that align with each stage of Garrison’s problem-solving model (presented in Newman et al. [(33)].
TABLE 2.
Case presentation: hypertension case study #2

| Gender: male | Waist circumference: 38” |
| Age: 57 years old | Hip circumference: 47” |
| Weight: 100 kg. | Resting heart rate: 78 beats/min |
| Height: 186 cm | Max heart rate: N/A |
| Percent fat body: 30% | Total serum chol.: 240 mg/dl |
| Occupation: airline pilot | HDL cholesterol: 50 mg/dl |
| Marital status: married | LDL cholesterol: 160 mg/dl |
| Resting BP: 160/96 mmHg | Fasting triglyceride: 300 mg/dl |
| Orthopedic status: N/A | Hematocrit: 45% |
| Exercise ECG: N/A | Fasting glucose: N/A |
| Resting ECG: normal | Smoker: No |

Max/peak ex. capacity: N/A

Primary goals
1. To get blood pressure down to normal level without medication.
2. To get fit to meet the job requirements of the Federal Aviation Administration (has been given 6 months before losing job and possibly retirement income). See below for other goals.

Current recreational activity
Weight lifts (body building) 3× a week; bowls 2× a week.

Family history
Mother died at age 60 in a car wreck (apparently healthy before that); father alive at age 75 but had heart attack at age 50; no siblings. Father has had mild/moderate hypertension since he was about 45 years old.

Medications
Aspirin every other day for prophylactic reasons; no other meds.

Diet
Eats in airports and restaurants plus consumes airline food while working. Loves cooking (and eating) French cuisine when at home.

Exercise equipment
Bicycles; treadmill; jump rope; cross-country skis; downhill skis; golf

Other information
Client has recently remarried (6 months ago). His new wife is 20 years younger than the client, is independently wealthy, and is a top-notch tennis and golf player. The wife wants her husband (who is in complete agreement) to learn to play tennis and golf so they can share the excitement and the social life accompanying the tennis/golf sets at the country club to which they belong.

A sample patient case presented and solved in the online learning module [OLM; previously referred to as adaptive learning environment (ALM)]. BP, blood pressure; ECG, electrocardiogram; N/A, not applicable; HDL and LDL, high- and low-density lipoprotein, respectively.

which focused on critical thinking and problem-solving skills that are generalizable across disciplines; and 2) a task-centered model, which focused on students generating domain-specific content after reading a prepared patient case history (31). While the students were learning the “process” for solving problems (15), the instructor assessed the quality of the students’ critical thinking performance on the basis of the five stages, skills, and activities of the critical thinking process proposed by Garrison and Henri (33) (Table 1).

Each OLM presented students with a patient case history (Table 2), developed by the course instructor, that was followed by a series of questions, decision points, and requests for rationale (Figs. 1-5). The OLM allowed students to easily reorder, rearrange, revise, substitute, and modify their work as they progressed through learning activities and provided students with a sequential and logical process for developing ExRx. Each OLM was designed to provide students with a structured learning environment that provided a process for developing ExRx for specific patient case studies. The key prompts (14, 27) for students included the following:

Review a patient case study (Table 2);
Develop a pathological problem list (Fig. 1);
Develop a non-pathological problem list (Fig. 2);
Prioritize and reorganize problems in the lists (Figs. 1 and 2);
Analyze problems in the lists (Fig. 3);
Develop ExRx plans (Fig. 4);
Problem List
Hypertension: Case Study #2

Subject Data

You will be developing two problem lists. One will be a list of pathological problems; the other will be a list of non-pathological problems that may affect the exercise prescription plan.

1. Pathological Problem List

Formulate a pathological problem list.

1. Problems may be entered by typing them into the provided input box. To add another record, click on the "Add record" button.
2. Problems may be deleted by selecting the problem you wish to delete and then clicking on the "Delete" button.
3. Problems may be prioritized by clicking the arrows on the right-hand side to rearrange each problem.

A pathological problem can be:
- a clinical abnormality
- a physical exam finding
- an abnormal laboratory value (e.g., hypercalcemia)
- a disease state (e.g., diabetes mellitus)
- a physical history finding
- less than optimum conditional status (e.g., 10 lbs overweight)

<table>
<thead>
<tr>
<th>Pathological Problem</th>
<th>Delete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood Pressure: 160/68 mmHg moderate (Stage 2)</td>
<td>X</td>
</tr>
<tr>
<td>Hypertension</td>
<td></td>
</tr>
<tr>
<td>Body Composition: 30% body fat, calculated BMI</td>
<td>X</td>
</tr>
<tr>
<td>20-29 Grade 1 obesity</td>
<td></td>
</tr>
<tr>
<td>LDL serum cholesterol: 140 mg/dL, high LDL cholesterol</td>
<td>X</td>
</tr>
<tr>
<td>Total serum cholesterol: 240 mg/dL, high total cholesterol</td>
<td>X</td>
</tr>
<tr>
<td>Fasting serum triglycerides: 300 mg/dL, borderline high triglycerides</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Prioritize your pathological problem list.

You should list high priority problems and problems of immediate concern at the top of the list. The list may be prioritized by clicking the arrow on the right-hand side of the associated problem into the order desired.

"High Priority" problems are the most important problems on which the exercise prescription should be focused.

"Low Priority" problems are ancillary problems which should also be addressed (if possible) in the exercise prescription:

For example, in a diabetic patient (Type 2) who is 25 lbs overweight and has a prosthesis, the diabetes and the obesity are high priority problems and the prosthesis is a low yield problem, but one which should be addressed.

FIG. 1.

Developing a pathological problem list.
2. Non-pathological Problem List

Formulate a non-pathological problem list.

- Problems may be entered and deleted in the same manner as above.

Non-pathological problems may include things such as social, economic, demographic, nutritional, or logistical issues.

<table>
<thead>
<tr>
<th>Non-Pathological Problem</th>
<th>Delete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Diet: Airport food and French cuisine, high fat, low nutritive value</td>
<td></td>
</tr>
<tr>
<td>2) Age/Gender: 57 years and male, positive risk factor</td>
<td></td>
</tr>
<tr>
<td>3) Exercise habits: sedentary with exception of weight lifting</td>
<td></td>
</tr>
<tr>
<td>4) Demographic/Socioeconomic: no issues of apparent concern</td>
<td></td>
</tr>
<tr>
<td>5) Medications: none important to exercise prescription plan</td>
<td></td>
</tr>
<tr>
<td>6) Lifestyle habits: Poor health habits</td>
<td></td>
</tr>
</tbody>
</table>

Prioritize your non-pathological problem list.

Like above, you should list high priority problems and problems of immediate concern at the top of the list. The list may be prioritized by clicking the arrow on the right hand side of the associated problem into the order desired.

Provide a rationale for each ExRx (Fig. 5); and

Discuss ExRx with the class.

Subjects

The Institutional Review Board at Washington State University (WSU) approved this study. Participants in this study were junior and senior undergraduate college students \((n = 7)\) and represented the entire class enrollment in an Exercise Testing and Prescription class at WSU. Students were given an opportunity to provide informed consent for participating in this research study and were informed that their grade would be unaffected regardless of their participation in this study. All students provided informed consent and developed ExRx in the OLM \((n = 7)\). However, one male student elected not to complete the survey administered at the end of the class, so the results of the survey are for only six students, including three females and three males.

Implementation of OLM

The Exercise Testing and Prescription class was an upper-division three-credit class for Exercise Science majors, and included three one-hour lectures and a two-hour laboratory each week. The OLM learning sessions took place during the weekly two-hour laboratory sessions. Lecture and laboratory topics covered pathological and nonpathological special conditions, such as hypertension, cardiovascular disease, obesity, pregnancy, advanced age, and diabetes with an OLM available for each condition. After a one-hour lecture, students were self-selected into groups of two or three per computer terminal and worked col-
In the boxes below, provide a brief analysis of each problem. At this point, your analysis of each problem should be specific to the patient including normalcy and deviations from normalcy.

<table>
<thead>
<tr>
<th>Pathological Problem</th>
<th>Pathological Problem Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood Pressure: 160/66 mmHg, moderate (Stage 2) hypertension</td>
<td>Patient blood pressure: Stage 2 hypertension based on systolic reading and Stage 1 based on</td>
</tr>
<tr>
<td>Body Composition: 30% body fat, calculated BMI 28.9 Grade 1 obesity</td>
<td>Patient BMI: Meets the criteria for Grade 1 obesity. Obesity is associated with increased</td>
</tr>
<tr>
<td>LDL serum cholesterol 160 mg/dL, high LDL cholesterol</td>
<td>Patient LDL: High, but is at the lowest level of classified as high serum LDL cholesterol.</td>
</tr>
<tr>
<td>Total serum cholesterol 240 mg/dL, high total cholesterol</td>
<td>Patient total serum cholesterol: High but is at the lowest level classified as high total serum</td>
</tr>
<tr>
<td>Fasting serum triglycerides 300 mg/dL, borderline high, high triglycerides</td>
<td>Patient fasting serum triglycerides: Borderline high. High serum triglycerides are associated</td>
</tr>
</tbody>
</table>

Note: The remainders of the responses are concealed in this screen capture by the scrolling text box, but are accessible by the students in the online environment.

Throughout the OLM activities, students were encouraged to rethink their conclusions and revise their original hypotheses or problem lists as discussion within their group provided additional information.

The OLM prompted students to move from simple, routine task orientation to questioning and evaluating their work at a higher cognitive level. The course instructor was available at all times during the laboratory sessions to guide and facilitate student critical thinking, and to provide content expertise and feedback. Students also accessed course...
Enter your plan description here.

- Write the plans in terms the subject can understand and follow.
- Remember to include all of the criteria deemed important in you "Criteria for Prescription Plans."
- Be specific and complete

Please enter a description for each of your DfRx Plans below

<table>
<thead>
<tr>
<th>DfRx</th>
<th>Plan Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Swimming Program</td>
<td>Student enters detailed description of each prescriptive plan here, including intensity, frequency, duration and special considerations</td>
</tr>
<tr>
<td>2. Walking Program</td>
<td></td>
</tr>
<tr>
<td>3. Combined Swimming</td>
<td></td>
</tr>
</tbody>
</table>

The term *Differential Prescription* (DfRx) refers to consideration of more than one ExRx at a time to determine the best fit for the person in consideration. Students developed several ExRx for each patient case and took into consideration physiological and non-pathological problems to select the best prescription.

Note: The acronym DfRx was used in the OLM described herein and corresponds to the ExRx acronym used in this paper.

**FIG. 4.** Developing exercise prescription (ExRx) plans. OLM, online learning module. The term *differential prescription* (DfRx) refers to consideration of more than 1 ExRx at a time to determine the best fit for the person in consideration. Students developed several ExRx for each patient case and took into consideration physiological and nonpathological problems to select the best prescription. Note: the acronym DfRx was used in the OLM described herein and corresponds to the ExRx acronym used in this paper.

Student-student interactions that took place as they worked in collaborative teams to analyze pathological, physiological, and logistical problems that affect the client and prepare an ExRx. They shared dynamic, free-flowing conversation within their own groups, with members of other groups, and with the instructor and came to a consensus within their group before entering data into the OLM. Laboratory activities culminated in a class-wide discussion that focused on student-generated problem lists and analyses and on the ExRx that the students had developed. During this discussion, the instructor guided and facilitated student critical thinking by asking probing questions that required students to elaborate, justify, or provide rationales for their choices. The instructor provided “what if” scenarios to challenge the students and to further their understanding of the course material. The instructor also provided supplementary content expertise during the final discussion when needed.

**Assessment**

Four main student performance items were assessed in this study:

Student-student interactions that took place as students worked collaboratively to analyze patient case histories and develop ExRx by use of the OLM;
Teacher-student interactions that took place as the instructor served as a facilitator for promoting critical thinking and as a content expert for mastering domain-specific content;

Self-reported evaluation of the learning environment, activities, and student learning; and

Course instructor evaluation of the accuracy and completeness of the final OLM product as well as content mastery.

Assessment 1. The instructor observed student-student interactions that took place while students worked in collaborative groups to solve patient case problems and assessed these competencies by means of content analysis, an analytical approach that elucidates critical dimensions of the learning process (33, 34). The instructor observed each student’s critical thinking abilities on the basis of Garrison’s (17) and Henri’s (23) criteria as the students worked collaboratively through the problem-based OLM activities and presented prescriptive solutions to complex clinical problems. In this way, the instructor qualitatively evaluated the learners’ thinking processes so that particular areas of conceptual confusion could be identified. The intent of the first assessment item was to look for critical thinking indicators that were developed within a social context (33). Instructor evaluation of student performance for critical thinking and problem-solving skills was based on the five stages and skills of the critical thinking process proposed by Garrison and Henri (33) (Table. 1).

Assessment 2. As students worked in collaborative groups to solve patient case problems and during the class discussion, the instructor listened for concep-
tual gaps in student understanding. Once a conceptual gap was recognized, the instructor involved the students in a series of prescriptive activities designed to address their particular confusion. Through student-student and teacher-student interactions, the instructor examined each group’s hypotheses and rationales for a specific exercise prescription and through this recursive, reflective process guided student development of both exercise prescription and critical thinking skills. For the first and second assessment items, the instructors qualitatively assessed these stages and skills on an ongoing basis.

Assessment 3. The third assessment item was evaluated by reviewing student self-reported data on a survey completed by students after the final laboratory class (Table 3). Student self-evaluation of learning efficacy and course satisfaction, as they related to the OLM, was assessed using selected questions from an online course assessment tool (Flashlight Silhouette can be found at URL: http://www.ctlt.wsu.edu).

Assessment 4. The final assessment item was performed by the course instructor, and focused on the accuracy and completeness of the student’s problem lists, problem analyses, and ExRx plans developed in the OLM, as well as student mastery of domain-specific content through the use of a paper-and-pencil test administered at the end of a specific class unit that incorporated concepts learned in multiple OLM units.

RESULTS
Assessments 1 and 2
The instructor observed activities supporting every one of Garrison’s problem solving stages (17) and Henri’s critical thinking skills (23) (Table 1) in every group for each OLM implemented. Students engaged in critical dialogue with other students and with the instructor as they defended their ExRx, questioned the ExRx put forth by others, and revised their ExRx on the basis of new insights gained during group discussions. Working within the OLM appeared to facilitate students’ analytical discussions, critical thinking, and idea generation.

Assessment 3
See Table 3 for survey responses. Quantitative assessment of the effects of the OLM and student-student and teacher-student interactions on student learning using the quantitative survey tool (Flashlight) revealed several key points. Students moderately to strongly felt that the course instructor emphasized students becoming responsible, self-reliant, confident, and productive learners within a collaborative social context. Students strongly felt that the emphasis placed on small group collaborative learning helped them to work through a complex problem-solving process with creativity, critical evaluation, and reflection with real-world, authentic tasks. Students moderately to strongly felt that their individual performance in constructing a prescription plan was more effective using collaborative small groups than working alone and felt that they got much more from the class than would have been the case without small-group learning. As the centerpiece of the collaborative group learning, students strongly felt that their experiences with problem solving and critical thinking processes as structured by the OLM (and facilitated by the course instructor) allowed them to understand each clinical situation, examine and evaluate relevant case study data associated with the clinical scenario, and make informed criticisms, judgments, and prescriptive solutions for each case.

Assessment 4
The instructor judged the final ExRx product for each student group as excellent, and students demonstrated competency on knowledge of course content.

DISCUSSION
Success in the modern workplace requires individuals to work cooperatively in small groups and to employ critical thinking skills to derive solutions to complex problems (6, 26). To better prepare for success on the job, students must engage in problem-solving activities that require critical thinking, take place in a social context, and represent an authentic postcollege work environment (24).

In this study, each OLM provided authentic patient case histories and required students to apply the same set of analytical and evaluative skills that would be
required of them in clinical and nonclinical settings when developing ExRx. OLM components that supported the problem solving and critical thinking processes included 1) reviewing a patient case history, 2) developing comprehensive pathological and non-pathological problem lists for the patient, 3) prioritizing the problems in the pathological problem list, 4) determining patient data that were missing but which would have been helpful to know, 5) analyzing each problem in the problem list and relating each problem to the physiological underpinnings by use of a physiological “systems” approach, 6) developing ExRx plans and providing a rationale for each, 7) selecting the most effective ExRx from the three ExRx developed, and 8) discussing, defending, and modifying the selected plans during a critical, reflective class discussion. One advantage of this particular process was that it was nonlinear and required students to conceptualize and critically reflect on formulating their own prescriptive plans at each stage of development. Another advantage was that the instructional design shifted some organizational responsibilities away from the instructor. Rather than having to prompt students to reconsider their responses, and think more deeply about their prescriptive plans, the OLM provided these prompts, thus allowing the instructor to be an active participant in critical discussions and to serve as a content expert.

TABLE 3.
Student survey responses to open-ended questions

<table>
<thead>
<tr>
<th>Open-Ended Questions</th>
<th>Student Survey Responses</th>
</tr>
</thead>
</table>
| What does the term “critical thinking” mean to you? Is it important to be able to think critically? | 1) Critical thinking is incorporating a large amount of info. It is evaluating many aspects of an issue to come to a conclusion.  
  2) Yes, it is important, I need to be able to apply the information.  
  3) This is putting what you know into action and thinking logically about a situation. Yes, it is important.  
  4) Thinking as if in the real world and making decisions.  
  5) Critical thinking means thinking on a higher level. Pulling in information from other sources/classes to solve a problem. Yes, it is important to think critically. |
| What does the term “higher order thinking” mean to you?                               | 1) Higher order thinking means analyzing, evaluating, decision making, all in one.  
  2) Thinking about something in depth, not just saying something to get the task done.  
  3) Thinking about info in an actual situation.  
  4) Thinking through problems/cases and looking at all available possibilities.  
  5) Using all the education from this major to use in the critical thinking.  
  6) Higher order thinking means that you are not only thinking critically, but you also challenge yourself and your peers to find solutions and create answers. |
| Do you think working in small groups with other students enhanced your learning process? Why or why not? | 1) Yes, because you get to use them as a sounding board & get feedback.  
  2) Yes, able to discuss & share ideas. Learn off of each other.  
  3) Yes, it helped to discuss different problems & solutions for the Rx.  
  4) Yes, it helps to share ideas.  
  5) Yes, could think better and come up with better plans/prescriptions.  
  6) Yes, I thought it did a good job of using what we learned in class and made us think about how we would go about doing something with out having full knowledge. |
| Do you think the process you used to develop the prescription plans in EXSCI 476 (the ALM) helped you to think critically about the case studies? Why or why not? | 1) Yes, because you’re forced.  
  2) Yes, looked at problem, analyzed, came to a decision.  
  3) Yes, it helped to see all the aspects that go into an Rx plan.  
  4) No, I thought it was very repetitive and time consuming.  
  5) Yes. |
Because student groups worked collaboratively and in a social context through the problem-based OLM activities and presented their prescriptive solutions in a class discussion format, the instructor was able to observe each student’s critical thinking abilities (18). In this way, the instructor was able to qualitatively evaluate the learners’ thinking processes [based on Garrison’s (17) and Henri’s (23) criteria] and identify particular areas of conceptual confusion. If a conceptual gap was recognized, the instructor was able to involve the students in a series of prescriptive activities designed to address the particular conceptual confusion. Through this recursive, reflective process, the instructor facilitated development of critical thinking skills.

Nontraditional instructional approaches that support student-centered, small-group collaborative learning may enhance student critical thinking skills and result in high-quality educational outcomes while not requiring significant additional instructor time or energy to teach a course (39). With proper design of learning activities, computer technology appears to be able to support the development of student critical thinking skills (27). However, for computer-enhanced instruction to be a boon rather than a bane, it is important that instructors maintain their emphasis on teaching and learning and not focus unduly on the technology (27). For the computer-enhanced tools used in this study, learning, rather than technology, was the focus. The OLM described in this study for developing ExRx could be replicated in a worksheet using a word processing program or even as a paper-and-pencil activity. However, the online version implemented in the present study may offer the advantages of students being able to easily reorder, rearrange, revise, substitute, and modify work easily while developing ExRx.

The small sample size in this study limits the generalizability of our results to other groups; large classes may yield different results. Whether these results can be replicated on a larger scale and in other disciplines would require further investigation.

In conclusion, on the basis of the preliminary data presented in this paper, the authors conclude that developing ExRx in OLM may be successful in enhancing student critical thinking through collaborative small group interactions. In addition, students may develop excellent ExRx by using an OLM as described in this study.

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