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Assessment of first-year medical student perceptions in the development of self-directed learning skills in a single medical school course

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Abstract

Self-directed learning (SDL) is a form of education in which learners take charge of their own learning process, with an active role in knowledge, skill and attitude acquisition. Developing SDL skills is essential to becoming a life-long learner, which is necessary in the current climate of rapidly expanding medical knowledge. Students must also develop the ability to reflect on their own strengths and weaknesses in SDL-related skills, allowing them to set appropriate learning goals and identify areas that require further improvement. Critical Reasoning Exercises (CREs), a student-driven, problem-based learning course, was introduced for first year medical students at New York Medical College School of Medicine to ensure all steps of the SDL cycle were covered in a comprehensive and standardized way. As part of the formative assessment process for CREs, we developed and validated a five-item self-reporting rubric of SDL competency to aid students' self-assessment of their acquisition of SDL skills. The increase in student self-assessed total score from midpoint to endpoint of CREs was statistically significant ($p < .001$), indicating students' perceived increase in SDL competency by the end of the CRE course. In addition to the total score, there was a significant perceived increase in competency for four of the five component skills of SDL ($p < .05$). Interestingly, there was also a statistically significant difference in student self-assessment total scores among facilitator groups at the midpoint of the CRE course. Integration of CREs into the curriculum demonstrated potential as an effective educational intervention for medical student development of competency in SDL.

Keywords Self-directed learning, Self-assessment, Self-evaluation, Formative assessment, Medical students

Introduction

Self-directed learning (SDL) is a form of education in which learners take charge of their own learning process, with an active role in knowledge, skill and attitude acquisition. SDL is described in detail by Malcolm Knowles (Bhandari, 2020; [10, 22, 33]). Learners engaging in SDL have an internal motivation to develop, implement, and evaluate their approach to learning [17, 31]. Developing SDL skills is an essential step in becoming a lifelong learner, which is necessary in the current climate of rapidly expanding medical knowledge for practicing medical professionals (Bhandari, 2020; [10, 21, 28, 31]). The main components of SDL include (1) self-assessment of learning needs; (2) independent identification, analysis, and synthesis of relevant information; (3) assessment of the credibility of information sources; and (4) receipt and incorporation of feedback from self, peers, and faculty facilitators (Bhandari, 2020; [13, 15, 21, 22, 28]). It is important to emphasize that while many steps in the SDL cycle are independently performed, teamwork with colleagues and others in the learning environment is also essential, as described in the collaborative self-directed learning framework [13, 23].

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As SDL is a method of learning, rather than a single specific classroom method, there are multiple education approaches that qualify, including problem- and case-based learning and flipped classroom exercises [19, 26]. Problem-based learning (PBL) is a method of small group collaborative active learning first popularized for medical education at McMaster University in the late 1960s [4, 27, 37]. PBL emphasizes problem solving to develop students' capacity for clinical reasoning and acquisition of both basic and clinical science knowledge in a way that enables retention, recall, and transfer to clinical tasks [3, 27, 38]. Pre-clerkship students are generally eager to be exposed to clinical situations as early as possible, and authentic "real world" problems are inherently cross-disciplinary, providing a central focus around which to gather information [2, 12, 40, 41]. Thus, the introduction of PBL into the pre-clerkship curriculum provides a clear method of early integrative learning and multidisciplinary assessment, while also allowing students some degree of early clinical exposure.

Development of SDL skills is also a requirement for medical school accreditation, as detailed by the guidelines of the Liaison Committee on Medical Education (LCME) [15]. To prepare for a 2024 LCME visit to the author's institution, newly designed Critical Reasoning Exercises (CREs) were introduced for first year medical students (M1s) to supplement the pre-existing opportunities for student development of SDL skills. This student-driven, PBL-based model was designed to ensure that all steps of the SDL cycle (as per LCME Standard 6.3) are covered in a comprehensive and standardized way. The CREs, while confined to a classroom setting, attempt to prepare M1 students for important competency areas of the "real world" of the clerkships, residency and ultimately, their careers. These exercises include problem solving, teamwork, interpersonal communication, lifelong learning and improvement, professionalism, and medical knowledge. This involves transformation of a student from dependency on an instructor to a self-directed learner who can independently identify and address individual learning needs and knowledge gaps.

The design of the CRE program is grounded in several educational theories/approaches, including humanism and constructivism. Humanistic theories are learner-centered and promote development of individuals who are self-directed and internally motivated [34, 36]. Learning is viewed as a personal act necessary to achieve one's full potential, with the goal of self-actualization and self-fulfillment [34, 36]. Knowles' theory of andragogy is a humanistic learning theory focused on the specific needs of adults [10]. Knowles emphasizes that adults are self-directed and expect to take responsibility for decisions, need to be involved in the planning and evaluation of their instruction, are most interested in educational experiences with immediate relevance, and learn best in problem-centered settings [10, 34, 36]. SDL is one of the most important and well-known educational principles of humanism and supporting learning methodologies include the use of PBL scenarios [34, 36]. Essential to SDL is that learners plan, conduct, and evaluate their own learning, all of which are incorporated into the structure of the CREs.

The active learning aspect of CREs builds on constructivist learning theory, which suggests that people learn by connecting new ideas and experiences to what they already know [8, 11, 22, 36]. Constructivist theory implies that effective learning should be by doing, applying knowledge and authentic problem solving, consistent with the structure of the CREs [8]. Learning is active and learners judge and control when and how to modify their own knowledge through critical reflection, a concept also critical in the SDL cycle [8, 11, 22]. The teacher is viewed not as a transmitter of knowledge but as a guide who facilitates learning by modeling, providing guidance and giving learners the opportunity to reflect [8, 22]. This is consistent with the role of faculty facilitators in the CREs and the opportunity for feedback at the end of each CRE case. Finally, group work, social interactions and discussion, all of which are fostered by the CRE curriculum, are also key to active learning [8, 11, 34, 36].

There is evidence to indicate PBL leads to greater student enjoyment and enthusiasm for learning than more "traditional" passive methods of medical education [18, 20, 24]. However, despite generally high student enthusiasm and satisfaction with active learning, the desired outcomes (increased SDL skills, deep content learning, higher-order thinking, clinical reasoning, teamwork, and increased problem-solving ability) are ill defined and hard to accurately measure [1, 5, 20]. Indeed, the existing literature provides inconsistent findings with respect to the effectiveness of PBL relative to more traditional methods in undergraduate medical education [20]. As students progress through a curricula, the goal is for them to attain, at a minimum, baseline knowledge and skills that will allow them to be effective professionals upon graduation [16]. This process of competency development is continuous, and facilitated and guided by both summative and formative assessments from multiple sources, including self, peer and faculty [13, 29].

To date no single gold-standard SDL skill measurement instrument has been established by the scientific and professional community [9]. Ideally, assessments provide a diagnostic tool to ensure students are progressing appropriately toward the desired learning goals and would assist in improving students' and instructors' performance [7, 39]. Described current methods

of summative assessment for PBL activities include construction of concept maps, briefs (summaries of the independent research students do to address their learning issues), knowledge-based written or oral exams, computer simulations, essays and standardized-patient based tests [7, 25, 29, 35].

Formative assessments are frequently included in PBL programs, and may involve self-, peer- and faculty evaluators assessing a range of skills, such as critical thinking, group cooperation, and communication [7, 29, 30]. Feedback can be a part of assessment and studies have reported that this motivates students to take the responsibility to monitor and advance their own learning and reflect on competency development [13]. Importantly, the ability to give and receive feedback and to appraise one's own needs are required in the daily activities of a physician [29]. Rubrics can be utilized to track student progress over time and repeated observations can indicate patterns of performance and function as more reliable assessments than a single observation point [7, 29]. Measuring and monitoring SDL competence over time allows individuals to identify areas of needed improvement and enables the institution to assess the effects of implemented educational strategies designed to foster students' SDL skill development [10].

As part of the formative assessment process for CREs, New York Medical College School of Medicine introduced a rubric to aid students' self-assessment of their acquisition of self-directed learning skills. The primary objectives of this study were to (1) evaluate students' self-assessment of their SDL competency, at mid-point and following the completion of a CRE course throughout the first-year medical school curriculum, and (2) assess student satisfaction regarding the provided educational opportunities for SDL competency development. A secondary objective of the study was to determine if the students' group facilitator was a significant factor in student self-assessed SDL competency.

Materials and methods

Research questions

1. What are students' levels of satisfaction with the current curricular opportunities to develop their SDL skills?
2. Do students self-assess themselves as achieving competency in SDL skills as measured at the mid-point and by the end of the M1 year and completion of the CRE course?
3. Is the students' group facilitator a significant factor in student self-assessed competency in SDL skills as measured at the mid-point and by the end of the M1 year and completion of the CRE course?

Setting and curricular context

The CREs were implemented in the New York Medical College School of Medicine M.D. program first-year medical student curriculum for the Class of 2026. Each CRE is centered around an authentic clinical case that emulates a "Core Clinical Condition" required of clerkship students. Cases are authored by the Director of SDL and/or in-house faculty members of the relevant discipline. The CREs run longitudinally, in parallel to the preclerkship curriculum, fostering integration of curricular content and increasing the amount of deliberate practice for foundational SDL skill development.

CRE small groups consist of one faculty facilitator and ten first-year medical students and are mandatory educational events. There is a total of twenty-two CRE groups, with each of eleven faculty facilitators having two separate groups of students. As CREs are student-driven and inquiry-based, the learners lead the sessions. The facilitator's role is as a group coach to ensure the group stays on track, help facilitate group discussion, confirm students are covering core concepts and provide feedback to each student as well as the group as a whole. Prior to engaging in any curricular activities, facilitators are provided with faculty development to train them on the techniques of effectively facilitating these specific educational exercises. Facilitators receive a general introduction to SDL and the CREs from the Director of Self-Directed Learning and are provided a faculty-specific syllabus that outlines the responsibilities of the facilitator (both in individual sessions, as well as in the program as a whole). More focused faculty development sessions on topics including principles of SDL, structure of CRE sessions, strategies to promote SDL skill development, small group teaching, and the art of effective feedback are also provided. In addition, one week before a CRE teaching session, faculty are presented a one-hour, case-specific session to adequately prepare facilitators for the medical knowledge aspect of the teaching duties. All sessions occur via Zoom and are recorded so that faculty can view the sessions at a later date if they are unable to attend the live session, or if they wish to review certain concepts. This extensive preparation trains facilitators to promote critical thinking in the learners through dialogue, feedback, direction, help in securing resources and evaluating usefulness of outcomes.Each CRE has three parts, as detailed below. Part 1 and Part 3 are 90 min in-person sessions, one week apart, held in medical education classrooms. The rooms are equipped with moveable desks (can be arranged into a circle to facilitate student interaction and discussion), whiteboards and a classroom computer with associated projector and large projection screen. Part 2 is independent work, built into students' weekly schedule as three hours of protected time.

- *Part 1: Case Presentation, Group Discussion, Identification of Individual Learning Needs.* During Part 1, the case is presented and discussed. No specified pre-work or pre-reading are required of students, though the scheduling of each CRE is designed to provide linkage to concurrent curricular content. Cases are presented via PowerPoint by "progressive disclosure" (unfolding step by step), usually as a written case vignette, but sometimes including additional educational technology such as images and videos. Once the case is complete, each student identifies an individual learning need and/or research question. This question may focus on any piece of information that is central to increasing the individual student's understanding of any aspect of the presented case.
- *Part 2: Student Self-Directed Research.* This portion of the exercise is entirely self-directed. Students research their individually identified learning need and prepare a four-minute presentation to share with the group during Part 3. Resources should be peer-reviewed and may include textbooks, course materials, review articles, and/or primary medical literature. Students should reference all sources used to find information for the case in any handouts, slides and/or teaching materials. Students are encouraged to consult library personnel and/or evidence-based medicine faculty for assistance during Part 2, but this is not required.
- *Part 3: Student Presentations and Discussion, Case Debrief, Formative Feedback.* During Part 3, students share the results of their individual research. Students may elect to utilize PowerPoint slides, draw diagrams on the whiteboard or create and provide a summary handout for classmates. Discussion follows each presentation, including questions, clarification, agreements, and/or disagreements. Following all presentations, group members review case author-provided PowerPoint slides that conclude the case. Students share and discuss any remaining questions about the case. At the conclusion of Part 3, students and the faculty facilitator provide verbal reflection about the session and give and receive formative feedback to improve individual and group effectiveness To encourage discussion and interaction during this period of feedback, students are asked to provide an example of something they did well during the session, as well as something they wish to improve on for next time. Facilitators then add their input to the students' self-assessment and may give feedback regarding any of the key aspects of SDL skill development. For example, the facilitator may provide feedback surrounding a student's choice of and assessment of reference, ability to synthesize new information into the case as a whole, or the ability of the student to work as a productive team member. Students are also encouraged to reach out to facilitators directly for one-on-one meetings if further feedback is desired.

Participants

All first-year students (n = 220) in the M.D. program curriculum at New York Medical College (Valhalla, NY) School of Medicine were required to participate in the CRE program. The Student Self-Assessment of Acquisition of Skills for Self-Directed Learning Form was distributed to all members of the first-year class via Qualtrics at the midpoint and end of the CRE course. Completion of the form was encouraged but not required. A total of 100 students completed it at the midpoint (response rate of 45.5%) and 179 students completed it at the conclusion of the course (response rate of 81.4%). A total of 89 students (response rate 40.5%) completed the self-assessment form at both time points. The Pre-Clerkship End of Course Student Evaluation Form was distributed to all members of the first-year class via LEO (the student electronic learning management system) at the end of the CRE course. Again, completion was encouraged but not required; 182 students completed the evaluation form, a response rate of 82.7%.

Procedure

The New York Medical College General Medical and Behavioral Institutional Review Board granted an exemption for this project (IRB #18895) and IRB approval for both data collection instruments was obtained prior to data collection. Student participation in completing both surveys was entirely voluntary, and all data was collected between February 2023 and May 2023. Surveys were distributed by the Office of Assessment and Evaluation and were open for responses for ten days.

The Student Self-Assessment of Acquisition of Skills for Self-Directed Learning Form (Fig. 1) was designed to aid students in reflecting upon and self-assessing their own cumulative progress in developing competency in SDL skills, as a result of participating in the CRE course throughout the first-year medical school curriculum (Kirkpatrick Level 2 / Learning)[32]. This data collection instrument was developed in-house at the New York Medical College School of Medicine and had been used previously at the institution for problem-based educational sessions prior to its incorporation into this study. In the creation of the form, items were selected from a larger pool of items individually written by members of the New York Medical College SDL Subcommittee. Suggested items were discussed and edited by the

Subcommittee, and overlapping items were eliminated to refine the survey to the final five self-report statements that were utilized, each of which represents an SDL competency. An exploratory factor analysis was conducted using principal components extraction with varimax rotation to explore patterns of covariance between survey items and to assess the degree to which the five items measured multidimensional constructs. Only one factor emerged ("SDL Competency"), accounting for 76.05% of the total variance. Cronbach's coefficient alpha was computed to measure reliability ($\alpha = 0.92$). The elimination of any one of the five items would have minimal effect on Cronbach's alpha and the reliability of the rubric, so all five items from the factor analysis were retained (Table 1).

Each item began with the prompt, "Participation in the scheduled CREs helped me develop my ability to" and was then followed by an SDL competency, such as "identify, analyze, and synthesize information relevant to my learning needs" or "engage in teamwork, communication and information sharing with my peers." For each of the five items, there were four options, varied along a scale of proficiency. The scale ranged from proficiency levels 1 to 4: 1 = Initial; 2 = Developing; 3 = Developed; 4 = Proficient, with behavioral anchors provided for each proficiency level. The scale was loosely based on the NIH Proficiency Scale (https://hr.nih.gov/about/faq/working-nih/competencies/what-nih-proficiency-scale), which describes an individual's level of proficiency in a particular competency. A total SDL competency score was calculated by adding the scores from each of the five items. The items are worded such that a high total score indicates a high level of competency in SDL skills, with a minimum possible score of 5 and a maximum possible score of 20.

At the end of the first-year medical school curriculum, students were asked to complete an anonymous Pre-Clerkship End of Year Student Evaluation Form to gauge overall satisfaction with the curriculum (Kirkpatrick Level 1/Reaction) [32]. This form contained a total of 17 questions, one of which was specific to the CRE course: "This course contributed to my ability to demonstrate initiative and self-direction in learning." This question was responded to using a five-point Likert scale, ranging from strongly disagree to strongly agree. An optional open text box was also available on this form for students to provide feedback regarding any aspect of the curriculum.

Statistical analysis

Once the surveys closed, data was exported to IBM Statistical Package for Social Sciences (SPSS) version 12 for analysis. Descriptive statistics (means and standard deviations) were calculated for student self-scores of each of the five surveyed skills and the total score at both the midway and endpoint of the CREs. Midway and final scores of student self-assessment were compared with a dependent (paired) samples t-test for perceived increase in SDL competency. Midway and final scores of student self-assessment were also compared among the eleven facilitators via a 1-way analysis of variance (ANOVA) to determine if the individual facilitator was a significant factor in student self-assessed competency. For all tests, the p-value limit for significance was $p < 0.05$.

Results

Student self-assessment of acquisition of skills for self-directed learning form

Descriptive Statistics

At the midpoint of the CRE course, the mean total score for student self-assessment of competency was 16.19, with a standard deviation of 2.87. At the course endpoint, the mean total score student self-assessment of competency was 17.41, with a standard deviation of 2.72. Descriptive statistics for each individual question are shown below in Table 2 (midpoint) and Table 3 (endpoint). At both the midpoint and endpoint, students self-assessed themselves as the lowest on Item 1 (*Participation in the scheduled CREs helped me develop my ability to identify, analyze, and synthesize information relevant to my learning needs*) and the highest on Item 3 (*Participation in the scheduled CREs helped me develop my ability to engage in teamwork, communication and information sharing with my peers*), though the differences in self-assessed scores for any individual pairs of items were not statistically significant (all $p > 0.05$).

As described in the Methods section, each of 11 facilitators was assigned two separate groups of ten students (for a total possible N of 20 students). Descriptive statistics (means and standard deviations) for the student self-assessed total score, as well as scores on each individual question, at the midpoint and endpoint were also calculated for students assigned to each of the eleven faculty facilitators. The total survey mean scores and standard deviations at course midpoint and endpoint are provided by facilitator across items in Table 4. Table 5 summarizes the means and standard deviations at course midpoint and endpoint by item across facilitators.

Changes between midpoint and end of course ratings

A dependent samples t-test was performed for the 89 students who completed the self-assessment form at both time points to determine if there was an increase in perceived competency by the end of the CRE course. There was a moderate positive correlation ($r = 0.423$) between the midpoint and endpoint total scores. The results showed a statistically significant increase from the self-assessed total score for competency from the

Student Self-Assessment of Acquisition of Skills for Self-Directed Learning

	Initial	Developing	Developed	Proficient
1. Identify, analyze, and synthesize information relevant to my learning needs	○ Identifies specific learning needs and formulate background questions; Uses information from multiple resources but focus is on background information	○ Identifies specific learning needs and formulate foreground questions; Identifies relevant information sources; Some analysis and synthesis of information related to specific learning needs	○ Identifies specific learning needs and formulate foreground questions; Identifies relevant information sources; Consistently analyzes and synthesizes information	○ Reviews literature related to practice and habitually evaluate learning gaps; Information search and analysis is sophisticated and aligns with specific learning needs
2. Assess the credibility of information sources	○ Limited ability to assess the credibility of information resources	○ Selects and appraises scholarly information resources, although resources selected may not be the "best evidence"	○ Selects and appraises high quality resources to support learning needs	○ Routinely critically assesses sources in terms of quality, legitimacy, relevance, and acknowledges conflicting evidence
3. Engage in teamwork, communication and information sharing with my peers	○ Passive participant; disengaged; resistant to group engagement, even when prompted	○ Well prepared and presents information learned to small group; some prompting needed to participate in group discussion	○ Active contributor to discussions; Willing to share information; Anticipates additional questions and can recommend resources to peers	○ Actively engaged in group discussion; Initiates sharing of knowledge among peers in the clinical setting
4. Critically think	○ Rarely questions or challenges others; rarely questions material being discussed	○ Sometimes (<50%) able to both raise and respond to challenges in group setting	○ Raises questions that display reflective thinking; Points out problems or controversies during discussion; Seeks out information for more understanding of material	○ Demonstrates a deep understanding of the material; Asks questions that promote a deeper understanding of the subject; Synthesizes information from different sources
5. Acknowledge and utilize facilitator and peer feedback to enhance my SDL-related skills	○ Learning to seek and accept feedback from faculty and peers	○ Receptive to feedback when provided; Demonstrates self-reflection related to prior feedback provided	○ Receptive to feedback from facilitator and peers; Demonstrates self-reflection and incorporation of feedback into practice	○ Consistently and actively seeks feedback from facilitator and peers; Consistently demonstrates thoughtful self-reflection and incorporation of feedback into practice

Fig. 1 Student Self-Assessment of Acquisition of Skills for Self-Directed Learning Form

Table 1 Item-Total Scale Statistics for Cronbach's Alpha

Item	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
1. Independently identify, analyze, and synthesize information relevant to my learning needs	11.33	7.21	.85	.89
2. Assess the credibility of information sources	11.24	8.38	.71	.92
3. Engage in teamwork, communication and information sharing with my peers	11.25	8.04	.74	.91
4. Critically think	11.30	7.38	.86	.89
5. Acknowledge and utilize facilitator and peer feedback to enhance my SDL-related skills	11.26	8.10	.83	.90

Table 2 Summary Statistics by Survey Item and Total Score for the Complete Sample of Student Respondents at the CRE Course Midpoint

	Item 1	*Item 2*	*Item 3*	*Item 4*	*Item 5*	*Total Score*
N	100	100	100	100	100	100
Mean	3.15	3.18	3.42	3.28	3.16	16.19
Std. Deviation	.70	.74	.64	.71	.71	2.87

Table 3 Summary Statistics by Survey Item and Total Score for the Complete Sample of Student Respondents at the CRE Course Endpoint

	Item 1	*Item 2*	*Item 3*	*Item 4*	*Item 5*	*Total Score*
N	179	179	179	179	179	179
Mean	3.39	3.51	3.58	3.45	3.49	17.41
Std. Deviation	.68	.70	.62	.68	.61	2.72

midpoint ($M = 16.34$) to the endpoint of the CRE course ($M = 17.61$), ($t(88) = 4.121$, $p < 0.001$) (Table 6). On average, total scores of competency at the endpoint of the course were 1.270 points higher than at the midpoint of the course. The effect size, as measured by Cohen's d, was d = 0.44, indicating a medium effect.

In addition to the total score, perceived increase in competency was considered for each of the five individual skills (Tables 7, 8, 9, 10 and 11). For Item 1, the skill of "Identify, analyze and synthesize information relevant to my learning needs," there was a positive correlation (r = 0.314) between the midpoint and endpoint scores and a statistically significant increase in the self-assessed score from the midpoint ($M = 3.18$) to the endpoint of the CRE course ($M = 3.47$), ($t(88) = 3.505$, $p < 0.001$). On average, scores of competency in this skill at the endpoint of the course were 0.29 points higher than at the midpoint of the course.

For Item 2, the skill of "Assess the credibility of information sources," there was a positive correlation (r = 0.386) between the midpoint and endpoint scores and a statistically significant increase in the self-assessed score for competency from the midpoint ($M = 3.19$) to the endpoint of the CRE course ($M = 3.60$), ($t(88) = 4.991$, $p < 0.001$). On average, scores of competency in this skill at the endpoint of the course were 0.40 points higher than at the midpoint of the course.

For Item 3, the skill of "Engage in teamwork, communication and information sharing with my peers," there was a moderate positive correlation (r = 0.408) between the midpoint and endpoint scores and a statistically significant increase in the self-assessed score for competency from the midpoint ($M = 3.45$) to the endpoint of the CRE course ($M = 3.60$), ($t(88) = 2.016$, $p < 0.05$). On average, self-rated scores of competency in this skill at the endpoint of the course were 0.15 points higher than at the midpoint of the course.

For Item 4, the skill of "Critically think," there was a positive correlation (r = 0.283) between the midpoint and endpoint scores. The results did not show a statistically significant increase in self-assessed competency in this

Table 4 Total Survey Statistics by Facilitator Across Items at Course Midpoint and Endpoint

		Total Score Midpoint	Total Score Endpoint
Facilitator 1	N	8	19
	Mean	17.00	17.53
	Std. Deviation	2.00	2.59
Facilitator 2	N	5	19
	Mean	17.00	18.47
	Std. Deviation	2.24	2.27
Facilitator 3	N	12	19
	Mean	16.42	17.58
	Std. Deviation	3.00	2.63
Facilitator 4	N	11	19
	Mean	17.73	16.47
	Std. Deviation	2.57	4.10
Facilitator 5	N	12	15
	Mean	16.17	18.33
	Std. Deviation	2.66	1.50
Facilitator 6	N	10	10
	Mean	14.00	16.00
	Std. Deviation	3.13	2.06
Facilitator 7	N	10	15
	Mean	17.20	18.33
	Std. Deviation	2.44	2.26
Facilitator 8	N	8	16
	Mean	13.38	16.63
	Std. Deviation	2.07	2.71
Facilitator 9	N	8	14
	Mean	15.75	17.21
	Std. Deviation	3.88	2.70
Facilitator 10	N	8	13
	Mean	17.25	17.85
	Std. Deviation	1.91	2.30
Facilitator 11	N	8	20
	Mean	16.13	16.80
	Std. Deviation	2.80	2.90
Total	N	100	179
	Mean	16.19	17.41
	Std. Deviation	2.87	2.72

skill from the midpoint ($M=3.33$) to the endpoint of the CRE course ($M=3.48$), ($t(88)=1.864$, $p>0.05$).

For Item 5, the skill of "Acknowledge and utilize facilitator and peer feedback to enhance my SDL-related skills," there was a positive correlation ($r=0.321$) between the midpoint and endpoint scores and a statistically significant increase in the self-assessed score for competency from the midpoint ($M=3.19$) to the endpoint of the CRE course ($M=3.46$), ($t(88)=3.325$, $p<0.001$). On average, scores of competency in this skill at the endpoint of the course were 0.27 points higher than at the midpoint of the course.

Faculty facilitator effect analyses

A one-way analysis of variance (ANOVA) was performed for the 89 students who completed the self-assessment at both time points to determine if the specific faculty facilitator was a key variable in student self-assessment of increased competency. The mean student self-assessment total score ranged from 13.38 (Facilitator 8) to 17.73 (Facilitator 4) at the course midpoint and from 16.25 (Facilitator 8) to 19.00 (Facilitator 7) at course endpoint. There was a statistically significant difference in student self-assessment total scores among facilitator groups at the midpoint of the course as determined by the ANOVA ($F(10,78)=2.49$, $p=0.012$) (Tables 12 and 13). However, there was no statistically significant difference in total score of self-assessed competency among facilitator groups at the endpoint of the CRE course ($F(10,78)=1.11$, $p>0.05$) (Tables 14 and 15).

As described in the Methods, all above data analyses were performed by assigning a score of 1 to 4 for each of the proficiency levels (1 = Initial; 2 = Developing; 3 = Developed; 4 = Proficient). Table 16 summarizes the percentage of students self-reporting at each proficiency level at course midpoint and endpoint across all items, for the 89 students who completed the self-assessment at both time points.

Pre-clerkship end-of-year student evaluation form

At the end of the first-year medical school curriculum, 63.2% of responding students indicated that they agreed

Table 5 Item Summary Statistics by Item Across Facilitators at Course Midpoint and Endpoint

		Item 1	*Item 2*	*Item 3*	*Item 4*	*Item 5*	*Total Score*
Total Midpoint	N	100	100	100	100	100	100
	Mean	3.15	3.18	3.42	3.28	3.16	16.19
	Std. Deviation	.70	.74	.64	.71	.71	2.87
Total Endpoint	N	179	179	179	179	179	179
	Mean	3.39	3.51	3.58	3.45	3.49	17.41
	Std. Deviation	.68	.70	.62	.68	.61	2.72

Table 6 Summary Statistics at Course Midpoint and Endpoint for Paired Students – Total SDL Score

	N	Mean	Std Deviation	Std Error Mean
Endpoint	89	17.61	2.70	.29
Midpoint	89	16.34	2.72	.29
Endpoint-Midpoint	89	1.27	2.91	.31

Table 7 Summary Statistics at Course Midpoint and Endpoint for Paired Students – Item 1

	N	Mean	Std Deviation	Std Error Mean
Endpoint	89	3.47	.66	.07
Midpoint	89	3.18	.68	.07
Endpoint-Midpoint	89	.29	.79	.08

Table 8 Summary Statistics at Course Midpoint and Endpoint for Paired Students – Item 2

	N	Mean	Std Deviation	Std Error Mean
Endpoint	89	3.60	.64	.07
Midpoint	89	3.19	.74	.08
Endpoint-Midpoint	89	.40	.77	.08

Table 9 Summary Statistics at Course Midpoint and Endpoint for Paired Students – Item 3

	N	Mean	Std Deviation	Std Error Mean
Endpoint	89	3.60	.64	.07
Midpoint	89	3.45	.62	.07
Endpoint-Midpoint	89	.15	.68	.07

Table 10 Summary Statistics at Course Midpoint and Endpoint for Paired Students – Item 4

	N	Mean	Std Deviation	Std Error Mean
Endpoint	89	3.48	.66	.07
Midpoint	89	3.33	.67	.07
Endpoint-Midpoint	89	.16	.80	.08

or strongly agreed that the CRE course contributed to their ability to demonstrate initiated and self-direction in learning, while 25.8% were neutral and 10.99% said they disagreed or strongly disagreed. Students answering "Strongly Disagree/Disagree" were requested to

Table 11 Summary Statistics at Course Midpoint and Endpoint for Paired Students – Item 5

	N	Mean	Std Deviation	Std Error Mean
Endpoint	89	3.46	.64	.07
Midpoint	89	3.19	.67	.07
Endpoint-Midpoint	89	.27	.77	.08

Table 12 Descriptive Statistics by Facilitator Group for Total SDL Competency Score – Course Midpoint

	N	Mean	Std Deviation	Std Error
Facilitator 1	7	17.00	2.16	.82
Facilitator 2	5	17.00	2.24	1.00
Facilitator 3	12	16.42	3.00	.87
Facilitator 4	11	17.73	2.57	.78
Facilitator 5	11	16.64	2.20	.66
Facilitator 6	6	13.50	2.59	1.06
Facilitator 7	9	17.22	2.59	.86
Facilitator 8	8	13.38	2.07	.73
Facilitator 9	5	16.80	3.03	1.36
Facilitator 10	7	17.00	1.92	.72
Facilitator 11	8	16.13	2.80	.99
Total	89	16.34	2.72	.29

Table 13 One-way ANOVA by Facilitator Group for Total SDL Score – Course Midpoint

	Sum of Squares	df	Mean Square	F	Sig
Between Groups	157.64	10	15.76	2.49	.01
Within Groups	492.25	78	6.31		
Total	649.89	88			

Table 14 Descriptive Statistics by Facilitator Group for Total SDL Competency Score – Course Endpoint

	N	Mean	Std Deviation	Std Error
Facilitator 1	7	18.57	1.90	.72
Facilitator 2	5	19.40	.89	.40
Facilitator 3	12	17.67	2.77	.80
Facilitator 4	11	16.73	4.56	1.38
Facilitator 5	11	18.09	1.51	.46
Facilitator 6	6	16.50	2.26	.92
Facilitator 7	9	19.00	1.58	.53
Facilitator 8	8	16.25	1.91	.68
Facilitator 9	5	17.80	2.28	1.02
Facilitator 10	7	17.43	2.70	1.02
Facilitator 11	8	16.75	3.45	1.22
Total	89	17.60	2.70	.29

Table 15 One-way ANOVA by Facilitator Group for Total SDL Score – Course Endpoint

	Sum of Squares	*df*	*Mean Square*	*F*	*Sig*
Between Groups	79.55	10	7.96	1.11	.37
Within Groups	559.69	78	7.18		
Total	639.24	88			

Table 16 Percent of Student Survey Responses at Each Scale Category at Course Midpoint and Endpoint Across Survey Items

	***Initial* (1)**	***Developing* (2)**	***Developed (3)***	***Proficient (4)***
Midpoint	0%	13.5%	46.3%	40.2%
Endpoint	1.1%	4.9%	34.6%	59.3%

explain their rationale in an open-field text box. Five unique comments were provided:

- *"I did not find them helpful or productive and would have rather spent that time studying and reviewing testable material"*
- *"I didn't learn anything from the self directed exercises. It was fun to meet with my peers though."*
- *"The CRE gave great opportunities for SDL"*
- *"There were too many presentations"*
- *"Too few sessions"*

Discussion

This study demonstrated a statistically significant improvement in students' self-assessed SDL competency. SDL is a form of education in which the learner takes charge of their own learning process, taking an active role in knowledge, skill and attitude acquisition. Critical Reasoning Exercises (CREs) were introduced at the author's institution for first-year medical students to supplement the pre-existing opportunities for student development of SDL skills.

The study of SDL ability represents a relatively young field of research [9]. Instruments for assessing SDL readiness and/or skill development that have been described in the literature and validated to varying degrees include the Self-Directed Learning Readiness Scale for Nursing Education, Self-Rating Scale of Self-directed Learning, Self-Directed Learning Instrument and the Self-Directed Learning Readiness Scale [9, 10]. A five-item self-report rubric of SDL competency was developed and validated in the current report. This rubric was designed to assess students' competency development in the different skill components of SDL. Out of a total possible score of 20 (which would indicate complete self-reported proficiency in all five components), the mean score for all students was 16.19 at the midpoint of the CRE course, and 17.41 at the conclusion of the course. While this increase in self-assessed total score from midpoint to endpoint was somewhat small, it reached statistical significance, indicating a perceived increase in competency in SDL skills by students by the end of the CRE course. Another way to visualize this change is by examining the percentage of students that self-reported themselves at each level of proficiency at the course midpoint and endpoint. At the midpoint, approximately 46% of students thought themselves to be "Developed" and another 40% considered themselves "Proficient," while at the endpoint, 59% of students considered themselves to be "Proficient." In addition, the percentage of students that considered themselves "Developing" decreased from 13.5% at the midpoint to just under 5% at the endpoint. There was also a statistically significant perceived increase in competency for four of the five individual skills of SDL (identify, analyze and synthesize information relevant learning needs; assess credibility of information sources; engage in teamwork, communication and information sharing with peers, acknowledge and utilize facilitator and peer feedback to enhance SDL-related skills).

At this stage of training (end of first year of medical school), our institution's goal is for students to be at an approximate midway stage of developing competency in each of these skills, with the goal for students to be at a "developed" or "proficient" stage by the time of entry into clerkships. Rubrics, such as the one utilized in this scale, can be used to chart progress over time, with repeated observations of students indicating patterns of performance and therefore, serving as more reliable assessments of true ability than a single observation timepoint [7]. Ideally, one would utilize this rubric longitudinally (once or twice per academic year, through the end of the pre-clerkship phase) to determine how students are progressing and to target individuals for remediation/assistance with skill development as needed [10]. Additionally, as students progress through curricula, their knowledge base and ability to self-assess should improve, which should lead to rubric scores that more closely resemble the actual skill level [16]. Beginning in AY24-25, students will also complete the self-report rubric before beginning the CRE course, to provide a pre-course, baseline self-assessment of perceived SDL skills upon entering the pre-clerkship curriculum.

There was a statistically significant difference in student self-assessed total SDL competency scores among facilitator groups at the midpoint of the course. It would be interesting to explore this finding further to determine what may account for the difference. Perhaps certain facilitators are more adept at teaching the skills of SDL,

leading to greater and quicker SDL skill development, as self-assessed by the students. Alternatively, perhaps certain facilitators are very encouraging, providing students with abundant positive feedback, leading students to self-assess themselves as highly proficient in the skills (whether or not it was an accurate assessment). Future targeted faculty development of SDL group facilitators will be important to establish a more consistent level of baseline quality of instruction in teaching students SDL skills, to ensure that all students are on an even plane for skill development. Interviewing the facilitators of groups with the highest student self-assessment scores, as well as those with the lowest, would potentially be useful in determining if there are common themes in teaching approach among the faculty of the highest-scoring groups and the faculty of the lowest-scoring groups.

Self-assessment has been defined broadly as the involvement of learners in judging whether or not learner-identified needs and standards have been met [14, 29]. Students often have difficulty accurately self-assessing, particularly early in their training and before achieving mastery of a subject. Even practicing physicians are frequently unable to reliably self-assess their knowledge or skills when compared to an objective evaluation of these performance measures [16]. Thus, a major limitation of this scale is that it is based on students' voluntary completion of a self-assessment, which may not be a true representation of their actual skillset (either an under- or overestimation) and, therefore, is not a direct measure of their SDL abilities. As medical school is likely the first time many of the students have been exposed to the educational approach of SDL, they may not fully understand how to reliably gauge their skill development. Previous reports have indicated that most populations undertaking self-assessment tend to overestimate their skills [14, 16]. Accordingly, students in this survey rated themselves very high in SDL skills, even at the midpoint of the course. While there was a significant improvement in self-assessed skills by the end of the course, there was little room on the scale for students to show this change. To address this in future cohorts, the scale may be refined to add additional levels of proficiency and/or clearer anchor descriptions for each level of proficiency. Additionally, the scale could also be introduced for student self-assessment of SDL skills prior to the CRE course beginning, to provide three time points for comparison.

Many higher education studies consider both perceptions and more tangible data points (pre- and post-intervention testing, examination scores, final course grades) to provide a comprehensive picture when evaluating the outcomes and impact of an educational intervention [14, 16]. Although SDL skills are not easily measurable on an objective examination, one could develop a faculty version of this survey to compare students' self-assessments of proficiency to those of an external observer (in this case, the group facilitator). As this is a new measurement instrument and the cohort described above was the first to experience the CRE course, it will be important to continue to analyze the results in subsequent cohorts, to further validate the rubric and ensure that it is behaving in a consistent way or if it requires adjustments. Although the rubric was subjected to measures of validation, lack of detailed psychometric analysis of the items is a possible limitation. This was also a pilot study at a single medical school, so it will be crucial to analyze results from other student cohorts (varying by such factors as geographic location, student demographics or medical school ranking) to determine if this scale can be applied in other environments. An additional limitation of this scale is its very short length. While the reliability is high for this five-item survey, one might consider adding additional items that more broadly cover the SDL competencies for future studies.

In this study, at the end of the first-year medical school curriculum, approximately 63% of responding students indicated that they agreed or strongly agreed that the CRE course contributed to their ability to demonstrate self-direction in learning, while 26% of students were neutral and 11% of students indicated disagreement. Provided explanations for disagreement included wanting to instead focus on reviewing/studying testable material, having to prepare too many presentations and having too few CRE sessions. Unfortunately, there were so few explanations provided in the open text box on the evaluation form that it is difficult to determine if these three reasons are representative of the 11% that disagreed. Small student focus groups are currently being formed to gather feedback on recent curricular modifications at the institution and follow up on this topic will be included. In addition, the large number of students answering "neutral" is also an issue requiring follow-up and action steps. Unfortunately, high numbers of "neutral" responses are frequently noted on end of course surveys. To attempt to combat this issue, medical education leadership at the institution has been working closely with student class representatives to indicate the importance of providing actionable feedback on forms/surveys. There is also discussion regarding changing the forms for the next academic year, to eliminate the neutral option as an answer choice.

As this was the first year piloting this course, the institution will continue to refine the CREs in future iterations with the goal of improving the exercises' ability to develop relevant skills and increasing student satisfaction. Specific modification suggested by several student focus groups include incorporation of

additional clinician facilitators and refinement of CRE scheduling to ensure closer alignment with parallel pre-clerkship curricular content. With these changes, and continued monitoring of feedback from both students and facilitators for additional opportunities for improvement, the institution will further optimize the development of and integration of CREs into the curriculum as an effective educational approach for medical student development of competency in SDL.

Clinical Trial Number

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Authors' contributions
Amanda P. Beck is the only author.

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This manuscript was created in partial fulfillment of the Master of Science in Education degree with a major in Health Professions Education. APB is currently the Director of Self-Directed Learning in the Department of Undergraduate Medical Education and an Associate Professor in the Department of Pathology, Microbiology, and Immunology at New York Medical College School of Medicine.

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Data availability
The de-identified datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The New York Medical College General Medical and Behavioral Institutional Review Board granted an exemption for this project (IRB #18895) and IRB approval for both data collection instruments was obtained prior to data collection. The consent to participate was waived by the IRB. Student participation was entirely voluntary. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

Consent for publication
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The authors declare no competing interests.

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