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WEB PAPER

Assessing self-regulatory processes during clinical skill performance: A pilot study

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Abstract

Background: Self-regulated learning (SRL) is a cyclical process involving the proactive use of strategies and feedback to optimise performance. Previous research has used SRL microanalysis to assess and inform the training of athletic skills but there has been no previous research in clinical contexts.

Aims: The aim of this pilot study was to evaluate the use SRL microanalysis to assess the regulatory profiles of students who were successful and unsuccessful in a venipuncture task.

Method: A SRL microanalysis protocol was administered to seven 3rd-year undergraduate medical students whilst they performed a venipuncture on a simulation mannequin arm.

Results: The use of SRL microanalytic questions had good inter-rater reliability. Students who were successful in venipuncture had high levels of strategic thinking before, during and after the clinical task, whereas the students who struggled on this task tended to focus on outcomes.

Conclusions: The results shown in this study mirror the findings from previous research using SRL microanalysis. SRL microanalysis has strong potential as a structured assessment technique targeting the self-regulatory processes underlying clinical skill performance. Further research is recommended, especially on how the assessment of self-regulatory skills can be used to guide training for struggling students.

Introduction

Self-regulated learning (SRL) has been described as a cyclical process whereby individuals proactively generate and use feedback about their learning to optimise their strategic pursuit of personal goals (Schunk 2001). Although theoretical models vary, social-cognitive researchers argue that self-regulation occurs in a cyclical loop characterised by three sequential phases: forethought, (processes preceding action), performance (processes during action) and self-reflection (processes following action) (Zimmerman 2000). From this perspective, forethought processes, such as goal-setting and strategic planning, impact how an individual engages in learning or performing a task. It is during the performance phase, when highly regulated individuals enlist the use of self-control tactics, such as attention-focusing or self-instruction and self-monitoring behaviours to gauge how well they are learning or performing. The information that is generated during performance, either by the student or from external sources, is used by a learner to self-reflect on his or her performance relative to goal attainment, perceived causes of his or her performance outcomes and the strategies that one needs to modify or sustain to optimise performance.

A hallmark feature of sophisticated self-regulated learners is that they are *strategically* engaged in the process of learning or performing a task during each phase of the cyclical loop (Cleary 2011). Thus, these individuals think in terms of strategies during task preparation or goal-setting, such as when a medical student mentally rehearses the steps of a clinical skill immediately before performing the task. Highly regulated individuals will also use highly refined tactics to perform a task (e.g. using self-talk to guide one's behaviour or to closely follow the steps in a protocol for a clinical skill) and will frequently self-monitor their use of strategies during task

Practice points

- SRL is a cyclical process involving the proactive use of strategies and feedback to optimise performance.
- SRL microanalysis has been used to assess and to inform the training of athletic skills but there has been no previous research in clinical contexts.
- Assessment of self-regulatory processes can be identified before, during and after actual performance of clinical skills by the use of SRL microanalysis.
- Students who displayed adequate skill in venipuncture exhibited strategic thinking before, during and after performance, whereas the students who struggled tended to focus on outcomes.
- SRL microanalysis has strong potential as a structured assessment technique targeting the self-regulatory processes underlying clinical skill performance and could be used to guide training for struggling students.

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performance. Finally, these types of students evaluate their performance relative to their effective use of learning strategies and continuously reflect on ways to enhance the proficiency of these tactics.

Research in the athletic domain has consistently shown that experts or high performers will engage in strategic self-regulatory thinking and processes more frequently than low performers (Cleary & Zimmerman 2001; Kitsantas & Zimmerman 2002). To comprehensively capture students' self-regulatory thoughts and processes before, during and after a learning or performance activity, social-cognitive researchers developed an assessment methodology, called SRL microanalysis (Bandura et al. 1982; Cleary & Zimmerman 2001; Cleary 2011). In general, this highly structured assessment approach involves administering context-specific questions targeting the various regulatory constructs embedded within each the three phases of the cyclical feedback loop (e.g. goal-setting, self-monitoring, strategy use, causal attributions) as an individual engages in a well-defined activity (Cleary 2011). The key objective in this approach is to identify whether individuals' preparation or approach to learning or performance (forethought), thoughts and beliefs during the activity (performance control) and reflective thoughts and reactions following performance reflect *strategic mindfulness*. That is, to what extent are individuals mindful and aware of the strategies that they need to learn or perform most effectively, the accuracy with which one uses these strategies and the overall effectiveness of these tactics for reaching their goals. The core features of SRL microanalysis include the use of individualised assessment protocols and the use of open-ended and close-ended questions targeting the specific processes within the three-phase regulatory loop. Furthermore, SRL microanalytic methodology allows researchers and practitioners to customise the microanalytic questions to match the particular contexts and/or performance situations of interest. That is, although the general phrasing of all questions are generated from conceptual definitions of the particular constructs (e.g. goal-setting, causal attributions) and prior research, questions are modified to reflect the particular performance events of interest.

Of greatest practical importance, is that intervention research shows that training low achievers to effectively utilise self-regulatory processes will improve their athletic performance by increasing their motivation and skills in managing their performance (Zimmerman & Kitsantas 1996; Cleary & Zimmerman 2001). For example, the use of structured multi-phasic self-regulation training, such as teaching students to set process instead of outcome goals and self-monitor during performance, has been shown to increase athletic skill and motivation (Cleary et al. 2006).

The aim of this pilot study was to evaluate an assessment procedure, called SRL microanalysis, in a medical context and to show how such a procedure can identify students' regulatory processes as they perform a specific clinical task (venipuncture on a simulation mannequin arm). Our intention was to develop a "proof of concept" illustration that SRL microanalysis can be used for the structured assessment of clinical skills in the medical context. Although this methodology has been studied in other domains, it has never been applied to the medical education field.

Table 1. Descriptive statistics across motivation belief measures for participants.

Participant	Pre-task self-efficacy	Post-task self-efficacy	Satisfaction
Successful			
A	60	70	70
B	60	80	70
C	45	–	40
D	50	90	70
F	75	70	75
	Mean = 58	Mean = 77.5	Mean = 65
Strugglers			
E	60	90	30
G	70	40	10
	Mean = 65	Mean = 65	Mean = 20

Note: "–", Student misunderstood self-efficacy measure directions and thus provided erroneous scores.

Method

Sample

Seven 3rd-year undergraduate medical students from one medical school in the UK participated in this study. An invitation email was sent by John Sandars to 3rd-year medical students, and the first eight students to schedule an appointment were enrolled. One of the eight students who volunteered was from a different year cohort and was ineligible for this study. The majority of the seven participants in this study were female ($n = 6$).

The participants were highly similar in terms of prior achievement and amount of practice using venipuncture. All participants had previously attended a training session in venipuncture (at which they had successfully obtained a blood sample from a mannequin arm), but had independently drawn blood from only two or three patients. The participants' pre-task self-efficacy for using venipuncture was also highly similar (Table 1).

Materials and procedures

Each student was asked to take a blood sample by venipuncture from a simulation mannequin arm using the same procedure that they had all been previously instructed to use approximately 3 months prior to this study. The mannequin arm and supplied equipment (including hand gel, gloves, tourniquet, needles, vacutainers and sample bottles) were identical to the materials used in the initial training session. In this study, participants were allowed to take as many attempts as necessary to successfully obtain a blood sample.

An SRL microanalytic assessment protocol was developed based on guidelines used in other contexts (Cleary 2011). Forethought, performance and reflection phase questions were developed to correspond to the before, during and after dimension of the venipuncture event. Forethought phase processes (i.e. self-efficacy, planning and goal-setting) were administered immediately preceding the participants' attempt to obtain a blood sample. A metacognitive monitoring question (i.e. performance phase) was asked during the venipuncture task, while self-reflection phase questions (self-evaluative standards and satisfaction) were administered immediately following this task. All sessions were audio recorded and transcribed by John Sandars.

Measures

Self-efficacy. Based on Bandura's (2006) guidelines for developing self-efficacy scales, a 2-item measure of self-efficacy was used to assess students' confidence in successfully drawing blood. All items began with the phrase, "On a scale from 0 to 100, with 10 being not sure, 40 being somewhat sure, 70 being pretty sure, and 100 being very sure, how sure are you that you can obtain an acceptable blood sample from this arm . . . ". This stem was followed by (a) on your first attempt, (b) on your second attempt. This 2-item measure was administered pre-task and post-task. The average coefficient alpha across pre-task and post-task was 0.81.

Strategic planning

This one-item microanalytic measure was designed to examine student cognition immediately preceding their attempt at taking blood from the mannequin. Participants were asked, "What are you thinking about as you prepare to draw blood from this arm?" Participant responses were coded independently by the two authors into one of six categories: process/technique, outcome, patient interaction/care, confidence, do not know and other. The majority of this coding scheme was based on coding schemes used in prior research across different tasks (Cleary & Zimmerman 2001; Kitsantas & Zimmerman 2002). The process or technique category involved responses pertaining the application or use of venipuncture steps (as defined by protocol that was for the initial training). An example of a response coded for this category included, "I need to focus on all of the steps . . . to put gel on and to get the needle at the right angle". An outcome response pertained to being able to draw blood, such as, "To get a bit of blood from the arm". The patient interaction category involved responses pertaining to verbally interacting with the patient or ensuring their comfort. An example of a patient interaction response was, "To first explain things to the patient and to make sure I don't hurt them" The confidence category involved responses pertaining to students' confidence or perceived ability to draw blood or their capability. An example of this category was, "To try to stay confident during the activity". The do not know category involved participant responses explicitly indicating that they were not sure or were not aware of any thoughts. Finally, the "other" response category included any response that did not fit into the above categories. Student responses were coded independently by the two authors. A per cent agreement of 93% was reached, with disagreements being resolved with discussion.

Goal-setting. This one-item microanalytic measure was designed to assess participant goals prior to their attempt at taking blood from the mannequin. After the planning question, the participants were asked, "Do you have a goal in mind before drawing this blood sample?" Identical recording and coding procedures using the same framework as with the planning measure were adhered to with the goal-setting measure. A per cent agreement of 100% was reached by the two coders.

Metacognitve monitoring. This measure targeted students' beliefs about specific mistakes they made during the venipuncture task. Immediately preceding the participant's attempt to put the needle into a vein, the participants were asked, "Do you think you have performed a flawless process thus far or have you made any mistakes? Tell me about them". For this question, student responses were coded into one of three categories: process/technique, non-process/technique and do not know. The process category was similar to that used for the planning and goal-setting questions. However, the non-process category was a global category that included all responses other than those involving the venipuncture technique or direct statements of "don't know". The process/non-process dichotomy has been successfully used in prior research. A per cent agreement of 100% was reached by the two coders.

Satisfaction. After the venipuncture task was completed, the participants were asked, "How satisfied are you with your current performance?" This one item measure is based on a 100-point likert scale with 10 point increments. This scale has been used extensively in prior research and has been shown to differentiate ability groups and also to predict students' self-efficacy and interest for a task (Zimmerman & Kitsantas 1997).

Self-evaluative standards. Following the satisfaction question, the participants were prompted to answer a question assessing the self-evaluative criteria that they used to judge their degree of satisfaction with their performance. The participants were asked, "What did you use to judge your degree of satisfaction?", and then were given a laminated card with the following response options: (a) how you think others might perform this task, (b) the number of attempts to obtain the blood sample, (c) how well you used the correct plan or technique, (d) other factors and (e) do not know. Participants were prompted to select only one response option.

Results

Qualitative case descriptions were used to analyse and report the self-regulatory processes and motivation beliefs of all seven participants (Table 2). Although the seven participants received identical training in venipuncture, the students had limited practice experiences in this approach. Based on their performance on the venipuncture task in this study, five of the students were able to draw blood on their first attempt and thus were labelled "successful" performers. Two individuals needed three attempts to successfully draw blood from the mannequin and were subsequently identified as "strugglers". Prior research has shown that high achievers tend to exhibit a high level of strategic thinking before, during and after an

Table 2. Self-regulatory profile of participants on the venipuncture task.

Participant	Planning	Goal-setting	Monitoring	Self-evaluative standards
Successful				
A	Process/technique	Process/technique	Process/technique	Process/technique
B	Process/technique	Outcome	Non-process	Process/technique
C	Process/technique	Process/technique	Process/technique	Number of attempts
D	Process/technique	Process/technique	Process/technique	Process/technique
F	Process/technique	Patient interaction	Process/technique	Number of attempts
Strugglers				
E	Outcome	Outcome	Do not know	Number of attempts
G	Outcome process/technique	Outcome	Non-process	Number of attempts

event. Thus, we examined the extent to which each of the participants in the two achievement groups exhibited strategic thinking across four self-regulatory processes (planning, goal-setting, self-monitoring and self-evaluation) as well as the quality of their motivation beliefs (self-efficacy and satisfaction).

Self-regulatory profile of successful task performers

In general, individuals who successfully obtained a blood sample on their first attempt exhibited a high level of strategic thinking across all four self-regulatory processes. Regarding the forethought processes of planning and goal-setting, all five participants reported focusing on the steps or technique of the venipuncture task as their primary preparatory thoughts, with four of these students also indicating that their primary goal was to perform the process of venipuncture correctly. For example, Student A indicated that she was thinking about, "All the steps that I have to go through as I have been taught to do for the OSCE . . . introduce myself to the patient, gel my hands, put on gloves and angle the needle at the right angle". As an example of setting process or technique goals, Student D indicated that she wanted to "go through the procedure in my head, step by step, before I actually do it . . . try to have a plan of action in my mind" (See Table 2 for a complete description of all coded responses).

To evaluate metacognitive monitoring during the venipuncture task, the examiner asked the participants to indicate whether they had performed the procedure correctly. Four of the five successful task performers conveyed specific aspects of the venipuncture procedure that they perceived were not performed effectively. For example, Student A indicated that, "I went to get the gloves and put them on before I alcohol swabbed it . . . I realised that before I did it. That's all", while Student C iterated, "I probably should have palpated the vein first . . . but it was quite prominent and I would take it from there". Interestingly, the one student who did not report strategy or process for this question, Student B, indicated that she had performed a flawless routine. Thus, Student B may have been monitoring her execution of the venipuncture steps but simply indicated that she had not made any mistakes.

After successfully completing the venipuncture task, the participants were prompted to indicate the primary factor that they used to evaluate their level of success or satisfaction with their performance on the venipuncture. In short, students A, B and D reported using process or technique-related self-evaluative criteria, whereas Student C and Student F reported performance outcome (i.e. drawing blood) as the primary criteria.

Regarding motivation beliefs, such as self-efficacy and satisfaction, four of the five students reported relatively high perceptions of satisfaction with their performance (Mean = 71.3), with one student, Student C, showing a moderate level of satisfaction (40). In terms of student perceptions of efficacy for successfully performing the venipuncture task, the average efficacy score for this group at pretest was a 58 but increased to a 78 following task performance.

Self-regulatory profile of strugglers

The profile of students (students E and G) who needed three attempts to successfully obtain a blood sample from the mannequin arm appeared to be qualitatively distinct from that of the successful performers (Table 2). The two strugglers were clearly more focused on outcomes (i.e. being able to obtain a blood sample) than they were in the process of performing the venipuncture task correctly. This non-strategic approach was exemplified across the before, during and after dimensions of the event.

For example, when asked to discuss what they were thinking about as they prepared to take a blood sample (planning) and what they wanted to accomplish (goal-setting), both students reported obtaining a blood sample from the arm. Student E indicated that she was thinking about, "Whether I can actually get blood . . . whether I can get any blood back into the vacutainer" and "I think my only goal would to actually get a drop of blood". Student G was also focused on outcomes, although he made a general reference to the venipuncture process and interacting with the patient; "What procedures I am going to do next and explain to the patient what I am doing. I'm prepared to listen to the patient if he is in pain and stop immediately". However, his goal was clearly outcome-oriented as he stated, "Yes I do have a goal–to get blood and not cause any pain". Although not wanting to cause any pain can be considered to be a part of a clinical procedure or process, it appears that his cognitive focus was more on the avoidance of causing pain than the use of the correct technique, as was the case with the successful performers.

When prompted to reflect on whether they had performed any mistakes during the venipuncture task, students E and G again, did not appear to be aware of or to focus on the tactics or methods for drawing blood. Student E stated, "I can't think of any right now but I'm guessing that I may have made some mistakes but I can't think of any right now''. Along the same lines, student G indicated that he would seek to determine if he was performing the procedure correctly by asking, ''the patient if he has any pain anywhere or does he have any bleeding problem or anything like that''. Collectively, these responses suggest that both strugglers were not mindful or aware of their execution of the venipuncture technique or process. They appeared to be using outcomes, drawing blood or patient discomfort, as a guide for their behaviours.

In terms of self-evaluative criteria, strugglers reported ''number of attempts to obtain the blood sample'' as the primary criteria that they used to judge their level of satisfaction. These responses were largely consistent with their outcome-based responses to forethought and performance control phase questions.

In terms of motivation beliefs, the strugglers' overall level of satisfaction with their performance was low ($M = 20$). In addition, their level of self-efficacy was 65 at both pre-test and post-test. However, student E evidenced a 30-point increase in her self-efficacy, whereas Student G displayed a 30-point decrease.

Discussion

In this study, we showed that SRL microanalytic questions generate information that can be used to determine the extent to which medical students are strategically engaged before, during and after engaging in an authentic clinical event (venipuncture). We found that all the open-ended SRL microanalytic questions (strategic planning, goal-setting and metacognitive monitoring) exhibited high levels of inter-rater reliability, which is consistent with previous research in athletic domains (Cleary & Zimmerman 2001; Kitsantas & Zimmerman 2002).

We also used SRL microanalysis to descriptively examine the self-regulatory profiles of successful performers and strugglers on the venipuncture task across six key processes: self-efficacy, planning, goal-setting, metacognitive monitoring, self-evaluation and satisfaction. Although direct comparisons of the two groups is not possible due to the small sample size, the findings nonetheless show that students who were successful at the venipuncture task were mindful and actively thinking about the venipuncture technique prior to, during and following performance on this activity. However, strugglers appeared to focus primarily on outcomes of drawing blood or preventing pain in patients. Interestingly, these results are highly consistent with previous research showing that experts or high performers set more specific and strategic goals, engage in self-monitoring during a task, and reflect strategically on their performances than low performers (Cleary & Zimmerman 2001; Kitsantas & Zimmerman 2002; Cleary et al. 2006).

Another important finding in our study was that the strugglers not only neglected to focus on the venipuncture strategy or technique, but also placed primary importance and attention on outcomes during all cyclical phases, such as drawing blood. From a SRL theoretical perspective, the quality of one's forethought will impact the types or quality of performance phase processes, which will in turn impact how individuals reflect on performance (Schunk 2001). We found that the successful performers on the venipuncture task exhibited strategic thinking across forethought (planning, goal-setting), performance (monitoring) and self-reflection processes (self-evaluation, satisfaction). In contrast, strugglers exhibited a relatively consistent profile of outcome-oriented thinking across all three phases. Given the nature of our study, we cannot make strong claims about the nature of the relationship between cyclical phase processes but our findings do suggest that the types of goals and plans that individuals have immediately preceding a task may be linked to the quality of their performance and self-reflection phase processes.

In terms of forethought, outcome goals are typically the desired products or performance markers, whereas process goals involve the techniques or steps of a learning approach on a task (Schunk 2001; Zimmerman 2008). The fact that the strugglers focused primarily on outcome goals is a theoretically important finding, because goals shift students' attention either towards or away from task strategies. As a result, the goals that one sets can influence the types of cognition and beliefs one exhibits while performing a task and when reflecting on that performance. For example, previous research has shown that individuals who set process goals are more likely to monitor how well they perform on tasks and will make more strategic adjustments to their learning approaches than those who set outcome goals (Schunk & Swartz 1993). Furthermore, individuals who focus on outcomes before they have truly mastered the process or techniques required for a specific task, will tend to perform at a sub-optimal level and will exhibit more maladaptive self-reflections and reactions (Cleary & Zimmerman 2001; Cleary et al. 2006).

The nature of the self-evaluative standards used by successful performers and strugglers in our study was also of interest. First, consistent with findings across forethought and performance control phase measures, three of the successful task performers used process (venipuncture technique) standards to judge their performance, whereas both strugglers used outcome standards. Adopting mastery standards or self-criteria when evaluating one's performance is highly adaptive because it focuses one's attention on the essential tactics that one needs to use to perform well on an activity or event. Unfortunately, the strugglers concentrated on outcome-based thinking. The use of outcome-based standards to judge poor performance is problematic, particularly for low achieving or at-risk students, because it can often lead to a variety of self-handicapping reactions and negative effects, such as avoidance and anxiety (Zimmerman 2008). However, research has shown that the use of outcome-based standards is not always maladaptive, particularly with regard to high achievers. That is, when students have demonstrated proficiency in a skill, they show heightened levels of achievement and motivation if they learn to shift from process goals to outcome goals (Zimmerman & Kitsantas 1997).

As we had indicated previously, the small sample size precluded us from statistically testing group differences across all categorical and metric variables, such as self-efficacy and satisfaction. However, a couple of important points about these two motivation beliefs are warranted. First, although both groups displayed moderate levels of self-efficacy for performing this task, the strugglers exhibited numerically higher self-efficacy pretest (7-point difference). Although counterintuitive at the outset, these findings are actually consistent with self-assessment and calibration accuracy research indicating that low achievers typically overestimate their performance capabilities; often due to their poor metacognitive awareness and knowledge of task demands (Klassen 2006; Kruger & Dunning 2009).

In terms of changes in self-efficacy from pre-test to post-test, there was an average 20-point increase in self-efficacy among successful task performers. These findings make sense as individuals' beliefs about their personal capabilities should increase following demonstrated success or mastery experiences (Bandura 1997). However, analysis of the two strugglers in this study underscores the potential importance of assessing at-risk students' beliefs or perceptions of ability along with the actual skill or ability on a clinical task. That is, although both students needed three attempts to perform the venipuncture task successfully, one student exhibited a 30-point *increase* in efficacy, whereas the other student exhibited a 30-point *decrease* in their self-perceptions. Although high self-efficacy can motivate students to display greater persistence and effort on future learning, over-inflated beliefs of capability, as exhibited by student E, can actually hinder performance, as students may under-estimate the skills and efforts needed to actually perform well in the future. Conversely, student G, who exhibited the large drop in self-efficacy, is clearly more vulnerable to motivation setbacks, such as avoidance and lack of persistence, due to self-doubts and perceived ability deficiencies.

A few limitations in this study must be highlighted. First, the small sample size precluded the use of statistical analyses to examine differences among achievement groups. Although we are not able to make any quantitative comparisons, the qualitative profiles of the two groups are highly consistent with the expert-novice literature showing that successful performers tend to be more strategic and efficacious than low performers. Another limitation of this study was that we only targeted one clinical skill with a self-selected group of students in a controlled test environment. Thus, the extent to which these results generalise to other settings or medical contexts needs to be addressed in future research. However, it is interesting that all the "successful" students obtained a grade B or C in their subsequent end-of-year Objective Structured Clinical Examination; an exam that includes 20 clinical tasks. Conversely, one of the "unsuccessful" students obtained a grade C (student E) while student G obtained a near failing mark of E. Thus, future research may want to consider whether deficient SRL skills as exhibited on one clinical task measured with SRL microanalysis is predictive of performance on high stakes comprehensive clinical exams and tasks. We also did not include the full array of SRL cyclical phase processes in our microanalytic protocol, such as task interest, task value, attributions and adaptive inferences. Inclusion of these processes in future research with larger samples would allow researchers to more comprehensively examine the self-regulatory and strategic differences among different achievement groups as well as the relationships among these variables in medical contexts.

The ultimate purpose in using SRL microanalysis in medical education is to allow educators not only to gather context-specific information about how an individual thinks, plans and reacts during authentic clinical activities, but also to use such information to guide training efforts. For example, Brydges et al. (2009) found that a self-guided group trained in process goals displayed greater skill retention than a comparable group who set outcome goals. Accordingly, a particularly fruitful line of research would also be to examine the extent to which SRL microanalysis and interventions based on SRL can be used by medical educators to guide training for students who struggle with clinical skills. Illustrative scenarios of how SRL microanalysis could be used to guide training are described in the recent publication by Sandars and Cleary (2011). In addition, the SRL–Medical College Admission Test is a recently developed conceptual model that describes the potential use of SRL microanalysis and interventions based on SRL for the remediation of under-performance in the medical context (Durning et al. 2011), although research has not yet examined the usefulness or effectiveness of such an approach.

Conclusion

SRL microanalysis is an assessment approach that has been used extensively in non-medical contexts to identify deficient self-regulatory processes in individuals during context-specific task performance. This study is the first attempt to evaluate microanalysis procedures with students engaging in clinical skills. The data presented in this study was consistent with prior research showing that high performers emphasise strategic thinking and actions during learning whereas struggling students do not. Clearly, there is much work to be done regarding the use of SRL microanalysis in medical contexts, and we strongly encourage further research to examine and evaluate this assessment technique, especially how it can guide training and remediation for struggling students.

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The research protocol was approved by the Educational Research Ethics Committee of the School of Medicine at the University of Leeds.

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