Structured oral examination as an effective assessment tool in lab-based physiology learning sessions

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INTRODUCTION

Physiology acts to bridge basic medicine, clinical knowledge, and skills. The subject is widely recognized as a difficult course and often features high dropout, withdrawal, and failure rates (14). Laboratory sessions function as dynamic learning experiences. These sessions are designed to develop “hands-on” skills: working on live animals or measuring physiological responses. Laboratory learning sessions are intended to motivate students to understand complex and abstract concepts of physiology (3, 4).

A critical problem we faced during our physiology teaching was that students could not connect the abstract concepts taught in a lecture class with the phenomenon observed in the laboratory course (1). During laboratory sessions, time is limited, reserved for performing operations (7). Our students’ focus seems to be fragmented, split between their motivation to complete experiments, hand in reports, and their desire to engage in broader learning. Many view the laboratory course homework as a perfunctory job (16): they often copy work from their peers and appear to have little motivation to explore the theory that lies behind phenomenon observed in laboratory sessions. Over time, this disconnection leads students to lose interest in laboratory courses. The competing demands of theoretical and practical learning experiences decrease engagement with physiology as a learning area. Here we explore how structured oral examination (SOE) can act to enhance laboratory course assessment, to motivate students to connect practical experience with theoretical knowledge.

Oral examination has long been exploited to evaluate the depth of medical students’ knowledge. This method of assessment focuses on the comprehension and application of basic knowledge. In addition, it offers a forum to assess attitude, communication skills, and higher cognitive ability (2, 6). Oral examinations are alluring due to their relevance to practice, flexibility, and feasibility; they measure facets of clinical competency that are perhaps not involved in written examinations.

Oral examinations provide students with an impetus to scrutinize the theoretical, practical, and social aspects of learning. The social dynamics of this form of assessment, particularly the opportunity to associate one on one with the teacher, have been shown to motivate learning (10). Whether engaged in theoretical or laboratory teaching process, it is crucial that this assessment tool be employed in a way that is thoughtful, rational, objective, and relevant to learners.

Notwithstanding the virtues detailed above, there are some challenges often faced in the process of facilitating traditional oral examinations (TOE). Core critiques of this assessment practice include comment on the shortage of reliability, standardization, and objectivity (13). The positive effects of TOE can be seen to be undermined by factors related to the social dynamics and logistics involved in this assessment practice. Many teachers are involved in the process of TOE, so the time allotted to each student, the number of questions asked, and difficulty level of the questions may vary from student to student (12). Teachers may also be predisposed to focus on their preferred content area or way of understanding the subject. In addition, oral performance ratings show that there is a

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tendency for some examiners to be more lenient than others (9). Assessment can also be affected by numerous environmental factors.

Social coding and power dynamics need to be considered in the process of oral assessment. In TOEs, candidates reply to questions asked by the examiner(s) (2). The assessment will be affected by student-related factors, including sex, gender, intonation, vocabulary, and gestural cues. A candidate’s level of anxiety and the physical test environment can also influence the assessment process (8). In TOE, emphasis is placed on comparison between students rather than individual achievement.

Here, we suggest that challenges to TOE may be addressed by introducing a process of SOE: a more viable, uniform, transparent, and effective tool of assessment (5). SOE requires that teaching and testing content be determined in advance. The probable or most correct answer(s) will also be defined before the test. Even the assessment process needs rehearsal (13). Few studies exist that utilize SOE in physiology laboratory courses. This study was designed to exploit the process of SOE during physiology laboratory sessions, to motivate students to connect abstract concepts taught in lecture classes with phenomenon observed in experimental work on live animals. We hope to translate this tool into a robust method of assessment, one that takes student well-being into account and ensures that learning is assessed in practical as well as theoretical domains.

MATERIALS AND METHODS

Design of Study

Participants for this study were second-year medical students (n = 114). The study was carried out over the course of eight physiology laboratory sessions. Each laboratory session ran for a duration of 4 h. This physiology laboratory course forms part of the second-year curriculum for students enrolled in a major of Clinical Medicine at Xinjiang Medical University, Urumqi, Xinjiang, China. Four faculty members ran the physiology laboratory sessions. The sessions were held once per fortnight over a 16-wk period. The course included eight comprehensive experiments, namely: 1) the relationship between stimulus and contraction in skeletal muscle; 2) observation of the compound action potential of nerve trunk; 3) analysis of reflex arc; 4) premature systole and compensatory pause; 5) basic skills of operation on rabbit; 6) regulation of cardiovascular activity; 7) regulation of respiratory activity; and 8) factors affecting urine formation.

In the laboratory sessions, most students consistently demonstrated the ability to complete an experiment and to attain the desired results from an experiment within the allotted class time. At the culmination of the first four laboratory sessions, students were assessed by TOE. One teacher conducted the assessment. The question bank was not prepared in advance. The time allotted to each student varied considerably, and assessment was to be highly subjective. In addition to the TOE process, the mean score of homework allocated from the first four laboratory sessions was calculated. After this, the midterm paper exam was held. Students then shared their perspectives on the TOE process and its impact on self-efficacy. Thes data were measured by a modified three-point Likert-type scale questionnaire.

Students were informed about the SOE process before the commencement of the final four laboratory sessions. The question cards for the SOE were constructed before the assessment and were consistent among all faculty members. The scoring criteria, including notation of key points required in answers, was also derived in advance (see the APPENDIX). Approximately nine questions were included from each laboratory session topic. Each question was categorized as a range of difficulty levels; questions were categorized as “must know,” “nice to know,” or “desirable to know.” Faculty members collaborated to design questions that were relevant to course curriculum and clinical practice. The questions covered operation skills and the application of theory to describe phenomenon observed in practice.

One week after the last laboratory session, SOE took place. Our aim here was to standardize the oral assessment process for students. Our predefined question bank and scoring criteria were implemented to effect this change. SOE followed a consistent format. Each student was asked to select three question cards, one from each category. Student responses were then recorded by an examination team comprising one associate professor and one lecturer.

Once a student had completed his/her examination, he/she were separated from the remaining candidates. Assessment feedback was delivered in written form via a list that detailed students’ areas of strength and weakness. In accordance with the TOE process, a posttest questionnaire was completed by students. This questionnaire gathered learner perspectives on the SOE process, including its impact on self-efficacy. These data were measured by a modified three-point Likert-type scale questionnaire. The mean score of homework allocated from the final four laboratory sessions was also calculated. Students’ then were introduced to a final paper exam. Results and comparison of the data gathered via our TOE and SOE processes are shown in Table 1. The TOE has been performed for several years. Therefore, the study received a moral exemption from the ethical committee of our university.

Evaluation Methods

Assessment of students’ perspectives and self-evaluation. Questionnaires included various questions to get students’ opinions on the TOE and SOE (Table 2). Some questions were designed to get students’ opinions on the overall oral examination process, anxiety levels, student-friendly environment, uniformity of questions, coverage of syllabus, carry-over effect (score of the second student will be affected by the performance of the previous one), etc. In addition, more questions were asked to collect information on students’ perspectives and self-efficacy on their competence and interest in the physiology laboratory (Table 3). Both were obtained with a modified three-point Likert-type scale questionnaire (disagree, neutral, agree).

Table 1. Comparison of the main characteristics of TOE and SOE

| Feature                          | TOE                                                                 | SOE                                                                 |
|---------------------------------|---------------------------------------------------------------------|----------------------------------------------------------------------|
| Time allotted to each student   | At the examiner’s discretion                                        | 10 min                                                             |
| Number of questions asked per student | At the examiner’s discretion                                        | 3 questions                                                        |
| Difficulty level of the questions | At the examiner’s discretion                                        | Three levels (easy, moderate, difficult)                            |
| Examiner participants           | Only one                                                            | Two examiners (one associate professor, one lecturer)               |
| Feedback availability           | No                                                                  | Yes                                                                 |

TOE, traditional oral examination; SOE, structured oral examination.

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1 This experiment was permitted by Xinjiang Medical University Committee on Animal Research and Ethics.
All responses were completed and returned, which equates to a 100% response rate.

Students' academic performance. Students' academic performance was measured by laboratory course homework score (Fig. 1) and the oral examination. Paper examination was held in the midterm (mid-term test) and at end of the semester (final exam).

Data collection and statistical analysis. The questionnaire data were analyzed using the paired \( t \) test and the Mann–Whitney \( U \) test. The average scores of laboratory reports were compared by paired \( t \) test. All preliminary statistical analyses were performed using the SPSS 20.0 version. Alpha was set at 0.05, and \( P \) values of \(<0.05 \) were considered statistically significant.

RESULTS

The feedback questionnaire of the students' views on the TOE and SOE was analyzed by applying the paired \( t \) test (Table 2). Each response of the items in the questionnaire was depicted as numerical data by Likert scale, and the mean \( \pm \) SD was listed. The results show that students were more satisfied with SOE. They reflected that the environment is friendlier and less confronting during SOE. The question bank was designed covering a broad syllabus with a precondition. The high uniformity of questions to the examinees minimized the "carry-over effect" in SOE compared with TOE (13). Less anxiety in the process of SOE was appealing among students. There were no students who agreed that any gender bias existed during both oral sessions.

The analysis of the questionnaire showed significant differences in students' self-evaluation on TOE and SOE by the Mann–Whitney \( U \) test (Table 3). More students agreed that the SOE improved their communication skills in the medical

| Table 2. Statistical analysis of the questionnaire for student opinions on TOE and SOE |
|-----------------|--------------|--------------|---------|---|
| Question No.    | TOE Mean    | SD           | SOE Mean | SD  |
| 1. Overall perspective | 3.21    | 0.78          | 4.02    | 0.92 |
| 2. Satisfaction level     | 3.01    | 0.69          | 3.97    | 0.87 |
| 3. Uniformity of questions | 2.38    | 0.61          | 3.58    | 0.82 |
| 4. Friendly environment       | 2.79    | 0.68          | 3.84    | 0.59 |
| 5. Anxiety levels           | 2.29    | 0.54          | 3.79    | 0.62 |
| 6. Syllabus coverage         | 3.18    | 0.66          | 3.67    | 0.68 |
| 7. Objectivity              | 2.99    | 0.80          | 3.850   | 0.71 |
| 8. Carryover effect          | 2.98    | 0.71          | 2.52    | 0.63 |
| 9. Gender bias               | 2.23    | 0.79          | 2.09    | 0.81 |

TOE, traditional oral examination; SOE, structured oral examination. *Significant difference.

Table 3. Comparison of students’ perspectives and self-efficacy on TOE and SOE

| Items                                                                 | Disagree | Neutral | Agree | \( P \) Value |
|----------------------------------------------------------------------|----------|---------|-------|---------------|
| 1. Improve my communication skill in medical language.              |          |         |       | 0.000*        |
| TOE                                                                  | 21 (18.7)| 62 (54.3)| 31 (27)|              |
| SOE                                                                  | 1 (1.2)  | 39 (34) | 74 (64.8) |
| 2. Improve my learning motivation.                                  |          |         |       | 0.000*        |
| TOE                                                                  | 18 (13.1)| 75 (66.0)| 21 (18.0) |
| SOE                                                                  | 0 (0)    | 30 (26.4)| 84 (73.6) |
| 3. Helpful for operation on animals.                                |          |         |       | 0.000*        |
| TOE                                                                  | 20 (17.5)| 61 (53.5)| 33 (29.0) |
| SOE                                                                  | 0 (0)    | 25 (22.2)| 89 (77.8) |
| 4. Helpful for application of physiology knowledge.                 |          |         |       | 0.000*        |
| TOE                                                                  | 21 (18.0)| 73 (64.0)| 20 (18.0) |
| SOE                                                                  | 2 (1.8)  | 30 (26.3)| 82 (71.9) |
| 5. I felt pretty competent in the laboratory session.                |          |         |       | 0.000*        |
| TOE                                                                  | 38 (34.0)| 57 (50.0)| 19 (16.0) |
| SOE                                                                  | 2 (1.8)  | 32 (27.8)| 80 (70.4) |
| 6. I felt sure that I have learned more from the laboratory session. |          |         |       | 0.000*        |
| TOE                                                                  | 47 (40.0)| 50 (44.0)| 17 (16.0) |
| SOE                                                                  | 0 (0)    | 25 (22.2)| 89 (77.8) |
| 7. I feel confident to conduct the practical from a manual.         |          |         |       | 0.000*        |
| TOE                                                                  | 48 (42.0)| 47 (40.0)| 19 (18.0) |
| SOE                                                                  | 2 (1.8)  | 27 (24.0)| 85 (74.2) |
| 8. I feel confident to compose the results in a laboratory report.  |          |         |       | 0.000*        |
| TOE                                                                  | 25 (22.0)| 52 (46.0)| 37 (32.0) |
| SOE                                                                  | 2 (1.8)  | 32 (27.8)| 80 (70.4) |
| 9. I feel confident to write the discussion and conclusion in a laboratory report. |          |         |       | 0.000*        |
| TOE                                                                  | 32 (28.0)| 36 (32.0)| 46 (40.0) |
| SOE                                                                  | 0 (0)    | 30 (26.0)| 84 (74.0) |
| 10. I would like this examination method to be applied to other medical courses. |          |         |       | 0.000*        |
| TOE                                                                  | 43 (37.7)| 36 (31.6)| 35 (30.7) |
| SOE                                                                  | 8 (7.0)  | 24 (21.0)| 82 (72.0) |

Values are the no. of student responses (with the percentage in parentheses); \( n = 114 \) students. TOE, traditional oral examination; SOE, structured oral examination. *Significant difference.
with SOE in the physiology laboratory session. Students were more comfortable with SOE (Table 2). They feel it is just that all students should be asked the same sets of predefined questions. Comments also note that the predefined questions here include broader coverage of our syllabus than TOE carried out in our laboratory course. In SOE, questions for each student stem from the question bank, rather than from teachers’ preferences for selection of relevant knowledge. This reduces the “luck factor” or subjectivity of the marks awarded to students. Less “luck factor” made the assessment conditions more consistent for all students.

The results of our study are consistent with others in this area. Recent studies show that SOE leads to less drift from the main topic and provides uniform coverage of topics in the given time (2, 9). Another study, done in an Indian setup in pharmacology, showed that students prefer SOE to TOE as it has minimal luck factor and reduced bias (2). Students reflect that they feel less anxious and depressed about the SOE due to its standardization and objectivity (Table 2). Thus SOE was believed to minimize the limitations, a lack of reliability, standardization, and objectivity, of TOE (Table 2).

A checklist in SOE covers operation skills and theoretical knowledge, which motivates students to prepare the experimental procedures and precautions more carefully. Enough preparations built up the students’ confidence in the laboratory sessions (Table 3). The perception of students is that this format of assessment is encouraging. More than 60% of students reflected that SOE improved their communication skills with the medical language, an essential ability for any clinical job. A friendlier environment with a lower level of anxiety may partially account for their better performance. It is well known that performance in oral examinations relates inversely with anxiety and shyness (9). Consistent with our findings, previous studies have shown that SOE improves students’ performance (6, 9, 13). Seventy-seven percent of students feel that the preparation for SOE (covering operation skills) is helpful for “hands-on” practice: operation on the animal. Before the introduction of SOE, students reported paying less attention to the operation procedures. Most students now believe they are competent in the laboratory sessions (Table 3). Most students agree that this structured assessment format required greater preparation than TOE. Our results show that this preparation process has a positive impact on engagement with theoretical knowledge: such efforts encourage students to explore the theory that corresponds with a laboratory session in depth. SOE scaffolds learners to see the connection between theory and practice, to apply knowledge of physiology. Thus they were endowed with stronger confidence in conducting the real laboratory events on live animals and composing the results and discussion in a laboratory report. Teachers noted that the last four laboratory reports were compiled more logically and coherently than the preceding four. This may explain why the scores from the last four laboratory sessions’ homework tasks (with SOE) were much higher than those from the previous four laboratories (with TOE) (Fig. 1A).

**DISCUSSION**

Organizing and planning oral exams in advance leads to better accuracy and reliability of the assessment tool for medical students. In our study, a structured questionnaire allows the rewarding of marks based on a predetermined scale. From the students’ comments on the several open-ended items in the questionnaire, it was obvious that, overall, they were satisfied language. The orals’ preparation boosted their motivation in learning physiology. They were well informed that some questions would be related to the operation skill in the SOE. Thus they paid more attention to preview the operation procedure. So the good preparations of the SOE helped them to manage the operation on the animal. More students felt competent in the laboratory. Students felt more confident to conduct the practical and compose the results and discussion of the laboratory report. It seems that they managed to exploit physiology knowledge taught in the classroom in the experimental context. Now students addressed that they learned more from laboratory sessions. Even more, students would like to introduce SOE to other medical laboratory courses.

**Students’ Academic Performance**

The scores of laboratory reports showed that students’ interest in the laboratories increased, and they composed their laboratory work more wisely in anticipation of the SOE. They had significantly higher scores on laboratory reports in the last four laboratory sessions than the previous one (88.2 ± 6.1 vs. 74.9 ± 7.9, P < 0.05, Fig. 1A). For paper examination, the scores of the final examination (after SOE) were higher than those of the midterm test (after TOE) (68.3 ± 5.4 vs. 52.8 ± 8.1, P < 0.05, Fig. 1B).

![Comparison of students' scores for laboratory reports (A) and paper exams (B).](image-url)

**Fig. 1.** Comparison of students’ scores for laboratory reports (A) and paper exams (B). A paired t test was used to compare the laboratory score and paper examination differences after traditional (TOE) and structured oral examination (SOE). Values are means ± SD. *P < 0.05.
cates that they believe in their potential to achieve the defined task. It is reported that self-efficacy in laboratory work was positive and correlated with academic performance at the final exam (3). This may explain why the scores of paper examination from SOE (final examination) are much higher than those from TOE (midterm test) (Fig. 1B). It is widely accepted that the final marks do not depend only on the laboratory reporting: the skills and knowledge demonstrated by the students to acquire the result should also be assessed.

Most students were in support of the SOE assessment tool. They acknowledged that this was a productive way of driving their learning for operation skill and theoretical knowledge. Seventy-two percent of students would like this examination method to be applied in other medical courses (Table 3). These findings encouraged educators to consider applying SOE as an assessment tool in other settings; our results have shown that it is very effective in improving students’ motivation for learning and ability to apply physiology knowledge. Students demonstrated enhanced ability to connect the abstract concepts taught in a lecture class with the phenomenon observed in laboratory sessions. Their motivation to learn in the laboratory course was bolstered and seems to have a significant effect on academic achievement (11).

We hope to enrich our process of SOE for application in the physiology laboratory session by reviewing the knowledge checklist and devising a standardized marking system. We feel that this is an exploratory study, the beginning of an ongoing learning process. Intensive groundwork is needed to shift assessment practice from TOE to SOE. These indicators support a SOE in our field of specialization, as well as a call for its implementation in all areas of medical education and learning.

Conclusion

Implementing SOE is an intensive exercise that requires extensive preparation. Orientation and training of examiners is necessary to standardize the process. Student feedback confirms that our learners preferred SOE to TOE in the context of physiology laboratory sessions. With some modifications, our SOE will be acceptable to students as well as instructors. SOE meets our basic requirements of a better assessment tool by offering enhanced reliability, standardization, and objectivity. The SOEs can also be seen to build the confidence of students to engage in “hands-on” experience, to conduct experiments; L.W. and J.D. analyzed data; L.W., D.L., and X.Y. interpreted findings.

AUTHOR CONTRIBUTIONS

L.W. conceived and designed research; M.G., J.L., and M.A. performed experiments; L.W. and J.D. analyzed data; L.W., D.L., and X.Y. interpreted results; L.W. wrote the first draft of the manuscript; L.W. and J.D. edited and revised the manuscript.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

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APPENDIX: QUESTION BANK OF LABORATORY NO. 1: THE RELATIONSHIP BETWEEN STIMULUS AND CONTRACTION IN SKELETAL MUSCLE

1. What do the electrical events conduct, along with the cell (plasma) membrane that stimulates contraction, which is called? (1 mark)
   ANSWER: Action potential

2. You will use (glass/metal) probes to gently free the nerve from its attached connective tissue. (1 mark)
   ANSWER: Glass probe

3. What substance couples electrical excitation to muscle contraction? (1 mark)
   ANSWER: Calcium

4. Definition of summation. (4 marks)
   ANSWER: Summation means adding individual twitch contractions together to increase the intensity of overall muscle contraction.

5. Definition of tetanization. (4 marks)
   ANSWER: When the frequency reaches a critical level, the successive contractions eventually become so rapid that they fuse together, and the whole muscle contraction appears to be completely smooth and continuous, which produces the maximal muscle tone. This is called tetanization.

6. Please tell us whether the following muscle contraction is an “isotonic contraction” or “isometric contraction.” (4 marks)
   - The contraction of biceps when you lift up a chair (isotonic contraction)
   - The contraction of biceps when you do push-ups (isometric contraction)
   - The contraction of biceps when you support an object in a fixed position (isometric contraction)
   - The contraction of postural muscles when you stand or sit motionless (isometric contraction)

7. What causes myasthenia gravis (myasthenia means abnormal muscle weakness or fatigue)? (10 marks)
   ANSWER: Antibodies secreted by the immune system block the muscle membrane receptors for acetylcholine, the neurotransmitter of somatic motor neurons. This autoimmune disease prevents the muscle from being properly stimulated by somatic motor neurons.

8. Predict the effects on muscles of a drug that blocks the action of acetylcholinesterase, an enzyme that breaks down acetylcholine. Compare that to the effects on muscles of a drug that blocks acetylcholine receptors. (10 marks)
   ANSWER:
   - If a drug blocks the action of acetylcholinesterase, the ACh will accumulate in the neural muscular junction and bind with acetylcholine receptors. Prolonged and strong contractions of muscle lead to the well-known state of muscle fatigue.
   - If a drug blocks acetylcholine receptors, the excitation on the neural cells cannot propagate to the muscle; the muscle will not contract and produce any tone.

9. Depict the process of excitation-contraction coupling in skeletal muscles. (10 marks)
   ANSWER:
   Step 1: Action potential (AP) generated and propagated across the surface membrane and down T tubules;
   Step 2: AP triggers Ca^{2+} release from sarcoplasmic reticulum;
   Step 3: Ca^{2+} releases and binds to troponin on thin filaments, and tropomyosin moved and uncovered cross-bridge binding site (need ATP);
   Step 4: Myosin cross bridges attach to actin and bend, and the sarcomere is shortened, powered by energy provided by ATP;
   Step 5: Ca^{2+} is actively taken up by sarcoplasmic reticulum when there is no AP (need ATP);
   Step 6: When Ca^{2+} no longer binds to troponin, tropomyosin slips back to its blocking position over binding sites on actin.

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... Further references for study on physiology education, muscle contractions, and assessment methods.

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results of experiments; L.W. and P.J. prepared figures; L.W. drafted manuscript; L.W. and A.T.K. edited and revised manuscript; Y.W. approved final version of manuscript.

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