TESOT: a teaching modality targeting the learning obstacles in global medical education

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Abstract

In higher education, it is a great challenge for instructors to teach international medical students (IMSs) efficiently. These students usually have different learning obstacles and learning style preferences from domestic students. Thus, it is necessary to use teaching modalities targeting the specific characteristics of IMSs. Accordingly, we have developed a teaching modality composed of classical teacher-centered approach (TCA), enriched with components of student-centered approach (SCA) and online interactions targeting the learning characteristics of IMSs, which we defined as TESOT (an acronym made of the underlined words’ initials). Aside from the online interactions that provide both answers to questions raised by students and guidance throughout a course, this modality contains additional in-classroom components (i.e., pre-lecture quiz, student-led summary, and post-lecture quiz). The effectiveness of this modality was tested in the nervous system module of the Physiology course for IMSs. The final exam scores in the nervous system module in the year taught with TESOT were higher than those earned by students taught with a classical TCA modality in preceding 2 yr. The improvement of teaching effectiveness is attributable to increasing communication, bridging course contexts, and meeting diverse learning style preferences. These results indicate that TESOT as an effective teaching modality is useful for enhancing efficiency of teaching IMSs.

INTRODUCTION

With the development of globalization of medical education, exchanges of medical students between countries have increased significantly over the past decade (1, 2). In China, for example, there were 62,357 international medical students (IMSs) in 2016, accounting for 14.08% of its international student cohort in that year (3). One dramatic problem is that the final exam scores of the IMSs in English medical courses were lower on average than those of the domestic students (4–7). Thus, how to teach IMSs as efficiently as the domestic students is a challenge in modern medical education.

According to Kolb’s theory of learning stages and cycles (8), teachers should critically evaluate the learning provision typically available to students and then develop more appropriate learning opportunities. In modern higher education, this theory is first manifested in teacher-centered approach (TCA) (9, 10) that allows students to master knowledge for clinical practice through a systematic education. The efficiency of TCA is largely influenced by the rate of attendance in addition to course structures (11). A student-centered approach (SCA) of learning (12, 13) may be implemented to increase students’ active participation, critical thinking, and self-directed learning (14). In fact, active-learning classrooms have been recognized to narrow achievement gaps among students better than traditional lecturing classroom (15). An example of successful active-learning classrooms is "Increased course structure" reported by Freeman and colleagues (16). They incorporated extensive in-class active-learning activities and weekly practice exam into the lecture (16). Thus active-learning classrooms should be applied in modern life science education.

Different experiences in the basic education make IMSs differ from domestic students in the learning obstacles and learning style preferences (17, 18), such as communication
between IMSs and teachers of host institution, etc. (19). In addition, medical education of IMSs is a challenge for both the teacher and students (with exception for native English-speaking countries) due to the requirement of using English, the second language for most of countries in the world. In our study in China (19), a large portion of the IMSs perceived difficulty in establishing course connections between different sets of medical knowledge, heavy course load and difficulty in communication with teachers. Most of them preferred an active-learning classroom. These issues require teachers not only to use the components of active-learning classroom in course structure (16) but also to target the learning obstacles and preferences of IMSs. However, there is no developed teaching modality that targets the characteristics of IMSs while incorporating SCA into TCA efficiently in international medical education.

To resolve this issue, we first investigated the learning obstacles and learning style preferences of the IMSs (19). Targeting these characteristics, we designed a teaching modality based on the ideas of active-learning classrooms (15). The modality is composed of classical TCA enriched with the components of SCA and online interactions targeting the learning characteristics of IMSs, i.e., TESOT (an acronym made of the underlined words’ initials). We then tested TESOT’s effectiveness in the nervous system module of Physiology course for the IMSs.

## MATERIALS AND METHODS

### Study Subjects

This study included 229 full-time IMSs across 3 academic calendar years, i.e., 106 in Class 2014, 67 in Class 2015, and 56 in Class 2016 at Harbin Medical University, recruited 1 yr before the course. As shown in Table 1, the vast majority of participating students were from India (91.7%) and Bangladesh (6.6%) across all 3 yr. There was no significant difference between the three classes in sex ($P = 0.226$ by chi-square test) and age ($P = 0.256$). Academically, students’ final scores in two courses preceding Physiology course, i.e., Cell Biology, and Histology and Embryology, did not show significant difference between different class years ($P > 0.05$).

In all 3 yr, the IMSs were taught separately from domestic medical students due to different course assignments. The Physiology course involved lectures only but not laboratories. All the course contents were delivered in English by two teachers. Both teachers had >3 yr of teaching experience in Physiology for medical students in English. This study was in accordance with the Declaration of Helsinki and the regulation of Institutional Review Board of Harbin Medical University. The IMSs were informed that the nervous system module would be delivered differently from other modules. All IMSs participated in this study voluntarily. The students who were taught with the new teaching modality provided a signed agreement.

### Course Contents

Physiology course was taught in the third semester (September–December) of the school years 2014–2016. The course included 90-min lectures held in the morning, two to three lectures per week, over 18 wk. The Physiology course was taught after courses in Anatomy, Cell Biology, and Histology and Embryology, in parallel with courses of Chinese language, Medical Chinese language, and Biochemistry, as well as two practicums of Physiology and Biochemistry.

The main source of teaching materials originated from the Guyton and Hall Textbook of Medical Physiology, 12th ed. (20). Physiology course materials were divided into the following 10 modules: 1) Introduction, 2) Cell Physiology, 3) Blood Physiology, 4) Circulatory System, 5) Respiratory System, 6) Gastrointestinal System, 7) Energy Metabolism and Body Temperature, 8) Urinary System, 9) Nervous System, and 10) Endocrine System and Reproduction. In evaluating the effectiveness of TESOT, we selected the nervous system module for the trial. The nervous system module had been a challenging module for students as evidenced by significantly lower final scores than the average score of all examinations.

### Table 1. Comparisons between classes in the age, gender, nationality, Cell Biology score, and Histology and Embryology score

|                         | 2014   | 2015   | 2016   | $P$ Value |
|-------------------------|--------|--------|--------|-----------|
| Number                  | 106    | 67     | 56     | 0.256*    |
| Admission age           |        |        |        |           |
| Median (IQR)            | 19 (1.4)| 19 (1.2)| 19 (1.2)|           |
| Means (SD)              | 19 (1.3)| 19 (1.2)| 19 (1.2)|           |
| Gender                  |        |        |        | 0.226b    |
| Male                    | 59     | 44     | 38     |           |
| Female                  | 47     | 23     | 18     |           |
| Nationality             |        |        |        |           |
| India                   | 103    | 65     | 42     |           |
| Bangladesh              | 1      | 1      | 0      |           |
| Jordan                  | 1      | 0      | 0      |           |
| Pakistan                | 0      | 1      | 0      |           |
| Nepal                   | 0      | 0      | 1      |           |
| South Korea             | 1      | 0      | 0      |           |
| Cell Biology score [means (SD)] | 72.9 (10.2) ($n = 105$)* | 75.1 (10.6) ($n = 63$)* | 74.1 (17.5) ($n = 56$)* | 0.528* |
| Histology and Embryology score [means (SD)] | 74.2 (12.1) ($n = 104$)* | 74.1 (12.2) ($n = 61$)* | 75.8 (13.4) ($n = 53$)* | 0.714* |

IQR, interquartile range. *Kruskal-Wallis test. **Chi-square test. One-way ANOVA. aNumbers of students completing courses and final examinations.
modules in the Physiology course in the years 2014 and 2015 taught with the classical TCA modality. The nervous system module contained 10 sections: 1) Fundamentals, 2) Synaptic transmission and synaptic electrical activity, 3) Reflexes, 4) Sensory function, 5) Visual system, 6) Auditory system, balance, olfaction and gustation, 7) Motor function, 8) Neural regulation of visceral activity, instinctive behavior, and mood, 9) Awakening and sleep, the brain’s advanced features, and 10) Integrative Review (Supplemental Table S1; all Supplemental material is available at https://doi.org/10.6084/m9.figshare.14138210). We referred to the lecture and its associated activities as an instructional block (see below and Supplemental Table S2). The final examination was performed 2 wk after completion of all the lectures. During these 2 wk, the students were preparing for the final exams of all courses taken in parallel, as disclosed above. The credit hours and contents of all courses, including the exams of all courses taken in parallel, as disclosed above.

During these 2 wk, the students were preparing for the final examination of entire 18-wk course was performed and used as the basis for the course grading, without considering pre- and post-lecture quizzes and student-led summaries. Contents for the final exam were determined using a randomly selected set of questions for each year. The equal difficulty index of the questions in the 3 different yr was verified by recruiting three experienced students to assess questions that were presented in random order and in a common format. They were blind to the study’s purpose and to the hypothesis being tested by the ratings. Point values for each question were omitted to avoid any bias introduced by high- versus low-point-value questions. The scores of the three raters to different sets of question were not different more than 5/100 points. The

**Classical TCA and TESOT**

The classical TCA modality included Microsoft PowerPoint presentations (21) accompanied with visual-aural-read/write-kinesthetic methods (22, 23). These additional methods included blackboard drawings, cartoon and short video demonstrations, interactive questions, and a teacher-led summary at the end of each lecture. This modality was used for teaching all the students with the exception of the nervous system module in Class 2016, which was taught with TESOT (Fig. 1). As indicated later, TESOT included additional course structures (see example of an instructional block in Supplemental Table S2).

Targeting the difficulty in establishing connections between previously taught neural structures and currently taught neural functions, troubles in communicating with teachers and the need for additional learning tasks of our IMSs (19), we designed the TESOT modality, which included four additional course features to that of classical TCA teaching. These features are as follows: pre-lecture quiz and post-lecture quiz (Supplemental Table S3), student-led summary (Supplemental Table S4), and online interactions (Supplemental Table S5). Figure 1 shows the details of considerations for including these new components.

**Website Construction and Maintenance**

We designed the course website using the site template and website services (Cloud Dream, Beijing, China). After registration of a web site, we added the teaching contents in the course module and then published the course module through the domain management platform (Aliyun, Hangzhou, China). The contents included answers to the quizzes, explanations for questions proven to be difficult as per experience with previous generations of students, and guidance throughout the nervous system module, which were posted on a lecture-by-lecture basis. Unsolicited student questions electronically submitted to the teachers were answered directly through e-mailing by the teachers.

**Evaluation of Students’ Performance**

The effectiveness of TESOT was evaluated by comparing the final scores of IMSs taught by the two teaching modalities. This metrics was the common denominator throughout all the 3 yr we studied. The final examination of entire Physiology course was worthy of 100 points, consisting of 32 questions of multiple choices (1 point each), 11 questions of fill-in the blanks (2 points each), 6 short (250-word limit; 5 points each), and 2 long (500-word limit; 8 points each) essays; the final score was expressed as percentage of the total of 100 points. We specifically compared the scores, expressed as percentage of allocated points, of the nervous system module with the circulatory module because they had similar question type and allocated points (20 and 18 points, respectively, with similar difficulty index and question combination). The final exam that covered the entire 18-wk course was performed and used as the basis for the course grading, without considering pre- and post-lecture quizzes and student-led summaries. Contents for the final exam were determined using a randomly selected set of questions for each year. The equal difficulty index of the questions in the 3 different yr was verified by recruiting three experienced students to assess questions that were presented in random order and in a common format. They were blind to the study’s purpose and to the hypothesis being tested by the ratings. Point values for each question were omitted to avoid any bias introduced by high- versus low-point-value questions. The scores of the three raters to different sets of question were not different more than 5/100 points. The
answers to final exams were scored by teachers who are experts in the field but were not directly involved in the study.

The scores were all expressed as the percentage of the student’s point divided by the corresponding total points (i.e., 20 points for the nervous system module, 18 points for the circulatory module, and 100 points for the whole Physiology course). Scores of the students who attended the final exam in the nervous system module of Class 2016 were taken as the measure of teaching efficiency using TESOT and were compared with control scores obtained by using the classical modality: 1) in the nervous system module of Class 2014 and Class 2015, and 2) in the circulatory system module and the whole Physiology course in Class 2016.

Evaluation of self-study time in Class 2016 was acquired through a repeated questionnaire performed before and after the nervous system module, which showed IMSs’ study time during the prior non-nervous system module and during the TESOT module. It was categorized in three intervals, <30 min, 30 to 60 min, and >60 min that a student spent on reviewing course contents.

**RESULTS**

All 229 IMSs enrolled in the Physiology course, within 3 consecutive classes/year, participated in this study. Sixteen students dropped out, so that a total of 213 students took the final examination to complete the coursework.

Effectiveness of the TESOT

In evaluating the effectiveness of TESOT, we analyzed the final scores in the nervous system module, in the circulatory system module and in the entire Physiology course. As shown in Fig. 2, students in Class 2016, taught with TESOT, earned significantly higher score in the nervous system module [61.4 (28.3)%] than those in Class 2014 [47.3 (23.1)%, P < 0.001] and Class 2015 [40.3 (18.6)%, P < 0.001] taught with the classical TCA (Fig. 2A). By contrast, there was no significant difference in the scores in the circulatory system module across the three cohorts [57.0 (27.1)%] for Class 2014, 58.9 (26.9)% for Class 2015, and 64.0 (24.2)% for Class 2016; P = 0.308; Fig. 2B]. Similarly, the average score of the entire Physiology course of Class 2016 [61.3 (17.3)%] was not significantly different from those in Class 2014 [59.3 (18.8)%] and Class 2015 [59.1 (17.0)%; P = 0.781; Fig. 2C].

Further comparing difference in the self-studying times of the Class 2016 before and after the nervous system module examined if TESOT-increased score was due to changes in self-study time. The results showed that the new modality did not significantly influence students’ self-studying habits (P = 0.189, by chi-square test; Table 2).

Correlation of Final Scores with Absence Rates

Attendance is usually considered important for learning efficiency (24). Thus we analyzed the absence rate, expressed as percentage of lecture attendance by each student and its correlation with the final score. As shown in Fig. 3A, the absence rate of Class 2016 [7.1 (12.7)%] was significantly lower than that of Class 2014 [17.9 (25.0)%, P = 0.025] or Class 2015 [20.7 (27.3)%; P = 0.006] for the nervous system module; however, absence rates of all the 3 yr were similar for the circulatory module. The absence rate of Physiology course in
Class 2016 [12.7 (13.6)%] was also significantly reduced when compared with the prior years [22.5 (20.0)% in Class 2014, $P = 0.012$; 25.6 (22.7)% in Class 2015, $P = 0.002$].

Then, we combined data of all the 3 class yr and analyzed the correlation between the absence rate and individual students’ final scores (Fig. 3B). There were significant negative correlations between the final score and the absence rate in the Physiology course ($r = -0.399, n = 213, P < 0.001$) as well as in the nervous system module ($r = -0.331, n = 213, P < 0.001$). However, this correlation showed only a negative trend in the circulatory system module ($P > 0.05$).

**TESOT Positively Affected the Final Score in the Nervous System Module**

Having determined the correlation of absence rates with the final scores in our modules, we further explored the contribution of TESOT to the final score independent of attendance. We hypothesized that if the lower absence rate in Class 2016 (Fig. 3A) might be the major reason for the better performance, there should be a high correlation between the final score and the attendance rate, irrelevant to the years and the modules. Thus we used data only from a subset of students who attended all the lectures, with the expectation of similar scores. However, results showed that the final scores in the nervous system module for the students with perfect attendance in Class 2016 [70.4 (25.9)%], $n = 34$] were significantly higher than those of their counterparts in Class 2014 [49.3 (22.4)%], $n = 60, P < 0.001]$ and Class 2015 [44.0 (15.0)%], $n = 35, P < 0.001$; Fig. 4A]. By contrast, the score for the circulatory system module did not show significant difference between students with perfect attendance in all the three Classes [58.9 (27.1)%] for Class 2014, 61.0 (26.0)%] for Class 2015, and 58.9 (27.1)% for Class 2016; $P = 0.064$; Fig. 4B]. Lastly, the final score of students with full attendance in the entire Physiology course for Class 2016 [68.8 (12.2)%] was significantly higher than that for Class 2014 [61.5 (17.3)%], $P = 0.026$] and Class 2015 [60.9 (13.4)%], $P = 0.033$, Fig. 4C]. Thus TESOT, which may have contributed to the increased attendance, rather than attendance alone appears to be the main reason for better final scores in the nervous system.

**Figure 3.** Correlation between the absence rate and final scores. A: absence rates over the 3 class yr (2014, 2015, and 2016) for the nervous system module (left), the circulatory module (middle), and the entire Physiology course (right). B. The correlations for the nervous system module (a), the circulatory system module (b), and the entire Physiology course (c). **$P < 0.01$, compared between class years within particular module/course by ANOVA. *$P < 0.01$, compared between modules/course within the same class year by ANOVA.

**Figure 4.** Final scores of the students with perfect attendance across different cohorts. A–C: the nervous system module (A), the circulatory system module (B), and the Physiology course (C). The numbers of students were 60, 35, and 34 in the Class 2014, 2015, and 2016, respectively. **$P < 0.01$, compared with Class 2014 and 2015.
module, which also impacted the improvement in the entire Physiology course.

**DISCUSSION**

The present study reveals that the TESOT modality can significantly enhance the final score of IMSs. This effect is because TESOT strengthens the link between prior knowledge and the ongoing lecture, promotes the communication between teachers and students, and facilitates peer teaching without increasing the learning burden of the students while meeting their diverse learning style preferences.

**Demographic Backgrounds of the IMSs**

India and Bangladesh have more than 1.93 billion people that account for 80% of Southern Asia and 24.89% of the world population. In these countries, English is not used extensively, except in higher education (https://www.unicef.org/rosa/what-we-do/quality-education). According to the "World Education News + Review," the United States, the United Kingdom, Canada, Germany, Australia, and New Zealand are the major destinations of international education of Indian students (https://wenr.wes.org/2018/09/education-in-india). In the U.S. approximately one-third of science and engineering postgraduate students are foreign born, particularly from India and China (25). Thus optimizing the education methods for this cohort of IMSs is beneficial not only for non-English-speaking countries but also for English-speaking countries.

In viewing our study subjects and their academic performance, the IMSs are suitable for participation in the evaluation of the TESOT modality. Obviously, the learning experience of the IMSs through the first school year in China gave them some abstract concepts about learning obstacles and learning style preferences (19). In agreement with Kolb’s theory that experience is the source of learning and development (8), knowing IMSs’ learning characteristics allows us to develop appropriate teaching modality to resolve their concerns.

**Learning Characteristics**

Much of Kolb’s theory (8) is concerned with the learner’s internal cognitive processes. Thus, before designing and carrying out the TESOT modality, we investigated the learning obstacles and learning style preferences faced by the IMSs (19). The results showed that a large portion of the IMSs (42%) perceived difficulty in establishing connections between neural structures learned in the Anatomy course (neuroanatomy module) and neural functions taught in the Physiology course (the nervous system module). This is likely a common problem for both the IMSs and domestic medical students (19). IMSs also reported on a heavy course load (28.8%) and on troubles in communicating with teachers (20%). Relative to domestic students, most of the IMSs preferred to distinguish themselves in learning tasks and interact with teachers in the classroom or through interactive website while some of the IMSs still had troubles attending class (19). These differences are likely due to differences in the sociocultural background between different student cohorts. In India, a comprehensive approach that integrates the efforts of teachers, students, health services, and the community has been executed and proven to be successful since decades ago (26). This practice creates a population of students more active in learning; however, this background also makes some of the IMSs difficult to adapt to a crowded course load. By contrast, most of the Chinese medical students have adapted to a passive learning style since early education despite the advocate of active learning in modern time. Thus IMSs are more likely to present themselves in course activities with strong SCA learning components than local medical students (12, 13, 19, 27).

In learning style preferences, 28.2% of the IMSs reported attending lectures as the major form of learning, and others preferred reading textbook, searching online resources, and joining team-based learning, etc. They also expressed a desire to have some additional learning tasks, such as random quizzes in the classroom (76.6%) and student-led summary of the course contents (90.2%). These students (89.7%) expected utilization of a teaching modality that includes some students’ initiatives. These diverse style preferences and strong signs of preferring SCA learning relative to the domestic students (19) also reflect the sociocultural background of the IMSs as discussed above. Notably, in our questionnaire among Class 2018, there were 95.2% of the IMSs preferring a combination of TCA with SCA and 83.3% showing preference for TESOT although the composition of IMSs (originating mainly from Southeast Asia, South Asia, Middle East, and North America) was significantly different from the Class 2014–2016 (our unpublished data). Thus the suitability of TESOT for IMSs might be more widespread, perhaps global.

**Theoretical Consideration of Teaching Modalities**

The complexity of the learning processes in medical education increases gradually from freshman year to senior year. Physiology course has a higher degree of abstraction and integration compared with Anatomy. The necessity of flexible and profound thinking requires the teacher to inspire students’ learning processes by adopting a loosely structured teaching modality and cultivating students’ conscious learning ability. However, SCA is limited by teaching environment, particularly the time limitations for both teachers and students (29). Therefore, teachers should apply a modality that combines the advantages of both TCA learning and SCA learning (15) while considering different learning obstacles and style preferences.

To establish such teaching modality, it is necessary to set up a program of relatively stable sets of teaching methods with fixed procedures. The first issue to consider in applying such a strategy is learning style preferences of the students (18). Learning style preferences are derived from learning obstacles that depend on individuals’ cultural, language, and socioeconomic backgrounds as well as the academic performance (18). In addition, learning the language of the host country and communicating with teachers should also be considered in any country, including in English-speaking countries (30). Thus, in designing a suitable teaching modality, students’ characteristics including learning style preferences and learning obstacles of a special cohort of IMSs should be fully considered.
CONTRIBUTION OF DIFFERENT COMPONENTS OF TESOT TO THE LEARNING EFFECTIVENESS

Lower efficiency of the classical TCA learning modality we used in the years 2014 and 2015 is likely due to diverse learning style preferences and/or not addressing the learning obstacles of IMSs (31, 32). Targeting these issues, we designed the TESOT that have the following four characteristics. First, the teaching content selects the most basic concepts, basic principles, basic regulations, etc. Second, the modality sets an ongoing lecture in the entire medical knowledge system, allowing students to establish a link among different course contents. Third, the paradigm awakens students’ potential, eliminates learning obstacles, and inspires students to resolve difficult problems. Fourth, it enforces the guidance of learning and resolves students’ questions in time by the teacher but does not significantly increase students’ self-study time.

The purpose of the pre-lecture quiz was to establish a link between previously learned knowledge and the ongoing lecture and to break interprofessional barrier. For example, we quessed whether “The central nervous system contains neurons and glial cells” and “The skeletal muscles can be controlled from many levels of the central nervous system” (Supplemental Table 3, Pre-Quiz IA and 1C). It also reminded students of the key contents of the lecture in the form of questioning rather than cramming. In Supplemental Table 3, Pre-lecture Quiz 3, for instance, we quessed that “The functions of neurons include all of the following EXCEPT: A. Sensing changes in the environment; B. Contraction; C. Synthesis and release of neurotransmitters; D. Generation of action potentials.” This quiz aimed to remind the IMSs of neuronal functions and its difference from other excitable cells. The significant increase in the correct answer rate in the last versus the first pre-lecture quiz supports the notion that this method effectively drives the students to prepare for the lecture beforehand. Student-led summary was designed to promote full understanding of the key contents in the ongoing lecture, at least for some advanced IMSs. After the main lecture given by the teacher, several IMSs voluntarily stood in the teacher’s position and restated the key contents of the course while the teacher gave timely confirmation and/or correction. Through this practice, these advanced IMSs become qualified “tutors” who can “translate” teacher’s lecture to their peer in more understandable terms/language(s) (33). The postlecture quiz was used to obtain the information of students’ learning efficiency and identify commonly difficult contents. The latter can be followed up via online instructions. An example is present in the Supplemental Table 3, Post-Quiz IA, in which we quessed that “The functions of neurons include all of the following EXCEPT: A. Generating action potentials in glial cells; B. Conducting signals; C. Integrating signals; D. Axoplasmic transport. It tests the extents of the IMSs’ mastering the focus/key contents. The increased rate of correct answers in the last versus the first post-lecture quiz supports the effectiveness of this method and is in agreement with a previous report (34).

These add-on features in the TESOT do not significantly impact routine delivery of key contents by the teacher but significantly improve the teaching efficiency by resolving the major learning obstacles. Thus it is not only a manifestation of the power of active-learning classrooms (15) but also a demonstration of successfully incorporating SCA into the TCA in a targeted manner. Therefore, the modality of TESOT can be applied to the education of a variety of student cohorts with different learning characteristics.

MECHANISMS UNDERLYING TESOT’S EFFECTIVENESS

The positive correlation between the attendance rate and the final score has been a feature in the nervous system module (Fig. 3). Chinese medical students taught in English in 2016 were rarely absent from class (97–99% attendance) but had higher average Physiology course score [77 (20.1%), our unpublished data]. The attendance rate has almost no correlation with individuals’ final scores. However, it could be an alternative proof for the positive correlation of attendance rate with score in general if they were pooled together with the IMSs in the correlation analysis. Therefore, although actively attending the lecture is both a sign of learning enthusiasm and an effective approach to obtain medical knowledge in intercohort comparisons (9, 10), it has only mild correlation with the final scores for the IMSs.

Consistent with this judgment, among students with the perfect attendance, the final scores using TESOT in 2016 were significantly higher than those of the prior cohorts in 2014 and 2015 using the classical modality (Fig. 4); consequently, the attendance rate seems not to be a major contributor of the increased learning efficiency among these IMSs. Thus the inherent learning obstacles of these IMSs cannot be resolved by a general improvement of the attendance under the frame of classical teaching modality. Therefore, the improvement of teaching efficiency should be attributable to increased communication, successfully bridging course contexts, and meeting diverse learning style preferences.

GENERALIZABILITY OF TESOT IN MODERN MEDICAL EDUCATION

In modern education, many teaching modalities targeting different cohorts of learners have been introduced. In medical education, Massive Open Online Course (35, 36), Problem-Based Learning (37, 38), Team-Based Learning (39, 40), Flipped or Inverted Classroom (28, 41), MACH model (42), and evidence-based teaching and many others (43, 44) are commonly used. Incorporation of these methods into the TESOT should result in even greater gains although we cannot systematically use these popular modalities for increasing the teaching efficiency for IMSs. This is because of their time limitation and the perception of heavy load of mandatory courses. While most medical schools in North America more or less use strategies of combination of TCA with SCA components under the guidance of active learning principle (15), TESOT is novel to the education of IMSs. This is because of its features of targeting actual learning obstacles of the special learning cohorts. It well illustrates Kolb’s theory (8) that educators should ensure that activities are designed and carried out in ways to offer each learner the chance to engage in the manner that suits them the best.

Importantly, these IMSs share some common issues with domestic students, such as perceiving difficulty in establishing connections between course contexts, preferring learning from lectures, and knowing the importance of ongoing course in whole medical education system. In addition, they all have higher expectations for educational reform that makes the teaching process more flexible with more
involvement of SCA components (19). Moreover, the learning obstacles are not specific for the IMSs in China but exist worldwide. For example, interprofessional collaborative practice, involving course connections, is also a concern in the U.S. (45) and Germany (46). In the United Kingdom, medical students in the operating theater education experience the obstacles of lack of clear learning objectives, fear, anxiety, feelings of humiliation and intimidation, lack of visualization, and lack of opportunity for participation as barriers to their satisfaction with theater placements and to their subjective learning (47), which can be partially overcome by highlighting the key objectives in the pre-lecture quiz and by encouraging students’ involvement. In the Middle East, lack of technical support and time constraints are the most common obstacles interfering with the effectuation of active learning across different fields of healthcare education (48), which is a suitable target of TESOT with its simple flow of course structure and the efficiency. In nursing education, nursing students are challenged by content-laden curricula and learning environments that emphasize testing outcomes, which require the application of TESOT to enhance the efficiency and the final scores through improvement of learning environments (49). Thus TESOT is worthy of application in the global health professional education of both international and domestic students. It is particularly meaningful to execute TESOT when the coronavirus pandemic limits in-person medical education, and most of its components can be applied through online instructions without a strong dependence on the attendance.

Conclusions

In alleviating the learning obstacles of IMSs in medical education, TESOT is a more efficient modality than classical TCA approaches. It does not rely on the attendance (albeit, it may improve it), does not increase self-study time, and thus fits the intense education scenario of IMSs in an alien teaching environment. The beneficial effect of this modality is attributable to the fact that it meets diverse learning style preferences while removing learning obstacles of the IMSs (Fig. 1). Thus further studies on TESOT are warranted in modern medical education.

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DISCLOSURES

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

AUTHOR CONTRIBUTIONS

Y.W., V.P., H.Z., and F.Z. conceived and designed research; X.W., Y.W., S.J., R.J., Y.Z., and L.T. performed experiments; X.W., X.L., S.J., and X.N. analyzed data; X.W., V.P., Y.W., X.L., S.J., R.J., and X.N. interpreted results of experiments; X.W. prepared figures; X.W. drafted manuscript; V.P. and Y.W. edited manuscript; X.W., V.P., Y.W., X.L., S.J., R.J., Y.Z., L.T., X.N., H.Z., and F.Z. revised and approved final version of manuscript.

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