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SHORT COMMUNICATION

The Flipped Classroom and Learning Analytics in Histology

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Abstract The success of the flipped classroom relies upon the preparation of students before class and their participation in class. Learning analytics allows faculty to determine the extent to which students are prepared. In a histology course utilizing the flipped classroom, learning analytics showed that only some students prepare for class. However, learning analytics also enabled faculty to determine problematic content in advance of the session.

Keywords Medical education · Histology · Analytics · Flipped classroom · Video module

Introduction

The flipped classroom is an instructional technique in which traditional learning activities are reversed. Instead of simply delivering basic content in class and then encouraging students to work problems, review, and study afterwards outside of class, the faculty assigns introductory materials to be learned before class so that class time can be spent with more advanced activities [1, 2]. For example, students are typically assigned a basic assignment to read or a short video module to view before class. Therefore, when they come to the classroom, they may be able to recall facts and basic concepts by stating basic definitions or repeating memorized lists; some students may even be able to explain basic ideas or concepts or recognize patterns. Although the knowledge of the students is quite basic and they simply remember and understand some basic facts, they are now prepared for a session that promotes critical thinking and application. In class, the students are now able to participate in active learning as opposed to a traditional lecture; for example, they may collaborate in small groups and use basic information in new situations by solving problems, demonstrating applications of basic knowledge, and interpreting data, thus developing a deeper understanding of the concepts about which they studied before class. In a well-designed classroom exercise, students may even draw connections among ideas by comparing and contrasting concepts and questioning basic assumptions. As they progress through a curriculum, some students will be able to justify a decision by appraising and arguing and even producing a new or original work by designing a new product. Thus, the flipped classroom produces a deeper understanding by promoting more than just remembering and understanding; instead, students are able to apply, analyze, evaluate, and eventually create [3]. In summary, it is often said that in a flipped classroom, students do what used to be "classwork" (basic definitions and explanations) at home and what used to be "homework" (problem solving) as "classwork." This new process allows for development of critical thinking and clinical reasoning [1].

To determine whether students are in fact preparing in advance by viewing assignments such as online instructional video modules, learning analytics can be employed. Learning analytics is an educational application in which technology allows an instructor to gather, interpret, and communicate meaningful patterns in data about learner preparation and performance. This type of learner profiling can be executed at the individual student level or at the class aggregate level. The goal is to develop better teaching strategies, target at risk student populations, promote engaged learning, and analyze factors that affect completion and student success [2]. Learning analytics allows instructors to ensure that key

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concepts have been mastered so that advanced concepts can be introduced.

Materials and Methods

In TEC (Translational Education at Carolina) at the University of North Carolina, School of Medicine, the preclinical curriculum has been compressed from four semesters into three semesters. Furthermore, there are no longer free-standing basic science courses such as histology, biochemistry, gross anatomy, and so on. Instead, a series of courses (approximately 4 weeks each) span the three-semester period, with each course representing an organ-system content that integrates the normal structure and function (histology, microbiology, physiology, etc.) and abnormal structure and function (pathophysiology, pharmacology, pathology, etc.). Thus, for example, the neurologic course begins with basic science and transitions into clinical science. Because of a loss of curriculum time and because of a focus on active learning in the classroom, histology lectures have been eliminated, and the flipped classroom has been implemented in histology sessions which are distributed in the organ-system curriculum over 18 months. Students are expected to prepare for class, which involves both faculty-student interaction and student-student interaction.

Online video modules have been developed using the "personal capture" feature of the Echo360 (Reston, VA) lecture capture system. These modules serve as a replacement for the histology lecture and as a preparation tool for class. It is expected that students will view these modules, each of which is less than 15 min in length, the night before class. By design, these modules do not include quiz questions or other techniques to promote higher-order thinking skills so that they are short, based on the attention span of students and taking into account their busy schedules.

The module introduces students to basic terminology associated with low-magnification cell structure so that they are prepared to maximize the in-class experience in which they work in teams of six students to identify cells at high magnification, learn about cell function, and apply basic knowledge to clinical applications. The learning analytics feature of Echo360 allows faculty to determine how many students are preparing for class, but more importantly this feature enables the instructor to determine which segments of the module are causing difficulty for students based on how long they repeat/replay those particular parts of the module. The results are conveyed using the following scale: (1) minimal engagement (thin blue line), (2) low engagement (thick blue line known as a "cool spot"), (3) moderate engagement (thick yellow line known as a "warm spot"), and (4) high engagement (thick red line known as a "hot spot.") These data are portrayed as a "heat map." This information can be utilized in real time the morning before the session as the lead faculty member can communicate anticipated difficult concepts and images to small-group leaders, who in turn emphasize those points during the session.

Results

Two modules were piloted in histology sessions of the recent iteration of the curriculum. For the session on the nervous system in the Neurologic Block, Echo360 learning analytics revealed that 123 unique students out of 180 in the first-year class viewed the module; this of course indicates that 57 students chose not to prepare for the flipped classroom experience using the module. There were, however, 157 cumulative views, so some students viewed the module more than once as either preview for or review of the classroom experience (Fig. 1).

By evaluating the extent to which a student rewinds a certain section, Echo360 learning analytics also indicates which portions of the module were particularly difficult for students. The heat map revealed four warm spots which correlate with areas of moderate student engagement (Fig. 2). In other words, in these particular parts of the module, students may have been confused or challenged or they may have been encountering material that was particularly new to them.

In particular, in this particular module, they found the following material easier, more straight-forward, or more familiar and thus exhibited a low level of engagement: the title (as one might expect), the cerebrum, peripheral nerve cut in cross section and stained with osmium, tongue, Pacinian corpuscle, and Meissner's corpuscle. These cells, tissues, and organs are in fact found in other parts of the course, are found in slides used previously in the curriculum, or used bolder and more obvious stains (Table 1).

Students, however, found certain topics slightly more difficult and thus showed low to moderate (or moderate to low) engagement by lingering on those parts of the module for a longer period of time by repeating/replaying. These topics included the cerebellum and peripheral nerve (both cross section and longitudinal section) stained with hematoxylin and eosin (Table 1).

Students showed even higher engagement (moderate in this case) by rewinding more extensively in certain parts of the module. These topics included the spinal cord, dorsal root ganglion, sympathetic ganglion, parasympathetic ganglion, and muscle spindle (Table 1).

Discussion

Results of learning analytics were conveyed to small-group laboratory leaders before the session began so that they could

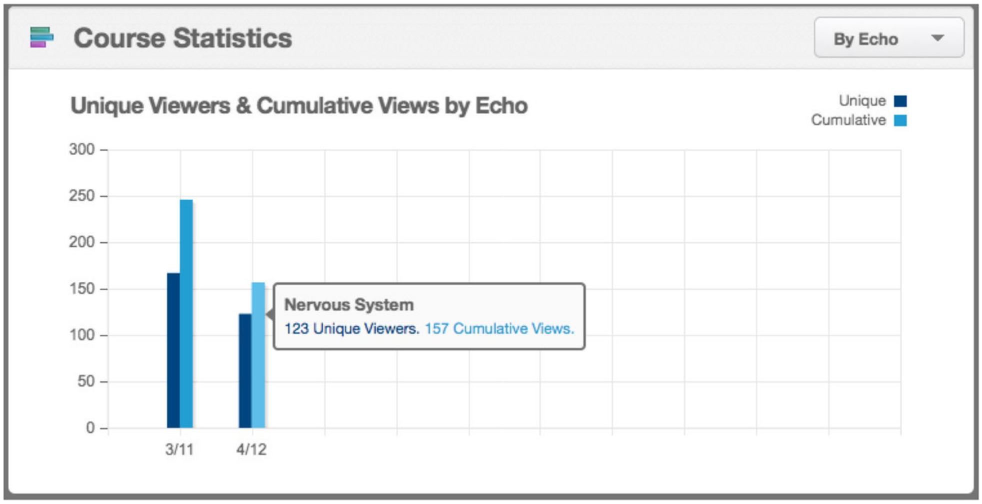

Fig. 1 The module on the nervous system (4/12) had 123 unique viewers and 157 cumulative views. The module on the gastrointestinal system (3/11) was not evaluated

spend more time on difficult concepts. Faculty commented that having these data gave them confidence in spending less time on simple concepts so that they could in fact spend more time on complex topics. They added that they were able to initiate discussions assertively rather than waiting on timid students to volunteer their weaknesses. They also suggested that as they wandered among the students in the laboratory session that they could be purposeful in looking for student competence (or lack thereof) with various slides, specimens, and tissues. Course directors were then able to adjust the questions that were utilized in practice sets in the week after the laboratory experience, and furthermore, they could adjust examination questions to be more or less difficult, as they saw fit. Finally, faculty leaders were able to emphasize difficult topics on customized mid-semester examinations that were derived from questions banks of the National Board of Medical Examiners (NBME).

Based on these experiences, curriculum deans were able to evaluate the extent to which students were preparing for the flipped classroom experience. Results of this study call into question whether students in a busy curriculum are able or willing to prepare for sessions in advance given their heavy workload. If all students do not prepare for sessions, then experiences within each small group are variable and possibly inefficient unless small-group dynamics are such that students are in fact peer-teaching one another.

In focus group conversations, students comment that learning analytics helps them to target their efforts so that they can work on their weaknesses as opposed to continuing to enhance their strengths. The integrated nature of examination questions makes it difficult to determine the extent to which learning analytics has been helpful, but upcoming licensing examinations (the US Medical Licensing Examination or USMLE) will give faculty and students some ability to compare student success in various disciplines.

Conclusions

The faculty have begun to realize that a "one-size-fits-all" method of instruction is not completely effective for students who are struggling with specific concepts or who are not grasping challenging material as quickly as their fellow students [4]. During the last few years, learning analytics technology and instructor access have improved, with faculty now having an increased ability to "personalize the learning experience" [5]. By developing teaching practices that are informed by data, faculty can potentially improve student outcomes. It has been hypothesized that there can be benefits for researchers, institutions, and even accrediting bodies and organizations. Learning analytics has evolved, transitioning from "hindsight to foresight." While learning analytics was initially used simply for describing results, it

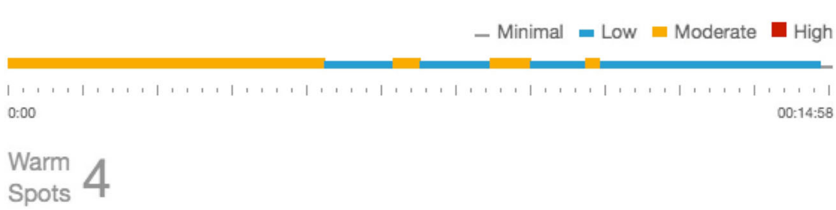

Fig. 2 The results are conveyed using the following "heat map": (1) minimal engagement (*thin blue line*, none shown), (2) low engagement (*thick blue line* known as a "cool spot"), (3) moderate engagement (*thick yellow line* known as a "warm spot," 4 shown), and (4) high engagement (*thick red line* known as a "hot spot," none shown)

Table 1 The module, which was 14:58 in total length, contained segments with low and moderate levels of student engagement

Time at the beginning of segment	Segment topic	Student engagement
0:00	Title	Moderate
0:25	Spinal cord	
3:03	Dorsal root ganglion	
4:12	Sympathetic ganglion	
5:08	Parasympathetic ganglion	
5:54	Cerebrum	Low
7:11	Cerebellum	Moderate decreasing to low
8:19	Peripheral nerve (cross section)	Low increasing to moderate
9:42	Peripheral nerve (longitudinal section)	Low increasing to moderate
11:11	Peripheral nerve (with osmium)	Low
11:50	Tongue	Low
12:45	Muscle spindle	Moderate
13:33	Pacinian corpuscle	Low
14:05	Meissner's corpuscle	Low

has progressed to being used for analysis of learning and now for the prediction of what will happen with respect to anticipated learning. The creation and analysis of data on which educational action can be taken is a distinguishing characteristic of adaptive learning [6].

It has been suggested that adaptive learning may be most effective in learning environments that are primarily or exclusively online, as activities of individual students or classes as a whole can be monitored by applications with tracking functions. This is evidenced by the fact that many publishers are now focusing on adaptive learning to modify and improve their textbooks, atlases, image viewers, board-exam review programs, and other applications [7]. At the undergraduate level, adaptive learning platforms are beginning to be shown to lead to better performances compared to activities in traditional courses, but thus far in medical curricula, studies are more preliminary. Educational scholars propose that adaptive learning will continue to advance as higher education becomes more aware of the power of this technique and implements it uniformly into curricula. The ultimate key to success of adaptive learning will be not only for faculty to track learner progress but also for learners to monitor their own development [8].

Institutions are under pressure to improve graduation rates. Medical schools in particular have excellent graduation rates, but they are under pressure to help students succeed so that those students do not need to decelerate—resulting in delayed graduation, higher student loans, and a questionable record during application to residency. Adaptive learning allows medical school faculty to identify students at risk of extending what is expected to be a 4-year program [9]. Some schools are beginning to utilize systems to monitor the amount of effort which students are applying to various assignments. Through the analysis of a student's history of reading online documents (e.g., syllabi, textbook excerpts, and laboratory manuals) and engaging with learning platforms (e.g., video modules), instructors can determine who needs intervention or which topics on the whole need more instruction for the class [10]. As schools pilot the use of this new technology, however, there is often hesitation to implement across the curriculum because of concerns about privacy and data safety. These barriers may in fact delay or prevent the use of adaptive learning technology in some settings [11].

There is escalating enthusiasm in the use of learning analytics and adaptive learning technologies, although there are not many studies that demonstrate outcomes. McGraw-Hill Education, however, has published a study indicating that "87% of undergraduate students report that having access to data analytics regarding their academic performance has a positive impact on their learning." The study also states that 75% of students find this technology to be helpful as they struggle to retain new and difficult concepts [2]. Learning analytics will likely be driven by the top and by the bottom—by administrators seeking less deceleration and higher graduation rates and by students seeking more efficient and deeper learning.

With the implementation of learning analytics and the adaptive response to analytics data by administrators, faculty, and students, curricula which are subjected to mandated compression can both become more efficient and promote deeper learning. Students can first master "threshold concepts," the core concepts of a basic discipline such as histology in this case [12]. Then students can relate individual concepts to one another and integrate specific topics together as they work towards a deeper understanding.

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