

Effectiveness of integrating case studies in online and face-to-face instruction of pathophysiology: a comparative study

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Saleh SM, Asi YM, Hamed KM. Effectiveness of integrating case studies in online and face-to-face instruction of pathophysiology: a comparative study. *Adv Physiol Educ* 37: 201–206, 2013; doi:10.1152/advan.00169.2012.—Due to growing demand from students and facilitated by innovations in educational technology, institutions of higher learning are increasingly offering online courses. Subjects in the hard sciences, such as pathophysiology, have traditionally been taught in the face-to-face format, but growing demand for preclinical science courses has compelled educators to incorporate online components into their classes to promote comprehension. Learning tools such as case studies are being integrated into such courses to aid in student interaction, engagement, and critical thinking skills. Careful assessment of pedagogical techniques is essential; hence, this study aimed to evaluate and compare student perceptions of the use of case studies in face-to-face and fully online pathophysiology classes. A series of case studies was incorporated into the curriculum of a pathophysiology class for both class modes (online and face to face). At the end of the semester, students filled out a survey assessing the effectiveness of the case studies. Both groups offered positive responses about the incorporation of case studies in the curriculum of the pathophysiology class. This study supports the argument that with proper use of innovative teaching tools, such as case studies, online pathophysiology classes can foster a sense of community and interaction that is typically only seen with face-to-face classes, based on student responses. Students also indicated that regardless of class teaching modality, use of case studies facilitates student learning and comprehension as well as prepares them for their future careers in health fields.

pathophysiology; online teaching; case studies; critical thinking

PATHOPHYSIOLOGY focuses on disease pathology as a deviation from normal physiological processes and usually has an introductory course in anatomy and physiology as a prerequisite. Mastery of this course is seen as particularly vital for students looking to pursue careers in healthcare. The content of this class can serve as a foundation for the later integration of more detailed processes and functions, as seen in medical or nursing school (4). Due to the important role this course plays in providing a theoretical basis for medical thinking, many scholars believe that a student preparing for a career in healthcare should be offered this course not only in postgraduate training but also as an undergraduate course (8). In fact, the American Physiological Society recommends such continuity between undergraduate and graduate level training to firmly establish important physiological principles (5).

Pathophysiology has been traditionally taught as face to face in class settings. However, to meet the hard-content challenges in teaching this subject, online components and modules are

now incorporated in these classes. Pathophysiology, as a core class for developing medical thought, can often require a more holistic or innovative approach to ensure student retention of knowledge as well as its applicability (4). Additionally, with the increase in student enrollment in these classes, mainly in undergraduate preclinical programs, fully online offerings of these classes are becoming an emerging trend (6).

Online classes have become an increasingly popular way to meet the changing needs of today's students without compromising quality or level of education. In 2007–2008, 20% of all undergraduate students took at least one online course (~4.3 million students); 4%, or 800,000 students, finished their entire undergraduate education online. This trend is unlikely to diminish, as the percentage of students enrolling in online courses has only grown (13). Online classes are already widely used in the sciences, and students have reported that the flexibility afforded by this mode of learning allows them to deepen their comprehension of the subject (12, 7).

While online learning is increasing in popularity, its use as a primary mode of instruction demands that instructors and institutions use innovative techniques to engage students in ways comparable to face-to-face instruction. Students have reported that it is difficult to foster a sense of community in online classes. Lack of community appears to be one of the largest weaknesses of online classes, even for students who were satisfied with their course and performed well (10). Additionally, there is extra pressure placed on the instructor to be heavily involved with the students and to find ways to keep motivation consistent throughout the semester (2, 11). A study (6) examining the use of case studies and other types of case learning (such as problem-based learning) as assessment tools found that case studies were found to be very valuable by students as an active way to approach the teaching and learning process.

A study (15) in 2000 found that exam scores between a pathophysiology web-based course and a face-to-face course were mostly consistent, indicating that learning objectives can be met equally well in both modalities, although the authors of that study were quick to point out that multiple-choice tests did not test for deeper levels of learning that would normally be included in tests featuring content garnered from case studies. Students especially value activities that focus on decision-making skills that are connected to a real-life situation in their field of study, as it leads them to higher levels of thinking and learning (3).

Project-based learning, particularly when case studies were included, has been shown to increase measures of learning in online coursework (9). Case studies and scenarios coupled with group work have been shown to supplement student learning for those engaged in all levels of physiology education, from high school to college and even graduate school, by increasing

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student engagement and applicability of course material (9). Students who are likely to be working in clinical settings also found value in the use of case studies, because it allowed them to bridge the gap between theory and practice. While case studies are useful as interactive assessment activities, they also provide online students with an opportunity to proceed at their own pace and have more motivation to work independently without the time constraints of a traditional face-to-face class meeting (14). Case studies can be used both as a mode of instruction, to augment traditional learning tools such as lecture, and also as a form of assessment, where students are expected to answer case-based questions that require them to use what they have learned in class. In this study, case studies were used in the latter sense, as a form of assessment that allows students to apply their knowledge to a practical situation.

Of course, use of online classes in the sciences is not without its challenges. It can be difficult to match the experience of a face-to-face class in a completely virtual setting, and many online classes also feature a much larger class size than face-to-face classes, which are limited by space. The interactions between the teacher and student are also unlikely to be the same in both modalities, which may impact levels of student learning. Part of what this report sought to address is whether use of a learning tool such as case studies can help bridge some of these gaps in pedagogy.

This report compared and contrasted student perceptions of the use of case studies as a pedagogical tool in undergraduate pathophysiology classes offered face to face or online. This pathophysiology course, pathophysiology I, is a required core course for all undergraduates majoring in the Health Sciences Preclinical major and who are planning to pursue graduate study in health professions at the University of Central Florida. This course is also taken by other majors, such as those of biology and biomedical sciences.

METHODS

Participants. A purposeful sample of students ($n = 252$) enrolled in the pathophysiology I class in the fall of 2011 at the University of Central Florida was used for this study (Table 1). Participants were enrolled in one of three offered sections of pathophysiology: two fully online sections ($n = 196$) and one face-to-face section ($n = 46$). At the end of the semester, students received an invitation to participate in this study by completing a survey about their experience in the course and the use of interactive case studies. Participation was voluntary, and students who responded to the survey were awarded extra credit points to their total points for the class. Students who elected not to participate in this study were given the choice to earn the extra credit by completing an alternate assignment. Of the 252 students enrolled, 242 students (96%) completed the survey.

Design. The pathophysiology I class is the first part of a two-semester pathophysiology course sequence, pathophysiology I and pathophysiology II. Pathophysiology I covers introductory topics in cellular pathophysiology, genetic disorders, and disorders of the immune, cardiovascular, and renal systems. This course is a three credit core class in the undergraduate Health Sciences Preclinical major. This major has over 2,000 students who plan to pursue graduate study in health professions. The pathophysiology class is typically taught face to face, but in this major a fully online version was developed to meet student demand. The same instructor developed the curriculum for both teaching modalities. In the semester when the study was done, three sections of the pathophysiology course were offered, one face-to-face section and two online sections. In the face-to-face section, case study pedagogy was coupled with a

Table 1. *Demographic characteristics of students enrolled in pathophysiology*

	Online Class		Face-to-Face Class	
	<i>n</i>	%	<i>n</i>	%
Total	196		46	
Age, yr				
18–20	18	9.1	7	15.2
21–23	123	62.8	30	65.2
24–26	28	14.2	8	17.4
27–30	10	5.1	1	2.2
30+	17	8.7	0	0
Sex				
Female	143	73	34	73.9
Male	53	27	12	26.1
Ethnicity				
White, non-Hispanic	109	55.6	23	50
Black, non-Hispanic	25	12.7	5	10.9
Hispanic or Latino/a	23	11.7	8	17.4
Biracial or multiracial	7	3.6	5	10.9
Other	31	15.8	5	10.9
Classification				
Sophomore	1	0.5	1	2.2
Junior	45	23	18	39.1
Senior	145	74.4	27	58.7
Nondegree seeking	4	2	0	0
Enrollment status				
Full time	177	90.3	41	89.1
Part time	19	9.7	5	10.9

n, Number of students.

group discussion strategy. Students worked in groups, and each group submitted one report for case studies. In the online class, the web contents were reformatted to include case studies to stimulate student engagement and improve critical thinking skills in the online environment. Students worked in groups, but students submitted individual reports for the case studies. The difference in reporting methods for the different classes was based on logistical considerations. The online class was a much larger class, and the dynamics of a virtual class made it more difficult to ensure equal group contribution from each student. Each case study included a patient clinical history and scenario followed by series of questions. A set of guidelines and explanation on how to approach and analyze a clinical case study was included to guide the students through the critical thinking process and group discussion. The grades in both face-to-face and online classes were based on four unit exams (40%), a series of short quizzes (20%), case studies (15%), and a comprehensive final exam (25%).

In this project, our goal was to assess the student perceptions of integrating case study group discussions as a teaching tool in pathophysiology in general and in the online class in particular. During the semester, students in both teaching modalities received the same instructional materials and completed the same assessments. At the end of the semester, students completed a survey about their experience with the case study assignments. Completion of the survey was voluntary. The survey included questions that evaluated the efficacy of the use of case studies in online instruction of pathophysiology compared with face-to-face courses (Table 2). The survey had two parts: questions about student demographics and questions about the use of case studies in the course. While the demographic questions were mostly multiple choice, the questions assessing the use of case studies were predominantly open ended, allowing students to respond freely. Approval was sought from and given by the campus Institutional Review Board for the study, and consent was collected from all participants before completion of the survey.

Data analysis. Students accessed the survey within the Webcourses component of their class at the end of the semester. The investigators used descriptive statistics to evaluate demographic differences be-

Table 2. Survey questions on student learning experiences along with variables measured and quantitative categories

Question	Assessed Variable	Answer Categories
What grade do you expect (not hope for) in this class?	Expected grade	A, B, C, D, or F
How do you rate your overall learning experience in this class?	Learning experience	Positive or negative
Did you encounter case studies in any of your previous classes?	Previous case study encounter	Yes or no
How effective was the case study approach to you in learning the concepts of this class?	Effectiveness of case studies	Effective, somewhat effective, or not effective
How enjoyable was the case study method as a learning tool?	Enjoyment of case studies	Enjoyable, somewhat enjoyable, or not enjoyable
For assessment purposes, would you rather have more exams or more case studies?	Assessment preference	Exams, case studies, neither, or both
What did you like about the case studies?	Case study likes	Nothing, group, application, comprehension, or career preparation
What did you dislike about the case studies?	Case study dislikes	Nothing, time, group, or difficulty
Would you prefer to do case studies individually or as a group?	Group dynamic	Group or individual
Would you recommend using more case studies in this class, and in similar classes?	Recommendation for more case studies use	Yes or no
What would you change about the case studies you had in this class?	Change in content of case studies	Nothing, groups, difficulty, or time
Were the case studies graded fairly?	Fair grading of case studies	Yes or no
If you were the professor of this class, would you teach the entire class using only case studies?	Assessment only based on case studies	Yes or no

tween the two course modalities (online and face to face). Upon the close of the survey, the researchers reviewed the open-ended student responses, and categorical themes were created to make for more substantial data analysis (Table 2). Responses were then quantitatively coded and input into the SPSS (version 20) application. Correlational analysis and ANOVA testing were performed to analyze student experiences with the case studies.

RESULTS

Student demographics in face-to-face and online class modalities. The data from the descriptive statistical analysis were largely supportive of the existing literature about online versus face-to-face classes. The online classes were significantly skewed in terms of age, with 5% between the ages of 27–30 yr and another 9% above the age of 30 yr compared with only 2% between the ages of 27–30 yr and none above the age of 30 in the face-to-face class (Table 1). In fitting with this trend, 74% of the students in the online class were seniors, as opposed to 58% of those in the face-to-face class. ANOVA revealed that student classification was statistically significantly related to class teaching mode [$F_{(1,240)} = 7.731, P = 0.006$], with more students in the online class reporting as seniors. The proportion of sex and enrollment status was evenly spread between the classes; however, more women reported having encountered case studies in previous classes than men [$F_{(1,240)} = 6.758, P = 0.010$]. Another interesting dimension of the study that fell along sex lines was what students reported they would change about the case studies: 33% of female students would change the amount of time required for the case studies compared with 23% of male students. These types of demographic attributes became important as further analysis of the data continued. For example, better understanding should be obtained of the needs of various groups of students and who may self-select into either online or face-to-face courses. If providing students with a learning tool such as case studies can bridge the gap between these types of classes, then it becomes a way to encourage and motivate older students who may be taking online classes for their flexibility but still want an engaging learning experience.

Correlational analysis of student perceptions in the two class modalities. Correlational analysis provided valuable insight into the perceptions of students. Overall, students who reported enjoying the case studies were also more likely to report finding them effective ($r = 0.374, P < 0.001, n = 242$). An overwhelming majority of students who found the case studies effective (96%) thought it was due to the fact that case studies allowed them to apply what they learned. This majority held throughout both types of class modalities, with 98% in the online class and 87% in the face-to-face class. The reasons that the students found the case studies effective were negatively correlated to the class modality ($r = -0.318, P < 0.001, n = 187$), indicating that the differences came from how each individual student perceived the case studies themselves and not necessarily how they were presented (online vs. face to face). However, higher percentage of students in the online classes (78%) reported that the case studies were effective compared with 50% in the face-to-face class. Students who enjoyed the case studies were also more likely to want more case studies used in the class ($r = 0.361, P < 0.001, n = 242$). A response that the case studies were graded fairly was positively correlated to reporting that they were effective learning tools ($r = 0.310, P < 0.001, n = 241$). Students were also able to accurately self-monitor their progress, with a very high positive correlation between the grade that students expected to receive in the class and their actual grade ($r = 0.708, P < 0.001, n = 242$).

Analysis was also conducted on each class modality individually to discern any patterns. Correlational data found that many of the trends seen from the overall class data were reflected in the online class as well (Table 3); for example, in the online class, 68% of those who found the case studies effective also considered them enjoyable, and only 8% of students who found them effective did not find them enjoyable, whereas 75% of students who did not find the case studies effective also did not consider them enjoyable. An important note to consider in an online class, with less professor-to-student interactions, is whether case studies as an assessment tool are considered by students to be graded fairly; in our

Table 3. Correlational analysis of the use of case studies in online and face-to-face pathophysiology instruction

	Face-to-Face Class			Online Class		
	<i>r</i>	<i>P</i>	<i>n</i>	<i>r</i>	<i>P</i>	<i>n</i>
Student age and assessment only based on case studies	-0.342	0.020	46	-0.062	0.388	196
Learning experience and expected grade	0.347	0.018	46	0.168	0.018	196
Actual grade and expected grade	0.748	0.000	46	0.670	0.000	196
Case study likes and enjoyment of case studies	0.470	0.001	46	-0.226	0.001	196
Effectiveness of case studies and enjoyment of case studies	0.312	0.035	46	0.473	0.000	196
Assessment preference and previous case study encounter	0.384	0.008	46	-0.013	0.861	196
Group dynamic and class mode	0.307	0.038	46	0.094	0.188	196
Effectiveness of case studies and fair grading of case studies	0.129	0.393	46	0.306	0.000	195

n, Number of students. See Table 2 for full survey questions.

sample, 96% of the students in the online class reported that they were graded fairly.

Data from the face-to-face class also proved to be very valuable. Correlational analysis showed several significant correlations that will be expanded on in the DISCUSSION in this report (Table 3). ANOVA testing found no significant difference in age, sex, class, or status between the online and face-to-face classes, indicating that the demographics of the courses did not differ enough to impact the results of how the students respond to the case studies. However, it was found that those who had not encountered case studies before this class were more likely to want to use case studies as a mode of assessment over exams than those who had seen them in other classes [$F_{(1,44)} = 7.361$, $P = 0.009$]. Interestingly, 28% of students reported that what they liked the least about the case studies was the group work aspect, but only 13% said they would change it.

DISCUSSION

Technology has allowed for enormous innovation in the realm of education, particularly in higher education, and has expanded its student base as a result. Although online teaching is not without its challenges, for example, the significantly increased presemester preparation time for instructors to set up each course, many instructors find that the benefits for themselves, students, and overall institutional adaptability outweigh the cost. Increased flexibility coupled with a university's ability to offer more sections of classes without being restricted by room availability or similar concerns of face-to-face classes has allowed many students with job and family obligations, or those who may have to contend with long commutes, to pursue their education, even in the hard sciences. The data collected from the three sections of this undergraduate pathophysiology class provided us with very valuable information that can be applied to other classes in the sciences.

Our data revealed that the population of the online class featured a much higher percentage of older students, including students above the age of 30 yr, of which there were none in the face-to-face class. Additionally, ~20% more of the students in the online class were seniors. We were surprised to find relatively similar proportions between class modalities of full-time and part-time students as well as male and female students. It appears that age and classification are higher indicators of enrollments in an online class than other demographic factors, reaffirming the position that one of the greatest strengths of online classes is their ability to meet the needs of older and/or nontraditional students (1).

Because the case studies integrated parts from various units covered in the course, they provided a unique assessment technique for students. Although there is a large archive of research of the use of case studies in both online and face-to-face learning (12, 14, 15), the existing literature is lacking in information that addresses case studies as not just a teaching tool but as an assessment tool, as was the case in this class. We found that 78% of the students in the online class found the case studies effective compared with 50% of the face-to-face students (Fig. 1). We attribute this to two factors: the time allotted and the group component. In the face-to-face class, most of the students who found the case studies ineffective either did not think that the time in class was enough to complete the course assignments due to the difficulty level or reported that they were in a group where no one else was doing any of the work. Due to the limitations of the online class, students worked in groups but were each responsible for turning in their own report. Thus, each individual student had to apply his or her knowledge.

Indeed, the majority of students that found the case studies effective in both the online class (98%) and the face-to-face class (87%) reported that they liked the fact that the case studies allowed them to apply their knowledge. However, while face-to-face students benefit from interactions with each other and with the professor, online classes seem to have less of this valuable interaction. Implementing case studies coupled with group discussion may have provided the online students

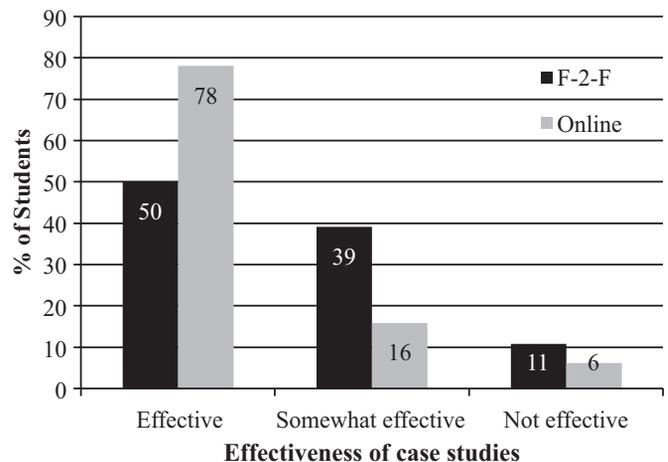


Fig. 1. Student evaluation of the effectiveness of case study group discussion in online and face-to-face (F-2-F) pathophysiology instruction. Numbers in bars are exact percentages.

with the opportunity to apply their knowledge and to interact with each other.

Not surprisingly, students from both class modalities who reported enjoying the case studies also commented that they would prefer more case studies, rather than exams, as assessment tools. This was a unique component of the intervention outlined in this study; the case studies were not just used as a tool to enhance student learning and the applicability of the course material but as an assessment tool in lieu of more exams. This speaks to a larger issue of student learning styles, one that is not explicitly covered in this report but is important when considering science education. Student learning styles differ greatly; some students prefer to progress at their own pace without lots of interaction, whereas other students enjoy the group dynamic and dislike working alone. Thus, we recommend that medical education practitioners consider incorporating multiple methods of assessment, including case studies, particularly in online classes where the instructor does not often get to know each individual student. A large majority of students did not think that case studies should be the only mode of assessment used, with 82% of students reporting they would not want the entire class taught in such a manner. However, used judiciously, case studies can not only be useful as a teaching and learning tool but also as an innovative way to assess student learning in a manner that is not easily addressed by exams and essays.

We were pleased to find a high correlation between student's expected grades and their actual grades for both class modalities. This indicates that regardless of class mode, the methods in which the instructor assessed the students were appropriate. Students were able to gauge their progress and were not surprised by their grade at the end of the semester, which can be especially important in online classes, since they are more self-paced. Almost all students in both class modes (96%) thought that the case studies were graded fairly by the instructor, an important factor because of the inherent subjectivity of case studies.

In the face-to-face course, students who had encountered case studies previously were more likely to want to use them as assessment methods rather than exams. We were surprised that 43% of students reported having never encountered case studies in a previous class, which could indicate an institutional hesitation to pursue different teaching and learning techniques in science education. Most of these students were juniors or seniors, so lack of diversity in instruction is an issue that should be addressed by science educators.

Among the students who expressed positive feedback on case studies, we found no statistically significant difference with regard to overall response to the use of case studies on almost all demographic characteristics, aside from those addressed in this DISCUSSION. This indicates that case studies, as a learning tool, are valuable to students regardless of age, sex, race, enrollment status, or class. In this report, we sought to examine this very idea: that case studies could be used to enhance learning of the sciences in either a face-to-face or online class regardless of demographic differences. In some indicators, we found that case studies were more successful in the online class, but qualitative analysis of the student responses indicated that this was likely tied to the manner in which the case studies were given to the classes. Student responses also supported the hypothesis that case studies, in an

online class, can bridge the gap between individual learning pace and interaction with the material.

Limitations. Because of the nature of the pathophysiology course in the term in which we collected our data, we had a much larger population of online students than face-to-face students. We corrected for this imbalance in our data analysis and interpretation. We attempted to keep most factors consistent between the courses, including the case studies themselves, but by their very nature, online classes and face-to-face classes offer diverse dynamics. Thus, some of the differences or similarities reported in our data could be due to outside factors that were not covered in the extensive questions we asked students.

One of the primary differences in classes, as addressed in the METHODS of this report, was the way that the groups submitted their reports on case studies. Students in both courses worked in groups; however, the students in the face-to-face class turned in a single report per group, whereas the students in the online class turned in individual reports. Although this may have had an impact on the ultimate results of the survey, this decision was made to accommodate for the differences in group dynamics in a face-to-face versus online environment, where students may not interact personally.

Conclusions and recommendations. Based on our data, we offer a few recommendations for science educators interested in using case studies in both online and face-to-face classes. First, instructors should adequately address the potentially problematic aspects of group work. Our face-to-face class worked together as groups in class, whereas the online students worked as groups but turned in their own final report. A higher percentage of students in the face-to-face class (28%) reported that the group component was what they would change about the case studies over other factors compared with only 3.5% of the students in the online class. Thus, we would recommend that case studies that are given as group work be graded on an individual basis, regardless of class modality. Giving the face-to-face students more out of class time could have increased their enjoyment of the case studies, possibly also increasing the reported effectiveness.

We also recommend that more instructors incorporate more overall diversity in course assessment for the sciences, rather than solely relying on full utilization of traditional methods, such as exams and essays. Along with case studies, professors can better use group assignments, use of multimedia and technology, and forms of assessment that better simulate real-life situations students may face in their careers. Most of the students in our pathophysiology class were planning to go on to careers in a variety of health professions, and thus case studies and other forms of applicative assessment are more in line with their eventual experiences in the field. While exams and other traditional methods of assessment are imperative to evaluating certain types of skills, we also feel that students benefit from assessments that integrate large chunks of information, rather than individual facts. Students reported that they felt they would be better able to retain the information covered in the case studies, because they were forced to consider multiple factors and depend on resources such as the text or their classmates for clarity. Many students commented that they thought case studies were important because they knew these were the types of situations they would encounter as future doctors, nurses, and physician assistants.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

AUTHOR CONTRIBUTIONS

Author contributions: S.M.S. and K.M.H. conception and design of research; S.M.S. performed experiments; S.M.S. and Y.M.A. analyzed data; S.M.S. and Y.M.A. interpreted results of experiments; S.M.S. and Y.M.A. prepared figures; S.M.S., Y.M.A., and K.M.H. drafted manuscript; S.M.S., Y.M.A., and K.M.H. edited and revised manuscript; S.M.S. approved final version of manuscript.

REFERENCES

1. **Aud S, Hussar W, Kena G, Bianco K, Frohlich L, Kemp J, Tahan K.** *The Condition of Education 2011 (NCES 2011-033)*. U.S. Department of Education, National Center for Education Statistics. Washington, DC: U.S. Government Printing Office, 2011.
2. **Dawson S.** A study of the relationship between student communication interaction and sense of community. *Internet Higher Educ* 9: 153–162, 2006.
3. **Gikandi JW, Morrow D, Davis NE.** Online formative assessment in higher education: a review of the literature. *Comput Educ* 57: 2333–2351, 2011.
4. **Guzak JW.** The shaping of the medical thought: a task for pathophysiology. *Pathophysiology* 2: 185–189, 1995.
5. **Henriksen EJ, Atwater AE, Delamere NA, Dantzer WA.** The physiology undergraduate major in the University of Arizona College of Medicine: past, present, and future. *Adv Physiol Educ* 35: 103–109, 2011.
6. **Krain M.** The effects of different types of case learning on student engagement. *Int Studies Perspect* 11: 291–308, 2010.
7. **Lin YH, Liang JC, Tsai CC.** Effects of different forms of physiology instruction on the development of students' conceptions of and approaches to science learning. *Adv Physiol Educ* 36: 42–47, 2012.
8. **Litvitsky PF.** Integrating role of pathophysiology in shaping the physician's thinking at the under- and postgraduate stages of medical training. *Pathophysiology* 3: 91–93, 1996.
9. **Oriol NE, Hayden EM, Joyal-Mowschenson J, Muret-Wagstaff S, Faux R, Gordon JA.** Using immersive healthcare simulation for physiology education: Initial experience in high school, college, and graduate school curricula. *Adv Physiol Educ* 35: 252–259, 2011.
10. **Overbaugh RC, Nickel CE.** A comparison of student satisfaction and value of academic community between blended and online sections of a university-level educational foundations course. *Internet Higher Educ* 14: 164–174, 2011.
11. **Schrum L, Burbank MD, Engle J, Chambers JA, Glassett KF.** Post-secondary educators' professional development: investigation of an online approach to enhancing teaching and learning. *Internet Higher Educ* 8: 279–289, 2005.
12. **Tse MM, Lo LW.** A web-based e-learning course: integration of pathophysiology into pharmacology. *Telemed e-Health* 14: 919–924, 2008.
13. **United States Department of Education.** *National Center for Education Statistics. Fast Facts* (online). <http://nces.ed.gov/fastfacts/display.asp?id=80> [4 March 2013].
14. **Van Dijken PC, Thevoz S, Jucker-Kupper P, Feihl F, Bonvin R, Waeber B.** Evaluation of an online, case-based interactive approach to teaching pathophysiology. *Med Teach* 30: e131–e136919–924, 2008.
15. **Yucha C, Princen T.** Insights learned from teaching pathophysiology on the world wide web. *J Nurs Educ* 39: 68–72, 2000.

