The use of simulation as a novel experiential learning module in undergraduate science pathophysiology education

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Submitted 11 December 2015; accepted in final form 4 May 2016

Chen H, Kelly M, Hayes C, van Reyk D, Herok G. The use of simulation as a novel experiential learning module in undergraduate science pathophysiology education. Adv Physiol Educ 40: 335–341, 2016; doi:10.1152/advan.00188.2015.—Teaching of pathophysiology concepts is a core feature in health professional programs, but it can be challenging in undergraduate medical/biomedical science education, which is often highly theoretical when delivered by lectures and pen-and-paper tutorials. Authentic case studies allow students to apply their theoretical knowledge but still require good imagination on the part of the students. Lecture content can be reinforced through practical learning experiences in clinical environments. In this study, we report a new approach using clinical simulation within a Human Pathophysiology course to enable undergraduate science students to see “pathophysiology in action” in a clinical setting. Students role played health professionals, and, in these roles, they were able to interact with each other and the manikin “patient,” take a medical history, perform a physical examination and consider relevant treatments. Evaluation of students’ experiences suggests that using clinical simulation to deliver case studies is more effective than traditional paper-based case studies by encouraging active learning and improving the understanding of physiological concepts.

Simulation; pathophysiology; practical class; medical science; undergraduate

THE TEACHING OF PATHOPHYSIOLOGY, i.e., the abnormal physiology of disease states, is a core feature in health professional programs. While content can be efficiently taught by lectures, it is generally accepted that a deep approach to learning necessitates embedding content knowledge into case studies (1). Such case studies are built around authentic scenarios, ideally prepared in consultation with practicing clinicians and educators to ensure contemporary practices are embedded into the case material. However, when taught in the classroom, the success of these case studies with regard to promoting a deeper approach to learning is in part reliant on the student’s capacity to successfully engage with the material and create a mental image of the clinical situation. This is very challenging for undergraduate science students who may have limited clinical experience with, or observation of, actual patients.

In the training of health professionals, the opportunity to see “pathophysiology in action” is provided by clinical practicum. The burgeoning demand for clinical placements (11) and considerations of patient and student safety have been drivers to supplement authentic clinical experience with simulations of varying fidelity (6). High-fidelity manikins have undergone significant advances in recent years. These highly technical manikins can be programmed to reflect physiological signs, such as heart sounds, breath sounds, pulses, blood pressure, and O2 saturation, and to respond to procedures performed by the students (4, 8, 10). Immediate feedback in the form of verbal responses via the manikins to student’s interventions and offering learning experiences within representative clinical settings are additional unique features of simulations. Thus, there is a strong argument for the use of simulations in teaching pathophysiology to undergraduate science students.

While the use of simulation in medical and nurse education has been previously reported (3, 6, 10, 13), there have been no reports of its use to train medical/biomedical scientists. In this study, we report on the development and incorporation of two simulation scenarios into a second-year medical science subject (Human Pathophysiology) at a large metropolitan university in an attempt to promote a greater understanding of the underlying pathophysiology as well as provide a means to support the development of desired graduate attributes, including communication skills, teamwork, leadership, and decision making.

METHODS

The present study was carried out in the spring semester (August to early November) of 3 consecutive years from 2011 to 2013 at the Faculty of Science, University of Technology Sydney (Sydney, NSW, Australia). Subjects comprised in total 433 students (100 students in 2011, 158 students in 2012, and 175 students in 2013) in their second year of the Bachelor of Medical or Biomedical Science programs participating in laboratory sessions in the Human Pathophysiology course. The particular session described in this study took place in the clinical simulation laboratories in the Faculty of Health, University of Technology Sydney.

Course Structure

The course consists of three 1-h lectures and a 2-h practical class each week. Different patient scenarios were used in each practical class to facilitate transfer of the theory learned during the face-to-face lecture into practice. In addition, students were exposed to requisite skill training on laboratory diagnostic methods.

The simulation practical classes used both a flipped learning (preclass self-study) and a problem-based learning (PBL) approach. Students were provided with case notes and questions, which required them to find the answers before the laboratory class. The questions consisted of the following aspects:

1. What aspects of this case do you wish to focus on?
2. Which examinations will you carry out on the patient immediately?
3. Given the patient’s history, what other conditions could account for his presentation?
4. Discuss the measures that need to be taken to limit the extent of the condition.

5. List the measures that you would advise the patient to take to reduce the progression of the current disease.

Each of the two simulation practical classes focused on two different organ systems: the cardiovascular and gastrointestinal systems. The first simulation scenario was based on an elderly patient who experienced a myocardial infarction, whereas the second scenario was that of a younger patient with a sudden haemorrhage due to a duodenal ulcer. To enhance authenticity and context, the patient cases were deliberately based on real hospital cases. Activities included taking a medical history, performing a physical examination, and performing medical treatments (e.g., sublingual administration of a drug and delivery of oxygen via a face mask). Before each simulation experience, the students were taught, during a face-to-face lecture, the principles underlying the diseases, including etiology, causes, symptoms, diagnosis, and treatments.

In each 2-h practical class, there was a maximum of 40 students. We divided the students into four subgroups (subgroups 1–4) with a maximum 10 students in each subgroup. The 2-h class was divided into two 1-h simulation sessions, and each student only attended one session. The simulation session comprised two parts (see Table 1): half of the student group (n = 10) rehearsed physical assessment skills on each other and on lower-fidelity manikins and the other half of the student group (n = 10) engaged in a facilitated simulation scenario with a high-fidelity manikin. Due to their nonhealth professional major, there were always a couple of students in each group who only wanted to observe the other students performing examinations on the manikin but who could still benefit from vicarious learning in seeing the disease state or process “come alive” through the simulation scenario. Scheduling smaller group experiences was a deliberate strategy to increase the engagement and interaction of students within the simulation experience. Due to the large overall student numbers, sessions were repeated 11 times over the day (see Table 1).

At the commencement of the simulation scenario, the demonstrator (science laboratory tutor) read out the patient history, clinical symptoms, and vital signs as given in the practical manual. Students were then given the opportunity to interact with the manikin to elicit a more detailed patient history. To have real-time conversations with the students and increase the fidelity of the experience, the voice of the manikin was provided by an academic staff member or a specially trained nursing student. This element of the learning experience facilitated two-way conversations between the “patient” and students to encourage the engagement of every student. Next, a physical examination (including blood pressure, heart and lung sounds, and radial pulse) of the manikin was performed. Subsequently, students worked together to come up with suggestions regarding additional tests that could be undertaken, a provisional diagnosis, and treatment strategies. Students then implemented some simple treatments. The session ended with the students being asked by the demonstrator additional questions related to a differential diagnosis during a preliminary debriefing. A more comprehensive debrief session was carried out in the following week when, after a period of reflection, students could discuss questions or concerns arising from the simulation experience with the demonstrators and review the preparatory patient case questions.

In talking with the manikin, taking a medical history, and performing a physical examination and patient treatments, students were role-playing health professionals, and, in these roles, they were taught how to read the patient monitors and interpret vital signs. Guidance was provided throughout the simulation scenario by the demonstrators and through responses via the manikin.

Study Design and Materials

At the end of the second simulation class, students were asked to participate in an anonymous questionnaire about their experiences with this renewed approach to learning. Student feedback was collected from 2011 to 2013. A bespoke survey was created, reviewed, and trialed by the authors to evaluate this innovation as there was a lack of suitable tools in the published literature specific to this context. The questionnaire consisted of 12 statements, and students were asked to rank each statement on a five-point Likert scale from “strongly disagree” to “strongly agree.” The statements addressed whether students felt the simulation experience had benefited their learning. Some qualitative data were also collected. Specifically, open-ended questions were included that allowed students to comment on how they felt the simulation experience had contributed to their learning compared with a paper-based study. Additional measures of the impact of the simulation on learning were sourced from students’ aggregated subject grades (marks). The student survey was anonymous and voluntary; hence, the evaluation was judged to be of negligible risk to the survey participants. This study was an approved activity within a peer-reviewed Teaching and Learning (T&L) grant sponsored by the university’s Deputy Vice Chancellor T&L and Associate Dean of T&L, Faculty of Science. Using students’ aggregated grades (marks) was considered as “nil risk” by the Human Research Ethics Committee of the University of Technology Sydney.

The evaluation form consisted of the following statements:

1. I understand what the simulations were supposed to represent
2. Simulation helped the understanding of the diseases
3. Using simulation is a better way to improve learning compared with a paper-based case study
4. The simulations were easy to perform
5. The level and clinical aspect are proper for a science student and the tasks are within their capabilities
6. The manikin simulation is a good experience
7. I would recommend the simulation class to the peers
8. I would feel overwhelmed if the manikin deteriorated and died due to wrong diagnosis or intervention
9. The simulations were a waste of time
10. Having more than one simulation class during the semester would be good for the learning experience
11. The simulation gave me some idea of a hospital setting
12. Although I may not become a health professional in the future, the simulation is a good experience

The question clusters and related aspects of the student experience tested in this evaluation are shown in Table 2.

Table 2. Question clusters and related aspects of the student experience tested

<table>
<thead>
<tr>
<th>Question Clusters</th>
<th>Related Areas of Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questions 1–3</td>
<td>Understanding of theory</td>
</tr>
<tr>
<td>Questions 4, 5, and 7–9</td>
<td>Comfort level with simulation</td>
</tr>
<tr>
<td>Question 11</td>
<td>Idea of hospital setting</td>
</tr>
<tr>
<td>Question 6, 9, and 12</td>
<td>Enjoyment and approval of the simulations</td>
</tr>
<tr>
<td>Question 7, 10, and 12</td>
<td>Approval level of how the simulations are incorporated into the course</td>
</tr>
<tr>
<td>Questions 3 and 10</td>
<td>Offers some idea of the impact of this new initiative for ongoing use and integration into the curricula</td>
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</tbody>
</table>
Case Scenarios

Two simulation scenarios were developed based on expected physiological changes during each scenario: an elderly patient who experienced a myocardial infarction (cardiovascular system) and a young patient with upper gastric bleeding due to a duodenal ulcer (gastrointestinal system).

Case scenario 1. Details about the patient who experienced a myocardial infarction included the following:

Mr M.H. is a 60-yr-old man who presents to the Emergency Department with his wife. He has a 2-h history of chest pain, nausea, and vomiting. He took two tablets of Panadol (name of a popular brand of paracetamol) at home, which did not help. His past medical history includes type 2 diabetes (treated with rosiglitazone), reflux esophagitis (treated with antacids), and rheumatoid arthritis (treated with piroxicam, a drug that possesses anti-inflammatory properties similar to aspirin). Social history includes moderate alcohol consumption (40–60 g/day) and cigarette smoking (20 cigarettes/day for the past 35 yr). M.H. works as a journalist for a daily newspaper. On examination, the patient is 70 kg with 170 cm in height. He is in considerable distress, clutching his chest with a clenched fist. He is sweating profusely and breathing rapidly. High-flow oxygen is immediately delivered by face mask.

Within this scenario, students engaged in using an ECG to diagnose a myocardial infarction and assessed and interviewed the “patient” to determine relevant signs and symptoms. In addition to the physical parameters, students engaged in dialogue with the “patient” to determine the severity of the pain and reactions to immediate treatment strategies (anginine, oxygen, and morphine). Appreciation of the timelines in relieving chest pain to minimize damage to the heart was a key learning outcome for students that was intended to be made more overt through the simulation experience.

Case scenario 2. Details about the patient with upper gastric hemorrhage included the following:

Your patient, Sam, is a hard-working science PhD student at the University of Technology Sydney. This afternoon, Sam had his second sushi roll when he suddenly had severe upper abdominal pain and vomited his food up. He immediately felt dizzy and had cold sweats. He lost balance when he tried to stand up. His supervisor was informed immediately and arranged a taxi to take him to the hospital. Sam told the triage nurse that he felt uncomfortable in the stomach (mild blunt pain) before lunch. He thought that it was only because he was hungry. He has been having this problem for a while, which was always relieved by food. He only had some water since he arrived at the Emergency Department and vomited a couple of times since admission. He had no significant health problems in the past. The triage nurse did a quick abdominal examination on him, suggesting no abdominal muscle guarding but pain in the middle upper abdominal area. The nurse passed the information to you when you took over caring for Sam. You observed that Sam is a tall and thin young guy, who is in a supine position in bed. He is very pale and looks anxious due to the abdominal pain. He could answer some questions but does not look focused. You could see the vomitus in the container next to his bed.

A bowl on the bedside table contained moulaged coffee ground vomit, which accurately depicted the vomit visually and by odor. This enabled students to chemically test for the presence of traces of blood. To make Sam’s case more engaging, we programmed physiological changes in the manikin that represented a significant amount of active blood loss due to increased internal bleeding, where blood pressure drops and heart and respiratory rates increased accordingly. Students were required to recognize this sudden life-threatening deterioration and provide emergency treatment strategies that could save the patient’s life. Once treatments were implemented the students were able to visualize improvements in Sam’s vital signs (blood pressure, heart and respiratory rates).

Staff Training

Before each practical class, members of the research team ran workshops for all demonstrators. During the workshops, the demonstrators were briefed on simulation learning objectives and were given the opportunity to prerun the scenarios. The learning objectives included 1) to understand the physiological regulation of heart rate, blood pressure, and breathing rate; 2) to identify the cause, developmental process, and consequences of the presenting disease; 3) to recognize the classical symptoms of the emergency situation within the case context; 4) to perform the essential examinations to diagnose the specific disease; 5) to gain knowledge of the principles underlying the medical treatment for this emergency; and 6) to master the skills to perform blood pressure, pulse, and ECG measurements on each other.

From 2012, second- and third-year undergraduate nursing students who had the prerequisite level of medical knowledge and clinical experience were employed to be the voice of the “patients.” Mentored by a team member, nursing students communicated with the science students via the manikins from a control room (with one-way glass). These “patients” engaged the science students in conversations and, through their advanced nursing and medical knowledge, were able to relate to the case and quickly prompt the participants as required. Questions from the “patients” were predetermined but personalized according to the personality of the individual role player. Impromptu dialogue was possible dependent on the interactions with the “patient” by the science students.

Data Analysis

Each questionnaire response was tallied to determine the extent to which the science students agreed or disagreed with each statement in each year group. This number was converted into a percentage of the total number of students in the year group to allow for comparison between year groups. The consensus of each statement was compared between the three cohorts from each year to determine consistencies and trends over time. Free text comments were analyzed using a qualitative thematic approach.

RESULTS

Student Feedback on the Learning Experience

The results of the evaluation are shown in Table 3. Response rates for each year were 53.2% in 2011, 89.8% in 2012, and 76.1% in 2013. Among the different student cohorts, there was overwhelming support for the simulations as a means of achieving a better understanding of the pathophysiology taught in the lectures. Students felt that the simulations were easy to undertake, and they welcomed a greater use of technology in the course. They also strongly expressed that the simulation provided them with an experience akin to working as a health professional. One unexpected result was that across the years of the study the cohorts were fairly evenly divided regarding their concern for the “patient” (cf. responses over the 3 yr for question 8).

Free text responses from students were mostly positive and constructive. Of the students who provided comments, which was <40%, responses ranged from a few words to complete sentences (24 responses in 2011, 48 responses in 2012, and 51 responses in 2013). The nature of these comments differed between years, however, words and phrases including “help-
ful,” “enjoyable,” “helped me to understand the concepts,” and good “experience” were common. Another common theme among student comments related to a sense that the simulations enhanced their learning by embedding the teaching in an authentic setting:

It makes the process of learning more interesting and engaging, really does capture a ‘real-life experience’ as in a hospital setting.

It demonstrated how theoretical knowledge is applied in a hospital setting.

I think they help by putting you in a real situation with patients. It’s very interesting since you usually don’t get the opportunity to work with manikins, and it is very exciting. I’d rather more simulation classes than theoretical classes.

I find it easier to learn/retain information from practical sessions. Definitely makes it more fun.

Provision of lectures and prelaboratory questions followed by the simulation session was judged to represent a flipped learning approach, which was recognized by the students.

It was really good to be able to apply knowledge instead of just remembering as assortment of facts. I can remember things like normal heart rate, blood pressure, etc., off by heart now.

Was really beneficial to apply the knowledge I had gained in lectures to physical/practical experience.

In addition to application of discipline knowledge, it was thought that the simulations would also contribute to development of communication skills both between students as well as with the “patient.” Notable comments from the students in relation to this aspect included:

We learnt how to interact with a patient and how to obtain patient history by asking the patient questions.

What texts are important when a patient is brought into a hospital? [The simulation offers] an idea of what questions to ask a patient. And the symptoms that are vital for a hospital? [The simulation offers] an idea of what questions to ask a patient.

Part of my focus throughout the day was prompting responses from those who were less inclined to be involved.

I found that my role in them changed a lot between the first and second sessions - I was able to stand back and observe the students rather than feeling like I was there to guide the session.

Learning Outcomes

We reviewed the mark distribution in 2010 (before the simulation practical class was implemented) and for the study period of 2011–2013 (Fig. 1). The results indicated a significant shift from a pass grade (50–64) toward higher grades and mark ranges (75–84 and >85) when we compared time period of 2010 with 2011–2013. In 2010, nearly 50% students were in the pass range (50–64), whereas only two students achieved an overall score of >85. This may reflect the difficulties for science students to understand the concept of pathophysiology through the teaching and learning strategies in place at that time. In 2011–2013, the marks moved toward a bell curve distribution with double the rate of students attaining a distinction grade (75–84) and a higher number of students in the high distinction category (>85). On the lower end of the distribution, the fail rate was also halved in period of 2011–2013 compared with the results in 2010. The distribution of marks and grades was relatively consistent across the period of 2011–2013.

Feedback in the form of e-mails from the demonstrators suggested an increased level of student’s engagement as well”

The sessions were guided well by the students who were most comfortable with engaging.

Part of my focus throughout the day was prompting responses from those who were less inclined to be involved.

I found that my role in them changed a lot between the first and second sessions - I was able to stand back and observe the students rather than feeling like I was there to guide the session.

I liked using the nursing manikins in this subject and that learning environment of the demonstrator shooting questions at students. It made me prepare and learn material before the demonstration, which makes me a better student.

Demonstrators really helpful, answered questions and allowed plenty of time to learn.

Demonstrator Feedback on Student Learning

Table 3. Summary of simulation evaluation items between 2011 and 2013

<table>
<thead>
<tr>
<th>Item</th>
<th>Student Opinions</th>
<th>2011, m(%)</th>
<th>2012, m(%)</th>
<th>2013, m(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I understand what the simulations were supposed to represent</td>
<td>Agree/strongly agree</td>
<td>89 (89)</td>
<td>150 (95)</td>
<td>156 (89)</td>
</tr>
<tr>
<td>2. Simulation helped the understanding of the diseases</td>
<td>Agree/strongly agree</td>
<td>96 (96)</td>
<td>155 (98)</td>
<td>158 (90)</td>
</tr>
<tr>
<td>3. Using simulation is a better way to improve learning</td>
<td>Agree/strongly agree</td>
<td>97 (97)</td>
<td>155 (98)</td>
<td>166 (95)</td>
</tr>
<tr>
<td>compared with a paper-based case study</td>
<td>Agree/strongly agree</td>
<td>85 (85)</td>
<td>150 (95)</td>
<td>147 (84)</td>
</tr>
<tr>
<td>4. The simulations were easy to perform</td>
<td>Agree/strongly agree</td>
<td>87 (87)</td>
<td>150 (95)</td>
<td>158 (90)</td>
</tr>
<tr>
<td>5. The level and clinical aspect are proper for a science student</td>
<td>Agree/strongly agree</td>
<td>85 (85)</td>
<td>150 (95)</td>
<td>147 (84)</td>
</tr>
<tr>
<td>and the tasks are within their capabilities</td>
<td>Agree/strongly agree</td>
<td>87 (87)</td>
<td>150 (95)</td>
<td>158 (90)</td>
</tr>
<tr>
<td>6. The manikin simulation is a good experience</td>
<td>Agree/strongly agree</td>
<td>100 (100)</td>
<td>149 (94)</td>
<td>154 (88)</td>
</tr>
<tr>
<td>7. I would recommend the simulation class to the peers</td>
<td>Agree/strongly agree</td>
<td>95 (95)</td>
<td>134 (89)</td>
<td>158 (90)</td>
</tr>
<tr>
<td>8. I would feel overwhelmed if the manikin deteriorated and died</td>
<td>Disagree/strongly disagree</td>
<td>49 (49)</td>
<td>88 (56)</td>
<td>75 (43)</td>
</tr>
<tr>
<td>due to wrong diagnosis or intervention</td>
<td>Disagree/strongly disagree</td>
<td>95 (95)</td>
<td>149 (94)</td>
<td>161 (92)</td>
</tr>
<tr>
<td>9. Simulations were a waste of time</td>
<td>Agree/strongly agree</td>
<td>85 (85)</td>
<td>131 (83)</td>
<td>159 (91)</td>
</tr>
<tr>
<td>10. Having more than one simulation class during the semester</td>
<td>Agree/strongly agree</td>
<td>95 (95)</td>
<td>152 (96)</td>
<td>158 (90)</td>
</tr>
<tr>
<td>would be good for the learning experience</td>
<td>Agree/strongly agree</td>
<td>100 (100)</td>
<td>156 (99)</td>
<td>154 (88)</td>
</tr>
<tr>
<td>11. The simulation gave me some idea of a hospital setting</td>
<td>Agree/strongly agree</td>
<td>95 (95)</td>
<td>152 (96)</td>
<td>158 (90)</td>
</tr>
<tr>
<td>12. Although I may not become a health professional in the future,</td>
<td>Agree/strongly agree</td>
<td>100 (100)</td>
<td>156 (99)</td>
<td>154 (88)</td>
</tr>
<tr>
<td>the simulation is a good experience</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

n = 100 students in 2011, 158 students in 2012, and 175 students in 2013.
and during the simulation pilot phase (2011–2013). Fig. 1. Students’ aggregated mark distribution and mark range before (2010)

"patient," students were able to respond verbally and through experience within the scenario. In communicating with the students could appreciate the hospital environment and patient laboratories, which are modeled on hospital wards, and thus students were delivered within the Faculty of Health simulation labo-

ratories, which were modeled on hospital wards, and thus students were delivered within the Faculty of Health simulation labo-

nors and by interacting with the “patient.” These sessions were delivered within the Faculty of Health simulation laboratories, which are modeled on hospital wards, and thus students could appreciate the hospital environment and patient experience within the scenario. In communicating with the “patient,” students were able to respond verbally and through touch, additionally appreciating the “patient’s” experience of being ill in hospital. Before this approach, students were traditionally trained to identify pathological conditions by reading through printed text in a manual, thus relying heavily on their imagination, which is difficult for someone who has never dealt with a patient in the context of a health professional. It was felt that the latter approach favored a surface approach to learning by students simply memorising the information without adequate context.

Simulations are problem-based tools thought to encourage students to learn through responding to immediate situations, providing a practical alternative to paper-based case studies. This PBL approach is believed to increase students’ knowledge efficiently and to assist in developing problem-solving skills (2, 5, 14). The increasing sophistication of the manikins enables students to perform all manner of clinical procedures. Through practicing physiological assessment (taking pulses and blood pressure) on each other or the manikins, students assumed health professional roles. Bedside monitors, oxygen masks, intravenous fluids, and additional moulage, e.g., “coffee ground vomit,” contributed to the authenticity of the patient scenarios. During the simulation scenario representing the stomach bleed with the “patient” feeling dizzy and sick, appropriate vocalizations and sounds were emitted from the manikin, and students responded by frantically offering a vomit bag.

In students having more than one simulation session, there was more opportunity to reinforce the importance of so-called “soft skills” such as leadership, teamwork, professional skills, problem solving and decision making, and caring for people in vulnerable situations. In the first sim-

ulation class, the demonstrators played a critical role in the briefing process and orientation to the environment and facilitating a change in approach to learning. Rather than students passively being questioned by the demonstrators, the shift in expectation was to active inquiry and physical examinations on the patients to obtain useful information relevant to the situation at hand. As such, at the commence-

ment of the second simulation class, demonstrators only gave a brief introduction of the “patient” and reasons for coming to hospital. One student in each group took over the leadership role to perform further verbal inquiry and led discussions with the other team members. Active discussion undertaken in response to a clinical problem between the students facilitated by the demonstrators encouraged critical thinking for problem solving (7). This contrasted with the predominant didactic delivery of conventional lectures, which only allows limited interactions between the teacher and students, while any opportunity for group discussions is equally difficult (2). Thus, a PBL approach within simulation practical classes focuses learning through hands on application, connecting students’ theoretical knowledge with opportunities to develop contextually relevant problem-solving skills (2, 14).

Such learning experiences can also promote a better understanding of the knowledge behind the case study, which is reflected by the significant shift in students’ marks distributions from a predominance of pass grades toward distinction and high distinction grades. There is likely some influence on these changes due to implementing the simulation strategies, that is, using an authentic setting where students were able to apply existing knowledge in “real-life”

<table>
<thead>
<tr>
<th>Mark range</th>
<th>2010 (n)</th>
<th>2011 (n)</th>
<th>2012 (n)</th>
<th>2013 (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;50</td>
<td>18</td>
<td>9</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>50-64</td>
<td>107</td>
<td>53</td>
<td>58</td>
<td>80</td>
</tr>
<tr>
<td>65-74</td>
<td>27</td>
<td>50</td>
<td>39</td>
<td>57</td>
</tr>
<tr>
<td>75-84</td>
<td>65</td>
<td>66</td>
<td>56</td>
<td>68</td>
</tr>
<tr>
<td>85-100</td>
<td>2</td>
<td>9</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Total enrolment</td>
<td>219</td>
<td>187</td>
<td>176</td>
<td>230</td>
</tr>
</tbody>
</table>

Fig. 1. Students’ aggregated mark distribution and mark range before (2010) and during the simulation pilot phase (2011–2013).

DISCUSSION

This study reports on the experiences and success of using simulation in motivating and encouraging science students to learn about human diseases. This has not been previously reported in the literature.

Simulation as a training strategy has been used within health, aviation, and military contexts for decades. Adoption of more simulation activities within health care has been influ-

enced by advances in the technological capabilities of manikins and driven by patient safety agendas (4, 9, 12, 13). When planned and delivered appropriately, participant engagement, learning, and reflection on practice are heightened more so than in traditional learning formats. At a minimum, the contextual nature of a scenario experienced within lifelike settings allows participants to act out what they know and learn from errors without consequences to the “patient,” in essence enabling experiential learning within a community of practice (9). Ben-

efits for future practice include learning how to work in teams, awareness of effective communication strategies, and appreci-

ating the holism of practice (9, 11).

The successful use and incorporation of a range of simulation strategies within the training of health professions encouraged us to examine how the patient cases used to teach pathophysiology to science students could “come alive” in the simulation laboratories. Students prepared for the session through lecture and online content and then in groups stepped through the patient cases guided by the science-trained demonstra-

pers and by interacting with the “patient.” These sessions were delivered within the Faculty of Health simulation laboratories, which are modeled on hospital wards, and thus students could appreciate the hospital environment and patient experience within the scenario. In communicating with the “patient,” students were able to respond verbally and through touch, additionally appreciating the “patient’s” experience of

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situations. Note that participants were all undergraduate science students who, in general, were less likely to be motivated to learn medical knowledge compared with medical students. Therefore, we believe that simulation is an effective approach in motivating science students to learn the different concepts of human diseases.

This novel approach also induced a significant role change for the demonstrators to one facilitating learning as students took on more active roles, with the demonstrators only giving advice or direction as required. Coaching and modeling were techniques used by the simulation team to assist demonstrators to deliver inquiry-based and experiential learning modes within the simulations rather than didactic approaches. Refresher on these techniques have been provided each year to ensure an equitable student experience across classes.

PBL is typified as a time-efficient and, thus, more effective educational model (7). However, the introduction of a PBL-style simulation with a “patient” is not without its difficulties. For example, teaching PBL to large groups of students (>100) is constrained by timetables and the availability of laboratory spaces (14). In addition, PBL is resource intensive in terms of staff and time spent teaching (2). In the case of the current approach, there is the additional demand for access to high-fidelity manikins to make the experience as authentic as possible. Training sessions provided to the demonstrators as well as to the academic staff/nursing students who played the manikin voice before the class were also essential. In the face of these challenges, we have successfully engaged >200 students in simulation sessions in 1 day. This suggests that simulation is scalable and able to be implemented in the study of the physiology of disease despite challenges in rigid time-tableing and resources to maximize student interactions. However, it is still worth noting that a gap exists between the reality and simulation laboratory experience regardless of how authentic it is. This is reflected by question 8 (“what if the ‘patient’ deteriorates due to wrong medical decision?”), where only half of the students had a sense of responsibility to keep their patient “alive.”

**Limitations**

The use of questionnaires in this study provided a practical methodological tool for collecting a large sample of data. The principal limitation is that they represent a snapshot of the student experience and rely heavily on the quality of responses and researchers’ interpretations. Inclusion of Likert-style questions does, however, provide some level of objectivity. Another limitation is that these survey questions were self-reported evaluations of student learning, which offer insights but are open to bias compared with more objective measures, that is, student grades. Although an improvement in grades were seen after the introduction of this intervention, specific causations could not be attributed to the simulation approach as other aspects of learning contribute to the overall results. These potential limitations of measuring “impact” are the focus of health care simulation groups globally; furthermore, some elements of learning and practice are difficult to quantify and need to be illuminated through qualitative or mixed-methods approaches.

**Future Directions**

This initiative, to offer an authentic learning environment to improve the understanding of pathophysiological concepts by applying it in real-life scenarios, is now incorporated into ongoing curricula in Human Pathophysiology education. An authentic assessment to examine soft skill sets, such as group collaboration, communication, and decision making, will be ideal to provide further evidence on such learning outcomes.

In conclusion, we found that using interactive learning approaches (e.g., role playing, flipped learning, and inquiry-based learning) led to an enhanced student experience of learning pathophysiology compared with that of a paper-based teaching strategy. With the resources available and strategic planning and management, we were able to deliver this teaching approach consistently to a large size class over several years.

**ACKNOWLEDGMENTS**

The authors thank Theresa Tran for collecting and collating the data from the questionnaires, the nursing students from the Faculty of Health for being the “patient’s” voice, and the laboratory staff of the Faculty of Health for managing the requirements of this initiative.

**GRANTS**

This work received funding support of a small Vice-Chancellor’s Learning and Teaching Grants, University of Technology Sydney.

**DISCLOSURES**

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

**AUTHOR CONTRIBUTIONS**


**REFERENCES**


