

Learning gains in a flipped classroom to teach the principles of envenomation

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Diagnosis and management of venomous bites and stings, particularly snakebite, is important for Australian clinicians. In 2015, a flipped classroom was trialled to teach the principles of envenomation to year 1 medical students in a MD program. A bespoke online resource was developed and then used by students to prepare for a face-to-face class tailored to their learning needs. Students reported positively about learning the principles of envenomation with the online resource and found it useful. Responses from students also indicated that the interactive class was beneficial to their learning, particularly the clinical application of envenomation. These findings were supported by comparisons of pre- and post-test scores that showed significant learning gains across eight questions. The study also provided some insights into students' perception of knowledge retention and why some students may prefer to prepare individually for content attainment.

Keywords: Flipped classroom, learning gains, learning benefits, biomedical science education

Introduction

The flipped classroom is a learning model that is gaining popularity in higher education. The Flipped Learning Network (2014) provide the following definition:

“Flipped Learning is a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter”

As this definition suggests, the transmission of information that typically occurs during a traditional face-to-face lecture is moved to out of class time, freeing up in-class time for active learning. The key to the approach, therefore, is individual work by students outside of class, either to prepare for the in-class application of newly gained knowledge, or to follow up and reinforce their learning after class. This places the responsibility of preparing for class, interacting during class, or consolidating knowledge after class with the student, so the approach is considered to be student-centred (McLaughlin et al, 2014).

The in-class component of the flipped classroom is teacher facilitated and involves the implementation of active learning tasks, for example: open questions; debates; audience response to clicker questions; quizzes; role-play; student presentations; and discussions (DeLozier & Rhodes, 2016). Many of these activities can be either implemented as individual, paired or group activities. The model has been described as ‘technology infused’ because lecture recordings, video and/or online resources are often provided to support students’ individual preparation during the out-of-class phase (Jensen, Kummer & Godoy, 2015).

Although adoption of the flipped classroom model has been rapid and widespread in recent years, research into the benefits and effectiveness of the method have not kept pace with implementation. This is not surprising considering the variation present in flipped classroom implementations. As indicated above, teachers can choose from a wide range of both in-class and out-of-class activities and technologies, which can be combined and sequenced in numerous ways. Additionally, some teachers may opt to flip all of their lectures, while others might only flip a proportion resulting in a ‘partial’ flip (DeLozier & Rhodes, 2016), although there is no evidence to suggest that flipping an entire course is more beneficial than a ‘partial’ flip (O’Flaherty & Phillips, 2015).

Most studies evaluating the effectiveness of the flipped classroom model in higher education have relied on student perceptions and self-reports of learning, which have been generally positive (O’Flaherty & Phillips, 2015). Although there have been some exceptions, where students have expressed negative views towards the flipped classroom approach (see Strayer, 2012). These exceptions highlight the fact that the flipped classroom may not be suitable for all subject matter.

In recent years, the number of flipped classroom studies that report measures of student performance has been steadily increasing across a range of disciplines. In language learning, for example, a study that compared three different formats (flipped, semi flipped and control group) found increased mean scores on lesson assessments for the flipped group over the other two formats (Hung, 2014). Also, Webb and Doman (2016) found that gains on grammar achievement were significant only for a flipped classroom group in a pre- post-test quasi-experimental mixed methods study. Studies on attainment are also emerging from the science disciplines. For example, recent longitudinal studies in chemistry have shown a reduction in Ds, Fs, withdrawal and failure rates, together with increases in student grade point averages and improvements in student scores, for flipped classroom groups (Fautch, 2015; Flynn, 2015). Weaver and Sturtevant (2015) were able to show a statistically significant increase in standardised exam scores for students in flipped classrooms compared with the prior lecture-based course in general chemistry.

These studies indicate that while the framework of the flipped classroom is reasonably solid, how learning gains are actually realised in a flipped classroom remains unclear. Research by Gross, Pietri, Anderson, Moyano-Camihort and Graham (2015) suggest that it may in part be due to students interacting with course material in a more timely and accurate manner. Another study by Jensen, Kummer and Godoy (2015), which compared an active flipped classroom with an active non-flipped classroom while only varying the role of the instructor, suggests that it may be the active learning that is implemented along side the flipped classroom that causes the positive effect on student performance, rather than the order in which the instructor participates in the process. For example, the study demonstrated equivalent student learning outcomes regardless of whether the instructor facilitated content attainment during class and then students performed individual concept application after class, or inversely, students engaged in individual content attainment before class and then the instructor facilitated concept application during class.

That other research has shown that the effect of flipped classrooms is more pronounced for the bottom third of students (measured by pre-test score or percentile rank) (Ryan & Reid, 2016) and those with lower grade point averages (Gross et al, 2015), points to the fact that there is still much to be learnt about the intricacies of implementing flipped classrooms, particularly if the desired outcomes for students are improved learning gains and attitudes towards learning.

Teaching the principles of envenomation

Envenomation is the introduction of venom into a body by means of the bite or sting of a venomous animal, for example, snake, spider, jellyfish, octopus, tick or platypus. Diagnosis and management of venomous bites and stings, particularly snakebite, is important for Australian clinicians working in rural and tropical locations, and increasingly for doctors practicing in urban fringes where wetlands and ‘green wedges’ have brought people into close proximity with snakes.

An understanding of the principles of envenomation brings together elements from several biomedical and bioscience disciplines, including, biochemistry (mechanism of toxin action), physiology (signs that characterise toxin responses), pharmacology (mechanism of antivenom action) and zoology (creature identification), placing them in a clinical context. This means that the topic doesn’t neatly fit into the teaching streams that are typical of first year graduate medicine curricula.

Our university’s Doctor of Medicine (MD) program, is a full-time, masters level course delivered over four years. The first year of the MD curriculum is designed to consolidate students’ biomedical science knowledge and prepare them for clinical placement. The former is achieved through a year-long subject *Foundations of Biomedical Sciences* (FBS). This subject utilises a mix of bioscience lectures, clinical cases and practical classes, and is organised around a series of teaching streams: Foundation, Cardiovascular; Respiratory; Gastrointestinal; Renal; Neuroscience; Endocrine; Metabolism; Locomotor; Exercise; Reproduction; and Intersystems. The bioscience lectures delivered in FBS generally follow a traditional face-to-face lecture format - to our knowledge there have been no flipped classrooms implemented across the teaching streams.

Principles of envenomation is taught during the *Intersystems* stream – this is the last teaching stream of the year finishing just prior to swat vac. *Intersystems* is designed to revise many key issues introduced in earlier streams, as well as introducing students to issues they will face in their clinical years. Students attend a two-hour ‘practical’ on the principles of envenomation where information is delivered in a traditional didactic style supported by a PowerPoint presentation; it has no ‘wet’ laboratory component.

Given the timing of the teaching stream, and its aim to introduce clinical issues, the content expert teaching the topic (who is both an academic and clinician) expressed an interest in moving away from the traditional style of delivery towards one that:

- reinforced the clinical differential diagnosis process;
- demonstrated the clinical relevance (and case-based nature) of the topic;
- incorporated active learning strategies for students;
- made the learning process more engaging for students; and
- could potentially improve student performance.

For these reasons, we decided to trial a flipped classroom to teach the principles of envenomation to year 1 MD students. This paper describes: the design and development of an online resource to support students' preparation for the class; the implementation of the flipped classroom approach; and evaluation findings that demonstrate learning gains made by students together with their perceptions of the flipped classroom as a useful learning experience

Methods

The project was conducted in three phases: Development of an online resource, Implementation of the flipped classroom, and Evaluation. Each of these phases is described below. A mixed methods design was used to evaluate the flipped classroom model (Creswell, 2014), which involved three data collection methods:

1. a questionnaire to provide a quantitative measure of students' perspectives of the online resource and interactive session for learning,
2. open-ended items to provide a qualitative measure of students' perspectives of the online resource and interactive session for learning, and
3. Pre- and post-tests to measure student learning gains.

The study proceeded with approval from the host university's human research ethics committee.

Developing an online resource

An online resource was developed to help students prepare for the face-to-face component of the flipped classroom. The resource was designed to help students build a differential diagnosis framework and to develop basic management plans for the diagnosis and treatment of venomous bites and stings. Specifically, on completion of the resource students were expected to be able to: identify the key presenting features of a venomous bite or sting in Australia; utilise appropriate management principles in such a presentation, with special reference to snakebite; understand the mechanism of action of venom in the human body; and understand the values and limitations of antivenom in the treatment of venomous bites or stings in Australia but with special reference to snakebite.

The resource was designed around a case study of a 50 year old farmer who is brought into hospital unconscious one summer afternoon. Students are guided through a series of menu options – History, Investigations, Physical examination, and Creature identification - to gather further information for a provisional diagnosis. As students continue through the resource they are provided with information about:

- Snakebite first aid;
- Snake venom effects (neurotoxicity, myotoxicity, renal function, necrosis, coagulopathy);
- Antivenom (how it's made, how it works, risks, when to use it);
- The dynamic nature of snakebite;
- Risks after discharge; and
- Additional resources and readings.

As students progress through these sections they encounter questions they are expected to answer that are related to topics they have been studying. Learning tasks were supported by a variety of media, including, videos, images, animations, and an interactive timeline. The resource was designed to take one hour to complete.

The resource was developed using an iterative development process on Smart Sparrow's adaptive eLearning Platform (<https://www.smartsparrow.com/>). It was created as part of the Biomedical, Education, Skills and Training (BEST) Network - a community of university academics who collaborate to create and share online resources for biomedical science education (see <https://www.best.edu.au/>).

Implementing the Flipped Classroom

The year 1 MD cohort (n=367) was divided into three groups of approximately 122 students each, and three classes were scheduled over a two-week time period towards the end of second semester 2015. Prior to their class, students were informed about the flipped classroom and were provided with general information about the model and its benefits for learning. Although the students had not been exposed to the flipped classroom model in the MD, since it is a graduate program some students may have had prior experience with flipped classrooms in their undergraduate studies. Students were also informed of the content expert's expectations that they should prepare for the face-to-face class by completing the online resource. Students were also given instructions on accessing the resource. Depending on when their class was scheduled, students had between one to two weeks in which to complete the one-hour online resource.

The resource began with a pre-test of eight questions to gauge students' prior understanding of the topic. This task was designed to help students prepare for the face-to-face class and therefore students were allowed multiple attempts. On the day before a class, students' electronic scores were extracted from the learning platform and analysed to determine the percentage of students obtaining a correct answer to each question. The data from all attempts was included in this analysis. This feedback was used by the content expert to inform the focus of class activities on the following day.

Face-to-face classes were 1.5 hours long and were held in a 126 capacity lecture theatre. They followed a Q&A format, which centered around discussions of real-life clinical scenarios of snakebite.

Evaluation

Immediately after the face-to-face class students were administered a paper-based post-test composed of the same eight questions that they had encountered at the beginning of the online resource. Post-tests were manually scored to determine the percentage of students obtaining a correct answer for each question.

After the face-to-face class, a questionnaire was also administered to students, which asked them to rate on five point Likert scales (1 strongly disagree, 5 strongly agree) their response to six items about the online resource:

1. Improved my venomous bites and sting-related knowledge;
2. Taught me to be mindful of diagnostic uncertainty in a clinical context;
3. Taught me strategies to improve my diagnostic framework for possible venomous bites;
4. Taught me about snakebite first aid;
5. Was interesting;
6. Will assist my preparation for clinical practice.

And eight items about the flipped classroom:

1. The interactive class was useful for learning about the clinical relevance of envenomation;
2. The interactive class was beneficial to my learning;
3. The interactive class clarified questions I had about envenomation diagnosis and management;
4. I was able to contribute to the interactive class.
5. Preparing for class in my own time was beneficial to my learning;
6. I had sufficient time to prepare for the class;
7. The online resource was useful in preparing for the class;
8. I prefer the combination of prior online learning with an interactive class to the standard lecture format;

The questionnaire ended with two open-ended items:

1. Please describe the most useful aspects of the flipped classroom approach
2. Please describe anything that you feel would improve the flipped classroom approach

Simple descriptive stats were used to analyse students' responses to questionnaire items. Responses to the open-ended items were manually analysed by one researcher (KE) to identify emerging themes (Krippendorff, 2004) and cross-checked by the second researcher (KW). The frequency of themes was calculated as a percentage of total number of comments, and selected quotes have been used to illustrate key themes identified.

Results

The majority of students came prepared to the face-to-face class with 308 (84%) students having completed the entire resource beforehand, taking a medium time of 39 minutes.

Pre- Post-tests

259 students (71%) completed the paper-based post-test immediately after the face-to-face class. When the scores of the post-test were compared to pre-test scores extracted from the learning platform, learning gains were seen across all eight questions (Figure 1). The greatest learning gains were observed in questions where specific knowledge was required to answer them, for example: Q2- Clinical investigations (11% correct pre-test, 65% post-test); Q3- Creature identification (23% correct pre-test, 94% post-test); Q5- Management of envenomation presentations (8% correct pre-test, 62% post-test); and Q8- Antivenom (16% correct pre-test, 82% post-test).

Moderate learning gains were seen in questions where some students may have had prior knowledge gained elsewhere in the course, for example: Q1- Differential diagnosis (41% correct pre-test, 82% post-test) - students have a general understanding of this concept from their case-based learning tutorials; Q4- First aid (63% correct pre-test, 96% post-test) and Q6- Bite site (73% correct pre-test, 93% post-test) – some students may have covered basic snakebite information in their first aid training. While learning gains were observed for Q7- Neurotoxicity, students generally performed poorly on this question (0.5% correct pre-test, 19% post-test), suggesting it was either a particularly difficult topic for students to grasp, or the design of the question was poor.

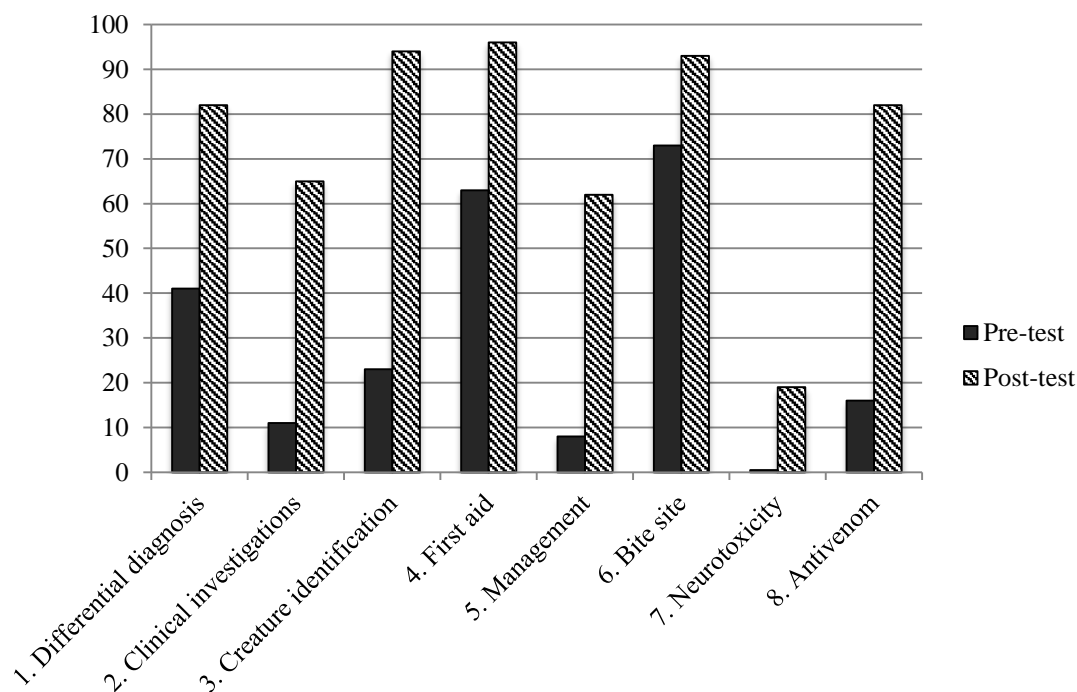


Figure 1: Percentage of students obtaining a correct answer to eight questions on the pre- and post-test

Pearson's chi squared and Cramer's V tests were performed on the pre- post-test data, which showed that the learning gains across all eight questions were significant at $p < .001$, and that the strength of the effect was moderately to extremely strong (see Table 1).

Table 1: The significance and strength of the effect of learning gains across eight questions on the pre- and post-test

	Pre-test		Post-test		$\chi^2 (1)$	Cramer's V§
	n*	%	n	%		
Q1. Differential diagnosis	466	41	259	82	114.8†	.40
Q 2. Clinical investigations	452	11	259	65	231.7†	.57
Q 3. Creature identification	446	23	259	94	335.7†	.69
Q 4. First aid	440	63	259	96	98.3†	.38
Q 5. Management	436	8	259	62	240.6†	.59
Q 6. Bite site	434	73	259	93	42.8†	.25
Q 7. Neurotoxicity	425	0.5	259	19	77.5†	.34
Q 8. Antivenom	422	16	259	82	281.1†	.64

* This includes multiple attempts by some students on the pre-test

† p<.001

§ Effect strength: very weak (.00-.15), moderately strong (.25-.30), extremely strong (>.40)

Questionnaire responses

295 students (80%) completed the questionnaire immediately after their scheduled face-to-face class. Their responses to six items about the online resource are shown in Table 2. Students were positive about learning with the online resource, reporting that it had improved their venomous bites and sting related knowledge (mean = 4.2). Students also agreed that it had taught them: to be mindful of diagnostic uncertainty in a clinical context (mean = 4.2); strategies to improve their diagnostic framework for possible venomous bites (mean = 4.1); and snakebite first aid (mean = 4.1). It was reassuring to see that students also agreed that the resource was interesting (mean = 4.1).

Table 2: Student responses to six items about the online resource used to prepare for the flipped classroom

Online resource	Mean	SD
Improved my venomous bites and sting-related knowledge	4.2	.65
Taught me to be mindful of diagnostic uncertainty in a clinical context	4.2	.61
Taught me strategies to improve my diagnostic framework for possible venomous bites	4.1	.60
Taught me about snakebite first aid	4.1	.64
Was interesting	4.1	.70
Will assist my preparation for clinical practice	4.0	.72

Student responses to eight items about different aspects of the flipped classroom are shown in Table 3. Students reported that the interactive class was beneficial to their learning (mean = 3.9), particularly in relation to the clinical context of envenomation (mean = 4.0). However, there was only moderate agreement that they had been able to contribute to the class (mean = 3.5), or that they preferred the flipped classroom approach to the standard lecture format (mean = 3.7).

Table 3: Student responses to eight items about the flipped classroom

Flipped classroom	Mean	SD
The interactive class was useful for learning about the clinical relevance...	4.0	.78
The interactive class was beneficial to my learning	3.9	.81
The interactive class clarified questions I had	3.8	.80
I was able to contribute to the interactive class	3.5	.91
Preparing for the class in my own time was beneficial to my learning	3.8	.90
I had sufficient time to prepare for the class	3.8	.92
The online resource was useful in preparing for the class	3.9	.78
I prefer the combination of prior online learning with an interactive class to the standard lecture format.	3.7	.90

Qualitative responses

Of the 295 students who completed the questionnaire, 112 (38%) provided written feedback to the open-ended items. These students provided 109 comments on the most useful aspects of the flipped classroom, and 39 comments on how it could be improved. A thematic analysis of comments on the most useful aspects identified nine major themes: Being prepared; Flexibility; Identifying knowledge gaps; Testing knowledge; Interest; Engagement; Learning; First-aid training; and Resource features. The frequency of comments relating to each of these themes is shown in Table 4.

Table 4. The frequency of comments relating to nine major themes on the most useful aspects of the flipped classroom approach

Theme	Frequency (%)
1. Resource features	35.5
• Video	22.0
2. Flexibility	20.2
3. Interest	14.7
4. Learning	13.8
5. Testing knowledge	11.0
6. First-aid training	11.0
7. Being prepared	10.1
8. Identify knowledge gaps	10.1
9. Engagement	10.1

Students reported that it was useful knowing in advance what to expect in the face-to-face class, knowing what the important areas were and the main points, so that they were better prepared:

“I now know what to expect before going into the classroom, rather than going in with no idea what’s happening and thinking about it for the first time as I’m doing it”

“Sometimes in lectures, I find myself taking notes without really processing what’s going on and then learning the material after the class. This way I’ve been able to get a basis handle on the information and was less overwhelmed in the prac”

In preparing for the face-to-face class, students appreciated the flexibility of being able to work on the online resource at their own pace and at a time that was convenient to them:

“The ability to engage with the material at my own pace helped learn the content, which was rather foreign to me”

“Able to learn at my own pace and in my preferred time”

Students’ comments regarding the flexibility of using the online resource for preparation accounted for 20.2 % of all comments.

Students also felt that preparing prior to class allowed them to identify gaps in their knowledge, which they could repair before coming to class through information easily found in the online resource:

“Gave me a chance to see where areas of weakness were prior to starting. Also made it feel like I was actually learning things I wasn’t 100% sure on - by realising I had a lack of knowledge at the start, it made me more interested in the material”

They also commented that structuring the online resource around a quiz had allowed them to test their knowledge as they progressed through the resource, applying new information to see what they had learnt:

“Starting with the questions was really helpful because it got me interested in the topic and looking for answers as I was reading the information. I think it’s really useful to have this kind of information before going to class”

Both these processes (repairing knowledge gaps and testing knowledge) contributed to students feeling better prepared for class.

Students reported that the preparation phase of the flipped classroom had increased their interest in the topic:

“I wasn’t expecting our course this year to cover bites and stings at all, and I was pleasantly surprised that we do have a prac on it. The online resource was certainly interesting and it encouraged me to read more widely about the topic”

I was a bit hesitant with this pre-prac thing, but I have to say I found it interesting and I learnt a lot”

Nearly 15% of all comments related to students’ interest in the topic.

Enjoyment of the flipped classroom was related to the clinical application of the material, especially in the interactive class:

“I really enjoyed the clinical nature of the task – I find I am able to remember things much more easily when they are linked to a patient. I know this would have taken a fair while to put together, though it would definitely be worth having more activities like this in the course”

“I particularly enjoyed the clinical scenarios and real life examples”

The preparation phase also increased student engagement with the topic for the interactive class and had enabled greater participation:

“Allows me to think about content and any related questions for when we have contact time with an experienced tutor...rather than using that time just learning the basics and not processing it effectively until later”

“Gave me an opportunity to research as I wished and collate any questions I had”

Students commented that through preparation, everybody was at the same level and content was reinforced during the face-to-face session.

“By the time of the interactive session, I was hearing the information for the second time, so it was already like a first revision. I feel like this will definitely improve my long term retention of the information”

Students reported on various aspects of learning that the flipped classroom had supported. These comments, which represented 13.8 % of the total, were grouped under the general theme of Learning and included: active learning (rather than listening passively), critical thinking, lateral thinking, extending the learner, reinforcing content, solidify concepts, targeted learning (direct and focussed). The revision of first aid, or first aid training was another benefit of the flipped classroom that 11.0% of students commented on.

A large proportion of responses (35.5% of all comments) were related to features of the online resource that students found useful. Remarkably, 22 % of all comments specifically related to the usefulness of video – explanation of material, informative, engaging.

The thematic analysis of comments about how the flipped classroom could be improved identified four major themes: Time; Technical issues; Video; and Lecture format. The frequency of comments relating to each of these themes is shown in Table 5.

Table 5. The frequency of comments relating to four major themes about how the flipped classroom approach could be improved

Theme	Frequency (%)
1. Time	30.8
2. Technical issues	12.8
3. Video	7.7
4. Lecture format	5.1

The theme of time identified in student responses related to three different aspects: timing of the flipped classroom approach – some students felt it would have been better to implement it earlier in the year; time to complete the online resource – some students felt it was too long and took too much time to complete; and time for out of class preparation – some students felt they didn't have sufficient time to prepare. Technical issues related to glitches that some students experienced while using the online resource, for example, videos not playing, questions not registering inputted answers, or clicking the Next button and not letting you pass. Several students reported that some videos were too long, while others reported that they would have preferred a lecture format than the flipped classroom approach.

Discussion and Conclusion

Students in this study were generally positive about learning about the principles of envenomation with the online resource and found it useful for preparing for the face-to-face component of the flipped classroom. Students also reported that the interactive class was beneficial to their learning, particularly regarding the clinical application of envenomation.

While student perceptions of improved learning were supported by significant learning gains made by students from the time of the pre- to the post-test, the nature of the study means that it is difficult to identify where the learning gains originate from. For example, it is not possible to conclude if the learning gains were the result of the preparation activity, the in-class activities or a combination of the two components. It could also be argued that the use of the same questions for the post-test may have been testing students' recall from the pre-test, rather than knowledge gains, however, we were cognisant of the risk of introducing potential variation in the level of difficulty through the use of different questions. Therefore, although the findings show promise they need to be interpreted with some caution.

The qualitative responses of students regarding the usefulness of the flipped classroom provide some understanding of students' perception of the retention of their envenomation knowledge, particularly when it is linked to a clinical context – *"I am able to remember things much more easily when they are linked to a patient"*, and when information is reinforced in the face-to-face class – *"by the time of the interactive session, I was hearing the information for the second time, so it was already like a first revision. I feel like this will definitely improve my long-term retention of the information"*. This suggests that there may be components of the flipped classroom model, such as the application of the bioscience information to a clinical context, or the revision of learning that contribute to knowledge retention.

The study by Jensen, Kummer & Godoy (2015) indicate that it is the active learning implemented along with a flipped classroom that is a better predictor of increased student performance, rather than whether the instructor has facilitated content attainment or concept application during class time. However, the qualitative responses of students in this study provides insights as to why students may prefer to prepare individually for content attainment, and what the additional benefits of this preparation might be for the class as a whole. Individual benefits reported by students in the current study, included, increased interest and engagement with the topic, identification of knowledge gaps (and being able to repair them), and testing of knowledge. Benefits of preparation for the class as a whole, included, everybody being at the same level, and the consolidation of knowledge as a group – rather than doing a post-prac follow up, realising as an individual that you have questions, and not having a convenient opportunity to follow them up.

However, findings from the questionnaire data suggest that not all students felt they were able to contribute to the interactive class. On reflection, the content expert was surprised that more students didn't ask questions or come prepared with questions to the face-to-face class. There seemed to be a reluctance on the part of some students to ask questions, especially in front of the 100 plus cohort. The content expert reflected that some students had waited until after the class to ask questions one-on-one. We had intended to conduct student interviews with a group of students to tease out this behaviour, but only two students volunteered. When asked if this situation might be improved by dividing the cohort into subgroups that reported back to the larger group, one of the two interviewed students felt this would make the process more competitive, and therefore more stressful. The implementation of clicker questions that can be anonymous might provide a solution here (DeLozier & Rhodes, 2016).

Furthermore, it appears that not all students prefer the flipped classroom approach to a standard lecture format. This finding has been reported elsewhere (Jensen, Kummer & Godoy, 2015) and was confirmed by one of the two interviewed students who commented that the flipped classroom was good for some topics, but not all. This student felt that the flipped classroom was good for topics that were more intuitive, or that students had some prior knowledge of. He specifically mentioned anatomy as a subject that would not be suitable for a flipped classroom as he felt it would be too intimidating to begin learning the intricacies of, for example, the structure of the knee, without being guided as to what was important, or what to focus on. The student remarked that this initial guidance gives learners the confidence to continue with individual learning.

It is noteworthy that since this study was conducted, the FBS curriculum has been reviewed and there is a strong desire on the part of subject co-ordinators to implement more flipped classrooms across the current lecture intense teaching streams. The findings of the current study will be used in part to inform this implementation, including the initial choice of topics to target for flipping. The intention of a more systematic implementation of flipped classrooms across year 1 of the MD program, underscores the importance of providing students with explicit education about the approach – its benefits and what is expected of them. This may assist students in feeling more comfortable with the approach, particularly in relation to asking questions, thereby encouraging greater participation and learning benefits.

In summary, this study has shown that a flipped classroom model comprised of a bespoke online resource for preparation, together with an interactive classroom that utilised a Q&A format (centered around discussions of real-life clinical scenarios of snakebite), resulted in improvements in students' understanding of the principles of envenomation. However, further research is required to determine if the observed learning gains were the result of the preparation activity, the in-class activities or a combination of the two components.

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