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Promoting Learning of Biomechanical Concepts with Game-Based Activities

Editorial

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Background

Many students avoid or withdraw/drop out of science, technology, engineering and mathematics (STEM) majors (including biomechanics) due to anxiety about science and mathematics. Physics education research has documented that many students fear and dislike university physics and these negative perceptions persist even after the course is completed (Docktor & Mestre, 2014; McDermott, 1991). This parallels the anxiety and negative perception of biomechanics held by many kinesiology/sport and exercise science majors (Hamill, 2007; Wallace & Kernozek, 2017) often resulting in poor student mastery of concepts and high dropout, fail, and withdrawal rates for the course. To address this anxiety and improve their academic performance, extensive physics education research has been conducted, with large improvements in learning reported for active learning approaches compared to traditional lecture (Bao & Koenig, 2019; Beichner et al., 2007; Hake, 1998). The evidence for the greater university student engagement and effectiveness of active learning across many fields of education and science is compelling (Freeman et al., 2014; Prince, 2004; Springer et al., 1999; Driessen et al., 2020) and evidence for the efficacy and utility of specific active learning techniques has been summarised in a systematic review (McConnell et al., 2017).

Sports biomechanics scholars have consistently reported 15-48% greater mean student learning of sport and exercise biomechanics concepts with active learning approaches compared to traditional lecture alone (Knudson, 2019; Knudson & Wallace, 2019; Riskowski, 2015). There is also evidence that these benefits to learning can be obtained from both low-tech and high-tech approaches (Knudson, 2019; Knudson & Wallace, 2019; Soneral & Wyse, 2017). There is one

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area, however, where potential improvements in student engagement and learning of biomechanics has not been explored. This area is the use of game-based learning activities. Game-based learning activities are another way to provide interactive and engaging learning activities that sports science university students enrolled in biomechanics courses feel would improve their learning, especially when taught in a blended learning environment (Keogh, Gowthorp & McLean, 2017). This editorial summarises the research on game-based learning for university students and recommends university-level biomechanics educators try these methods and document their effects on improving student learning.

Game-based learning

In biomechanics, students often require the ability to integrate a number of mathematics, physics, anatomy and analytical skills to fully comprehend the concepts (Abraham et al., 2018) before they can apply this knowledge to sports. As suggested, these skills include creating and reading graphs, applying physical equations and mechanical concepts, and forming hypotheses (Riskowski, 2015). Even if a student is strong in most of these skills, if they experience even some difficulty in just one skill, their overall ability to integrate the concepts into a workable model and performance in assessments may be compromised. Utilising game-based learning during classes presents a range of options for students to work through problems, answer questions, and assess their learning during real-time lectures and presentations as well as during their self-directed study.

Game-based learning involves the use of 'serious games' in teaching and learning, where the games are primarily focused on education rather than recreation (Moro et al., 2020b). This

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practice can also be referred to as using gamification, games for good, alternative purpose games, or serious gaming, although these terms are not necessarily well-defined (Gentry et al., 2018). Game-based learning can present content and assess learning in multiple formats including graphics, achievement levels and competition. Perhaps due to the diversity of game-based learning options, a recent systematic review demonstrates aspects of its implementation has strong support from both educators and students in higher education (Subhash and Cudney, 2018).

Within the wider field of adult education research, the implementation of game-based learning has been observed to result in a range of benefits across a variety of disciplines. These benefits have included fostering student enthusiasm and motivation (Sailer and Homner, 2020, Zainuddin et al., 2020), providing learners with an ability for their skills to be recognised (Bai et al., 2020) and enhancing student enjoyment when studying challenging concepts such as physics (Asiksoy, 2018; Forndran and Zacharias, 2019; Malahito and Quimbo, 2020; Shute et al., 2019). There is also some evidence to support enhancements to overall student performance across disciplines such as biotechnology (Bonde et al., 2014), information literacy (Knautz et al., 2014) and computer science (Ibáñez et al., 2014). Further, game-based learning may provide educators more in-class feedback on students' progression and comprehension of session content as well as improve students' attitudes about concepts and courses they otherwise perceive as challenging, such as mathematics and statistics (Smith, 2017). This may be particularly important for students who are initially apprehensive or fearful regarding aspects of biomechanics courses such as the physics and mathematics content.

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For educators wishing to employ game-based approaches into their instruction (Figure 1), some recommendations are listed below based on extensive research in other areas of higher education.

Please insert Figure 1 about here

In-class polling and quizzing

The use of live quizzing during sessions is being increasingly adopted by educators worldwide, where students can use their mobile phones or tablets to answer questions in real-time during a class. Prior to the session, educators compile the quiz using a variety of software including: PollEv; Kahoot!; Qualtrics; TurningPoint; iSpring Quizmaker; ClassMarker; Poll Maker; Straw Poll; Quiz Works; Articulate Studio or even Microsoft PowerPoint for the Web (using the normal PowerPoint functionality to create polls that can be accessed online). Some of the online services offer free, yet basic, functionality for limited online responses, such as Poll Maker. These quizzes can be simple to create, but after polling the students, it is up to the educator to incorporate their own leaderboards, recognitions of achievement (i.e. prizes, awards or titles ["student of the hour"]), which the students can then display on their own class profiles if they wish to do so. Other online software, such as Kahoot!, has more powerful features to completely gamify the experience using sounds, graphics, response countdowns, badges and leaderboards (Moro and Stromberga, 2020). Overall test results do not appear to be influenced whether the quizzes are interspersed throughout the lesson or accumulated at the end of the class (Weinstein et al., 2016). However, utilising these games at the end of specific content

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topics/modules may better enhance student motivation and engagement and be an effective time to incorporate gamified quizzing in general. One additional benefit of online quizzing is that it can be utilised by students during face-to-face lessons (via their phones or laptops) and by those learning online. This makes it a feasible option for multi-modal classes, where some students are present and others attending remotely.

Adventure quests

A quest is a mission with an objective. Students can work independently or in teams to solve a problem or work through a scenario. Common biomechanics questions can be reformed into an integrative "CSI-style investigation" or "what when wrong cases" (e.g. the football was not kicked far enough or with sufficient accuracy). This could be gamified by adding a timer, 'levels' that students' progress through, and even a 'boss scenario at the end' which incorporates additional concepts, equations or considerations. This type of quest works well in groups or could even be structured as a single-person option for self-study, with the most popular genres for these types of games being either simulation or role-playing (Boyle et al., 2016). The delivery platform can be through quest triggers (or problems) displayed on PowerPoint slides, or even structured in an adventure role-playing game, such as *The Kings Request: Anatomy and Physiology revision game*, which guides students through revision concepts (Moro et al., 2020a). There remains no best way to embed a quest-oriented gamified session within a lesson (Welbers et al., 2019), but the practice does allow educators the freedom to implement an engaging, interactive and innovative method to deliver content and promote student self-directed learning.

Gamifying content using virtual, mixed or augmented reality

As anatomical structures and organ systems can be provided to students in full 3D virtual, augmented and mixed reality environments, a number of game-based learning activities could be incorporated into these environments (Birt et al., 2018; Moro et al., 2017a). Using virtual reality, the human body can be displayed and animated in a way not possible using plastic or silicone models or through the use of traditional anatomical resources such as cadavers (Kuehn, 2018). This virtual reality environment may assist the students to better understand the 3D location of anatomical structures such as bones, ligaments, muscles and tendons and how real-time changes to monoarticular and biarticular muscle lengths may influence human movement. This technology is still relatively new, and with the upcoming commercial releases of new devices such as the Microsoft HoloLens, this space will likely present increasing opportunities for using technology in future biomechanical, including game-based curricula. In addition, virtual reality-based applications can now run on mobile phones with an attached head-mounted-display (Moro et al., 2017b), which may greatly increase the accessibility of this technology and its scalability to large cohorts of students in the future.

Achievements and badges

One of the most common and accessible forms of gamifying curricula includes the provision of digital ‘rewards’ such as badges. As competencies are met, learners are awarded digital badges to acknowledge their achievements. Students may have fun collecting the badges, with each student having the option to publicly display these on a learning management software suite or a class website. The incorporation of digital badges into science and health professional

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programs can increase student knowledge, content retention and overall motivation to learn (Noyes et al., 2020; Vermeir et al., 2020).

Potential limitations of incorporating a gamified curriculum

There can be a novelty effect, where a great interest may be obtained in digital badges and fun gamified activities at the start, yet then drop off over the course of a semester (Garnett and Button, 2018). A relative lack of impact may also occur if the students had previously enrolled in another heavily gamified course or degree, where they may find future iterations of the same activities less engaging and interesting. Further, the excessive use of gamification in university level education for adult-aged biomechanics students may increase the dependency of the students on the educator, an outcome that will not transfer well to their future careers (Knowles, 1977).

Not all learners find game-based curricula enticing. Potential reasons for this may include a perception that it does not bring additional utility, that it causes anxiety or jealousy (Bai et al., 2020), or that some students simply consider themselves “not gamers” and so do not wish to fully engage with this delivery mode (Moro et al., 2020a). Game-based learning also requires an effective delivery method and underlying rationale. Gamifying content without any plan as to why it could be beneficial is likely to have no positive impact on overall engagement and learning. In some cases, the provision of gamified curricula, such as badges, has not led to any improvements with either motivation or performance (Kyewski and Krämer, 2018). This potential lack of increased motivation may reflect a wider discussion of whether games may be

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considered a more relevant pedagogical approach that has less relevance to andragogy e.g, university level education (Pew, 2007).

There are also limitations to current research, with a paucity of proper controls and theoretical foundations in published literature (Zainuddin et al., 2020). There is also a complete lack of studies on the impact of game-based learning in biomechanics, let alone sport biomechanics, from the perspective of either the educators or students. As a result of this lack of research in the discipline of sports biomechanics, it is unclear if our students would necessarily obtain the same engagement and learning benefits that has been described in the wider literature (Ibáñez et al., 2014; Malahito and Quimbo, 2020; Sailer and Homner, 2020). However, as many sports biomechanics students appear to be quite competitive and have a strong affinity for games and sports, the many similarities that exist between games and sports would suggest that many of our students would likely enjoy and benefit from the inclusion of more game-based learning activities.

Recommendations

Given these well documented benefits and limitations of game-based learning in promoting learning in higher education, we propose several recommendations to readers of *Sports Biomechanics.* First, we recommend that biomechanics educators consider implementation of specific game-based learning activities that fit their course, students and infrastructure (Figure 1). Many students' fear and difficulty with biomechanics might be reduced if game-based learning is utilised intelligently so that some elements of the course can be made more engaging and provide students more opportunities to demonstrate their understanding of

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key biomechanical concepts. The most accessible of these is to incorporate badges, leaderboards and achievements into relevant teaching settings, that could include lectures, tutorials and/or practical laboratory classes. Simple game-based learning activities including crossword puzzles, Biomechanics Cluedo or Jeopardy, could be used as fun review activities especially at the end of semester when students may be feeling fatigued but still need to prepare for their exams. For more technology-savvy educators, live online polling through interactive websites, such as using Kahoot! can incorporate a degree of participant engagement. For important concepts that warrant more time spent on them, the introduction of ‘quests’ will likely be well-received by the students. While developing these quests may take some planning on behalf of the educator, they may assist the students better focus their attention on specific tasks and result in enhanced learning.

Second, biomechanics educators that do choose to implement games-based learning activities should consider simultaneously conducting collaborative research with other biomechanics educators on this active learning approach. Such research could focus on the student perceptions around game-based learning as well as its effect on student learning outcomes and overall course results. Although correlated, learning (change scores) and achievement (course grade) are not the same. This simultaneous inclusion of game-based learning in biomechanics andragogy and research regarding student perceptions and learning outcomes will hopefully enhance student engagement and learning.

Summary

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Many students fear and dislike introductory biomechanics, which can add to the difficulties educators may have in assisting their students' learning. There is strong evidence that active learning approaches create large improvements in student engagement and mastery of biomechanics concepts in the required introductory course, however it appears that the benefits of game-based learning seen in other disciplines has not been widely used or researched in biomechanics. As game-based learning has been shown to significantly improve student engagement and learning in a wide variety of other related disciplines, this editorial recommends that biomechanics educators consider appropriate implementation of game-based instructional activities and simultaneously conduct research on its effectiveness and limitations. Advances in sports biomechanics instruction benefit both the field and the application of our knowledge in professional practice.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Figure legend

Figure 1: (Left) Author's recommendations regarding the accessibility, difficulty and time investment required for each of the game-based learning modes based on experience. (Right) A science student completes an interactive online quiz during an anatomical laboratory.

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Game-based approach	Accessibility to Educators and students	Difficulty to implement	Educator's time investment to implement
Online Quizzing (i.e. Kahoot!)	High	Low	Medium
Adventure quests	Low	High	High
Virtual, Mixed and Augmented reality	Low	High	High
Badges / Achievements	High	Low	Low
Leaderboards	Medium	Medium	Low

Figure 1: (Left) Author's recommendations, based on personal experience and peer-reviewed evidence regarding the accessibility, difficulty and time investment required for each of the game-based learning modes based on experience. (Right) A student enrolled in Health Sciences completes a Kahoot! quiz during an anatomy class.

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