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Descriptive Article

The universal design for learning framework in anatomical sciences education

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Running title: Universal Design for Learning in Anatomy

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ABSTRACT

Over the past decades, teaching and learning within the discipline of anatomy has undergone significant changes. Some of these changes are due to a reduction in the number of teaching hours, while others are related to advancements in technology. Faced with these many choices for change, it can be difficult for faculty to decide on which new developments in anatomical education need or indeed can be integrated into their course to enhance student learning.

This paper presents the Universal Design for Learning (UDL) framework - an informed, evidence-based and robust approach to underpin new course design and pedagogical reform in anatomy education. Universal design for learning is not a theory but a framework grounded in cognitive neuroscience that focuses on engaging multiple brain networks. The guidelines for UDL are organized into three core principles: (1) provide multiple means of representation, (2) provide multiple means of action and expression, and (3) provide multiple means of engagement. The learning space within the anatomy laboratory provides an excellent opportunity in which to apply this framework. This article also describes current trends employed in the teaching of anatomy. The principles of UDL are then outlined, followed by a description of how UDL approaches have been applied in the design and delivery of anatomy practical teaching to first year medical students at University College Cork. Future implications for this work are a consideration and investigation of how a course designed with the principles of UDL at is heart ultimately benefits student learning.

Key words: Anatomy; Pedagogy; Universal design; Learning; Integrated Curriculum; Medical Education

INTRODUCTION

Changes in Anatomy

Human anatomy as a discipline is taught to students across a variety of programs. While all these students are taught the anatomical details of the human body, every group needs to learn different disciplinary content at a depth most relevant to their profession. For example, medical students require an overall understanding of the anatomy of the human body and for that reason, several studies have been published to address the required anatomical knowledge that is needed to train competent and safe clinicians (McHanwell et al., 2007; Tubbs et al., 2014; Smith et al., 2016). The teaching of anatomical sciences on the medical curriculum has undergone significant changes in recent decades which has seen a move away from a more traditional Flexnerian model, to a new era of integrated curricula that now predominate (Drake et al., 2009, 2014; Hartley et al., 2018). In response to this, new teaching methods such as team, case or problem-based learning have been introduced into the medical curriculum (Davis and Harden, 1999; Vasan et al., 2011; Thistlethwaite et al., 2012). The effectiveness of those teaching methods such as team-based learning on student performance has been reported in the literature (Fatmi et al, 2013), while the ability to aid in connecting theory to practice was also reported for case-based learning (McLean, 2016). These integrated curricula require the incorporation of courses designed to build a broader skills base for students, including medical ethics, professionalism and communication (Hundert et al., 1996). As a consequence of this, there have been significant decreases in the total contact hours for gross and microscopic anatomy in medical and allied health disciplines (McBride and Drake, 2018). This change has impacted anatomy education in different countries around the world such as Australia (Craig et al., 201) and South Korea (Cho and Hwang, 2010), which led to the introduction of new teaching methods (Topping, 2014;

Halliday et al., 2015). Coupled with the decrease in contact hours, these new teaching methods were inspired by the significant advancements in technology-enhanced learning which includes computer software, web-based tools, mobile applications, virtual and augmented reality devices (Barry et al., 2016; Trelease, 2016; Swinnerton et al., 2017). More recently, three-dimensional printing has become an effective teaching tool within the discipline of anatomy (McMenamin et al., 2014; Smith and Jones, 2018). This technology-enhanced type of learning has proven to be advantageous for student learning (Greenhalgh, 2001; Cook, 2007), along with providing educational satisfaction and enjoyment to the learner (Tam et al., 2000) and most importantly providing good exam results (Losco et al., 2017). While the debate continues on the ideal integration of technology in the teaching of anatomy, cadaveric dissection remains the ideal teaching method and the cornerstone of anatomical education (Hu et al., 2018; Wilson et al., 2018).

These new pedagogical approaches pose a number of challenges for educators such as time, expense and developing new expertise (Nicholson et al., 2006). However, they also offer enormous possibilities for the future development of this field. While this new practice is an ideal to be strived for, there is a need to embed these new educational approaches into a cohesive pedagogical framework (Barry et al., 2016). The need for this is perhaps highlighted by the following questions: How do faculty decide which new developments in anatomical education to integrate into their course? How do they examine whether their existing practice is optimal for student learning?

An approach to education using the Universal Design for Learning (UDL) framework helps educators to answer these important questions. This article demonstrates how UDL is an informed, evidence-based and robust approach to underpin new course design and pedagogical

reform in anatomy education (Rose and Meyer, 2002). This article also presents some practical teaching applications and experience of teaching anatomy to medical students as a UDL case study.

Universal Design for Learning

Universal design for learning (UDL) is an education framework grounded in cognitive neuroscience that was originally proposed by Rose and Meyer at the Center for Applied Special Technology (CAST) (Rose and Meyer, 2002). It is an example of 'educational neuroscience' which is an emerging field of research focusing on the practical applications of neuroscience research in educational contexts for the benefit of student learning (Fischer et al., 2010). From a neuroscience perspective, the core principles of UDL propose to engage multiple brain networks to create an optimal environment for learning: the affective network, the recognition network, and the strategic network (Novak and Thibodeau, 2016). However, although there have been some studies that have demonstrated neural correlates of learning (for review see Ansari et al. 2012), the translation of brain imaging data into educational applicability largely remains a future goal (Van der Meulen et al. 2015). Therefore, in a practical sense, UDL can be thought of as an inclusive, pedagogical approach that can be applied to any educational context regardless of discipline, student age, demographic or skill level. The principles can be used in planning whole programs, courses, modules or smaller units such as individual classroom- or laboratory-based sessions. Moreover, all learning which is underpinned by a UDL approach is considered to be student-centered (Novak and Thibodeau, 2016).

What does the UDL framework look like and how can faculty adopt it to suit their individual needs? In simple terms, a UDL approach to learning can be summarized by the old adage; "*Tell*

me and I forget. Teach me and I remember. Involve me and I learn" (Novak and Thibodeau, 2016). The guidelines for UDL are organized into three core principles which are also shown in Table 1. A previous publication by the authors has also considered these concepts in relation to the teaching of anatomy (Balta et al., 2019).

[Table 1]

Table 1 is a simplified version of the full and detailed UDL framework which is available from the CAST website (CAST, 2020). In planning a curriculum all the way down to an individual teaching session, UDL allows educators to scaffold any teaching with reference to this UDL framework. To do this in a practical sense the authors propose that this centers around asking a number of questions that are aligned with each principle as per the following section.

Principle 1: Provide multiple means of representation.

Guiding Questions: How will students interact or persist in the program / module / course / lesson / session? How am I going to provide 'multiple means of representation' for the anatomical topics under study?

Principle 2: Provide multiple means of action and expression.

Guiding Questions: How will students engage in actions to demonstrate their understanding of the material? How will I provide opportunity for students to express their knowledge for the anatomical topics?

Principle 3: Provide multiple means of engagement.

Guiding Questions: How will students interact with the content of the program / module / course / lesson / session? How will students interact with each other and the teaching team? (Adapted from Novak and Thibodeau, 2016).

Universal Design for Learning in the Literature

Universal Design for Learning is well-represented and explored within educational literature, positioned as part of a paradigm shift which acknowledges learner diversity and movement away from a 'one-size-fits-all' approach to teaching (Deardorff and Birdsong, 2003; Leinenbach and Corey, 2004; Gradel and Edson, 2009; Al-Azawei et al., 2016). Approaches to UDL- informed teaching have been applied and reported on around the world (Anstead, 2016; Dalton et al, 2019); however there still remains much to investigate regarding the specific application to the teaching of anatomy in higher education (Izzo et al., 2011; Brenner et al., 2015); especially within the Irish higher education context. Moreover, the anatomy laboratory as a teaching space is a potentially rich environment to implement the UDL framework due to the availability of myriad teaching resources that can serve as different entry points to learning. Utilizing this learning space effectively can enhance student learning (Balta et al., 2019).

The reviewed literature indicates that a UDL-based curriculum design reduces learning barriers, improves satisfaction rates and attitudes for students, as well as having a positive impact on the teachers delivering the content (Al-Azawei et al., 2016; Rydeman et al., 2018). Significantly, a UDL approach to curricula design respects student attributes and embraces instructor creativity in developing teaching strategies and assessment techniques that are effective for all learners, while maintaining the integrity of the course and lesson objectives (Bernacchio and Mullen, 2007; Lieberman et al., 2008).

Various case studies represent different applications and contexts for implementing UDL such as within primary and high school educational settings (Lieberman et al., 2008; Katz, 2013; Zydney et al., 2014). Arguably however the application of approaches such as Katz's (2013) Three Block Model of UDL which incorporates fieldwork, photographs and videos or Zydney's (2014) use of individualized instruction via short videos is also relevant to a higher educational context.

It could be argued however that innovative and creative approaches to teaching are regarded as the mainstay in primary and high school but are not so in higher education. The traditional passive learning/lecture-style method is often the default for many teaching faculty in higher education (Izzo et al., 2011). While this is changing, it is certainly easier to find case studies and approaches to UDL in the classroom in primary and secondary school settings than in third level, and literature regarding third level anatomy teaching is sparse. While Brenner et al.'s 2015 paper and Choudhury and Freemont's 2017 study both present a UDL context for higher education anatomy, the focus of both papers are on assessment rather than approaches to teaching. This is the real value of a UDL approach – "Because UDL principles can be applied to various instructional elements, including resources, strategies, activities, and assessments, there are innumerable ways that the principles can be applied to practice" (Rao and Bryant, 2014) – as this paper will now describe.

As mentioned above, most case studies and implementation of UDL has been reported within primary and high school application setting. This is also true for the evidence of the impact of UDL on students' performance (Al-Azawei et al., 2016). Several studies have reported a significant positive impact on high school student learning when UDL is used in their coursework, some of which are related to student performance (Coyne et al., 2012) and others associated to student engagement (OK et al., 2017). While a limited number of studies have

investigated the impact of UDL on student performance at university level, a study by Kennedy et al. reported that their students scored significantly higher when using a teaching tool grounded in UDL theory (Kennedy et al., 2014). A few studies have discussed the use of UDL within the discipline of anatomy, but none of them assessed its impact on student performance (Balta et al., 2019; Ferreira et al., 2019).

DESCRIPTION

Overview of Anatomy Teaching

There are two entry routes to medical education in Ireland. 1. Students enroll directly from high school into direct entry to medicine or DEM (Direct Entry to Medicine), which is a five-year program or 2. Students first complete an undergraduate degree and then enroll in graduate entry to medicine or GEM (Graduate Entry to Medicine), which is a four-year program, similar to the US system. At University College Cork, the DEM anatomy curriculum is delivered in three modules in first year and two modules in the second year. The GEM curriculum is delivered in three modules in first year and one module in the second year (O'Mahony et al. 2016). The teaching of anatomy in both streams follows a similar format and DEM and GEM students merge for the last two years of both courses. Both courses consist of approximately 150 hours of anatomy content that is divided roughly into 30% lectures and 70% practicals (O'Mahony et al. 2016). The anatomy practical classes are primarily prosection based in which small groups of students work with a faculty member (senior medical demonstrator) to work through the anatomical content of the area under study. Different teaching resources are used within the small group teaching that includes anatomical models, computer aided learning stations,

multimedia resources and medical imaging, which will be discussed in further detail in the next section.

Practical Teaching of Anatomy

The curriculum design stage and planning for this module takes into account the main tenets of UDL at a semester level. Table 2 is an example of how this is implemented. Following from this, different teaching methods are used to provide the best learning experience for anatomy students. Active lectures and case based learning sessions, as well as integrated cadaver-based blended learning sessions provide multiple means of representation, action and expression and engagement as per Table 2. These practical sessions are typically two hours long and they run in the anatomy laboratory, which is designed to accommodate this type of learning as demonstrated in the figure below.

These two-hour practical classes are generally divided into four 25-minute rotation-based sessions where the students rotate between four different stations. The use of station-based rotations in the anatomy laboratory have also been reported in the literature (Abu-Hijleh et al., 1995; Drake, 2007; Shaibah et al., 2013; Yaqinuddin et al., 2013). After completing those four stations, students have 20 minutes at the end of the session for free-style learning. In those 20 minutes, students have the liberty to choose how they would like to spend their time, for example some students go around asking questions, looking at different prosection or utilizing different models; and given the intense cognitive load of the sessions students are also offered the choice to leave early. While some students are challenged by this intense cognitive load and hence decide to leave early, others are comfortable with this level which is why they decide to take

advantage of the available resources. Completing the four stations helps the students in achieving the learning outcomes devised for the anatomy laboratory practical.

In order to facilitate the rotation-based system, every student is assigned a table number and a subgroup within that table. Below is a detailed description of the four stations that students rotate around.

Station 1- Cadaver Demonstration Area: This takes place around the dark blue tables (see Figure) where a faculty member leads an interactive clinical tutorial utilizing human cadavers, prosections, plastinated specimens and plastic models.

Station 2- Practice Spot Examination: This is a formative spot quiz that takes place around the dark blue table. During this session, students walk around the table and try to identify different structures that are pinned on prosections. Every question has a part A, which asks the students to identify a structure, and a part B which is a follow up question on that structure. Questions in part B are usually related to the function, innervation or clinical relevance of the structure examined in part A. The answers for these questions are posted on the walls around the room.

Station 3- Computer Assisted Learning: This station is completed on a computer-based resource that is available at every student table (light blue in Figure). Every pair of students that are part of a subgroup work together through a list of tasks on the computer aided learning software "Anatomy and Physiology Revealed" by McGraw Hill Education (APR, 2009).

Station 4- Variable learning Area: The fourth station varies depending on the topic being covered and in parallel to the outlined learning outcomes of every session. This self-directed activity could include a histology, osteology, radiology or a clinical station.

DISCUSSION

A UDL approach to teaching and learning provides the students with multiple means of representation, enables students to demonstrate their learning through multiple means of expression and provides multiple means of recruiting interest. This active engagement in the learning process through clear application of skills is enabled through the following approaches: problem-based and active learning.

Multiple Means of Representation in Anatomy

In the laboratory, anatomy is taught using different modalities where the same content is presented in different ways, which defines multiple means of representation. For example, students could be learning about the anatomy of the heart through a clinical tutorial delivered by a faculty member, while other students are using self-directed learning to examine prosections, radiological images, or plastic models of the heart. In the first station, a faculty member will predominantly use prosected human material to deliver the content of the session. While this is primarily the case, in some specific sessions students learn anatomy by dissecting a specific body region instead of using prosections. During dissections, students are working as a group to primarily learn anatomy, but they are also developing important dissection skills. Prosections are used as part of an active clinical tutorial delivered by a faculty member. In those sessions, students are engaging with questions asked by the faculty member while looking at a prosection and listening to the content being delivered. Some students might be challenged by the cognitive load associated with learning anatomy in the laboratory, for this reason, plastic models might be a good alternative to bridge the gap between 2D images in lectures and the realistic 3D aspect of a human cadaver (Cantwell et al., 2015; Pather, 2015). It is important to acknowledge the impact of the cognitive load on student learning and adopt several means to reduce this load to achieve a

better learning environment (Mayer and Moreno, 2003; Mayer, 2010) Moreover, students have access to computer assisted learning tools which is extremely beneficial as a complementary learning aid that students can access in the laboratory and from home.

Multiple Means of Action and Expression in Anatomy

In addition to the multiple means of representing the knowledge, students have multiple opportunities of expression and putting this knowledge into action. This provides a rich active learning environment which has demonstrated to be environment for adult learning (Collins, 2004). The general layout of the laboratory promotes physical interaction as the students move between stations and browse the laboratory looking for models and prosections. As mentioned above, students also learn through physical action by dissecting human material and maneuvering the human cadaver. While working in groups or interacting with the teaching staff, students are able to verbally communicate what they know and engage in intellectual discussions. This is extremely valuable for the students as they work on developing their communication skills. Another form of expression is available to the students while completing the formative spot quiz. During this station students get to practice self-assessment as they work on identifying structures which is then followed by correcting their own answer sheets.

In the last 20 minutes, the students get to choose how they want to utilize this time, which promotes executive functions as they develop and act on plans to make the most out of learning. This will also encourage the students to exercise reflective practice which will help in their learning (Kolb, 1984). While some students chose to leave early during this time, most students end up staying in the laboratory and making the most out of the available resources. This includes viewing the different prosections that are available on the different faculty stations,

which will help the students appreciate anatomical variations. Others end up spending this time going through a list of questions, which they prepared, with a faculty member.

Multiple Means of Engagement in Anatomy

All of the above-mentioned resources and activities that are part of the anatomy laboratory will provide the students with multiple means of engagement. Students are better engaged through the different innovative activities to spark excitement and curiosity for learning. This will help motivate the students and hence providing them with a better learning experience (Collins, 2004). Additionally, it has been reported that 63% of first year medical students report that they find it difficult to apply their knowledge to a cadaveric specimen (Chakrabarti et al., 2018). In this context, it is apparent to all educators that the design of the learning environment in the anatomy laboratory is therefore an important variable to consider in anatomy course design. When considering human material and electronic resources as two different means of engagement, students should be able to experiment around their learning preference. For example, studies showing that handling physical specimens had major positive impact on learning for certain students which was not seen when a commercial e-learning tool was used (Van Nuland and Rogers, 2017). Meanwhile, questions could be raised on whether some of this knowledge could be taught using computer assisted learning (CAL) after being introduced as part of the curriculum (Guimarães et al., 2019).

Table 2 represents the different elements within the anatomy laboratory and how they apply to the core principles of Universal Design for Learning.

[Table 2]

Advantages of Universal Design for Learning

Perhaps one of the biggest advantages is that the use of a UDL framework allows for diversity within the curriculum to accommodate for diversity in student learning, rather than the expectation that students will change their learning approaches based on the constraints of the curriculum (Supple and Abgenyega, 2011). Universal design for learning focuses on a learner centered approach created through the provision of multiple means of engagement, multiple means of representation and multiple means of action and expression (Gradel and Edson 2009, Al-Azawei et al. 2016, CAST 2020). These core UDL principles are designed to lead to the ultimate goal of UDL which is to develop expert learners that are "*each in their own way, resourceful and knowledgeable, strategic and goal-directed, purposeful and motivated*" (CAST 2020). It also speaks to a strengths-based or 'growth mind set' approach rather than deficit-based which sees students as empowered with the ownership over how they learn (Dweck, 1986; Lang, 2016). Specifically the UDL framework:

> *"Assumes variability in motivation, interest, and readiness [to learn], and so provides scaffolding in language function, explicit skills, and executive function while keeping learner engagement and choice at the forefront"* (Novak and Thibodeau, 2016).

Universal design for learning also encourages meta-cognitive awareness around the processes of learning and prompts students to think more broadly about how they learn best, while also providing scope for engaging with learning outcomes from surface to deep learning (Bloom, 1956). This makes the learning experience more meaningful and more valuable (Laurillard,

2012). Meta-cognitive reflection has also been shown to be important to allow students to reflect on how they know and why they know, which is important for conceptual understanding (Zepeda et al., 2015) Hence, a UDL framework approach carries profound implications for learning beyond the classroom, into both personal and professional domains (Laurillard, 2012; Lang, 2016). However while an awareness of UDL is important, the real power of a UDL approach lies in its practical application. To illustrate this for anatomy educators, this article discusses how UDL has been applied in a practical way in anatomy practical classes at University College Cork.

Innovative Teaching Tools and their Place in the Curriculum

A curriculum which is built to enable the elements discussed here as a way of ensuring optimal student learning needs considered time and attention. A framework which enables educators to make informed decisions regarding the use of technology, a consideration of space and multiple layers of student learning in terms of UDL is required.

The authors propose an approach to constructive alignment (consideration of learning outcomes mapped across the semester and aligned with teaching and learning activities and assessments) as informed by Laurillard (2012). Laurillard categorizes learning activities as encompassing the following: acquisition, investigation, discussion, collaboration, practice, and production (Laurillard, 2012). Any and all of these learning activities can form the basis of an assessment and can be utilized in both face-to-face and blended formats. Mapping key elements such as these as part of a planning process can be a key way for faculty to ensure a fulsome consideration of all of the elements of UDL, such as through the ABC approach to learning design (ABC,

2019); an approach which has been utilized in professional development with faculty members by the second author of this paper.

Limitation of the study

While applying UDL principles has been recommended to improve student learning, several limitations can hinder its application within the discipline of anatomy. Implementing several means of representation, engagement, action and expression might require extra contact teaching hours with students, which is a challenge facing many anatomists teaching on different academic programs. Moreover, implementing some of these principles would require resources that could be expensive for some institutions and is not considered as a priority.

The impact of using UDL on student performance has only been reported for primarily high school students and to a less extent on undergraduates. Therefore, another limitation that could hinder the application of UDL is the lack of evidence-based literature on its efficacy for anatomy teaching at professional and graduate levels.

CONCLUSIONS

In summary, this paper has attempted to outline the UDL framework and why it is an excellent approach to course design in anatomy education. A UDL approach to course design can act as a common language for educators to discuss how even quite different course designs can still from a UDL point of view provide multiple means of representation, multiple means of action and expression and multiple means of engagement. The UDL is flexible enough to allow the incorporation of any new teaching approach into an existing course and helps to provide educators with the educational rationale (in addition to any disciplinary need) for doing so. More

importantly, providing those multiple means of representation, expression and engagement will provide students with an enhanced learning environment.

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FIGURE LEGEND:

Figure 1: The layout of the anatomy laboratory in the anatomy practical classes. The ratio of students per faculty in the demonstration area is 4 students per faculty. Students in green, red, purple and yellow represent different groups working on the same task.