ARTICLE
Elevating Student Potential: Creating Digital Video to Teach Neurotransmission

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Students today have unprecedented access to technology, the Internet, and social media. Their nearly ubiquitous use of these platforms is well documented. Given that today's students may be primed to learn using a different medium, incorporating various technological elements into the classroom in a manner compatible with traditional approaches to teaching becomes a challenge.

We recently designed and implemented a strategy that capitalized on this knowledge. Students in their first neuroscience course were required to create a 3-5 minute digital video using video-making freeware available on any Mac or PC. They used images, text, animation, as well as downloaded music to describe the fundamental process of neurotransmission as it applies to a topic of their choice. In comparison to students taught using other more traditional approaches to demonstrate the process of neurotransmission, we observed that students who took part in the video-making project exhibited better understanding of the neurological process at multiple levels, as defined by Bloom's revised taxonomy. This was true even of students who had no aspirations of pursuing a Neuroscience career, thus suggesting that there was an overall increased level of student engagement regardless of personal career interests. The utility of our approach was validated by both direct and indirect assessments. Importantly, this particular strategy to teaching difficult concepts offers a high degree of flexibility allowing it to potentially be incorporated into any upper-level Neuroscience course.

Key words: neurotransmission; e-learning; digital video; neurological disease; neurodegeneration; Facebook

Smartphones, IPods, and internet social platforms have evolved from computing technology at a breakneck pace in the last decade and pervade nearly every aspect of our life. Unsurprisingly, the new norm for college students of this generation is a heavy reliance on technology to engage in communication within their many social circles. The ubiquitous use of networking sites by young adults (94% of 18-24 year olds) and undergraduates as a means to communicate has been well documented (Higher Education Research Institute, 2007; Smith and Caruso, 2010). The popularity of social networking sites, such as Facebook, is a testament to this. These trendy sites allow individuals to connect rapidly through their personal use of images, videos, and music while using very little text to relay information.

Meanwhile, in a typical classroom, educators rely heavily on text as a means to provide understanding of concepts. This is vastly different from the social standards used daily by students to communicate, thus posing a challenge for how to best reach this social-media generation of learners. Simple dismissal of their social habits may no longer be an option and perhaps, incorporating some of this technology may result in enhanced learning. Various studies on multimedia instruction have provided evidence for the effectiveness of using pictures in addition to text to improve undergraduate learning outcomes (Mayer, 2003). Furthermore, the incorporation and benefits of multimedia instruction in the Neuroscience education field has already been demonstrated in teaching journals. One needs to look no further than the pedagogical initiatives published in the Journal of Undergraduate Neuroscience Education for some excellent examples that include realistic computer software simulations (Bish and Schleidt, 2008), web-based digital library classroom resources (Korey, 2009), and online multimedia teaching tools that include case study video clips for Parkinson's disease (Misiaszek et al., 2008).

In this study, we investigated whether students could extend their knowledge of technology to a multimedia project that required them to create a digital video that included music, images, text, and animation. Students were asked to use video-making freeware that can be used on any PC or Mac computer and were assigned the concept of neurotransmission as the focus of their video. In our experience, neurotransmission is a process that is traditionally difficult for students to understand in their first "brain" class. As part of our assessment, we wished to determine the level of student engagement in the video-making process and whether this translated to increased learning of neuroscience-related course material. In this paper, we describe the evolution of an introductory neuroscience course as different strategies were used to teach the concept of neurotransmission. We hypothesized that the process of creating a video would increase student learning of neurotransmission because it would require that students break down the process into its most salient elements prior to demonstrating its application to a topic of their choosing. Data for this study was collected over a three-year period of time.

Neurotransmission: A Necessary Foundation for Understanding How the Brain Works

It is critical for early neuroscience students to possess a

solid understanding of the process of neurotransmission prior to stepping into upper-level neuroscience classes. Neurotransmission can be broadly defined to include elements of cellular neuroanatomy; resting, action, and postsynaptic potentials; synaptic transmission; and neurotransmitter signaling (see Figure 1). These elements of neurotransmission can play a fundamental role in the etiology, symptomology, or progression of many neurodegenerative diseases that ultimately affect behavior (cf. Palep et al., 2006). Also, common addictive drugs exert their physiological affects by altering the process of neurotransmission through existing neural pathways and structures (cf. Robinson and Kolb, 2004). Additionally, the neural basis of learning and memory relies on enduring modifications of synaptic transmission via long-term depression and long-term potentiation (Bliss and Lomo, 1973).

Part of the complexity of neuroscience is that it is an interdisciplinary field by nature. As such, students who are early in their academic career, with a rudimentary understanding of biology, face specific challenges in their first introduction to the brain and how it works. For us, this is especially true for neurotransmission, a process that requires some understanding of cell biology, molecular signaling, and electrophysiology. Because of these common struggles with neurotransmission, we designed the digital video project, an activity at the "Creating" level of Bloom's revised taxonomy (Anderson and Krathwohl, 2001). Essentially, students were required to build neurotransmission up from its parts into the whole as it applied to a topic of their choosing. We assessed learning at the "Remembering" and "Understanding" levels of Bloom's revised taxonomy. Our unique teaching tool is described more fully below.

MATERIALS AND METHODS
Participants
This study took place over a six-semester period from 2009-2012. Participants (N=257) were traditional students, primarily in their sophomore year, attending Emmanuel College, a private liberal arts college in Boston, Massachusetts with an approximate enrollment of 1,800 undergraduate students. Students at Emmanuel have the following general demographics: 71% are female, 17% identify as Asian, Latino, African, Native American (this does not include international students; 12% of student body is of unknown race/ethnicity), 63% graduate within five years, and 72% live on campus.

They were enrolled in "Physiological Bases of Behavior," a core course that also serves as the gateway course for the neuroscience concentration in the psychology department, attracting students in the hard sciences as well. Two sections of the course were taught most semesters (three to four sections/year) by the same professor with 24-30 students/section.

Pedagogical Strategies for the Teaching of Neurotransmission
Students in different sections of the course were taught neurotransmission using the following strategies:

1) The "Conventional Approach" (CA; n=55) introduced neurotransmission to students with lectures spanning two class periods, as outlined above. Web-based animations were utilized to show how these elements interacted during different steps of the process (http://thebrain.mcgill.ca/flash/i/i_03/i_03_m/i_03_m_par/i_03_m_par_alcool.html#drogues). At the end of the second class period, the professor used a whiteboard to review the entire process of
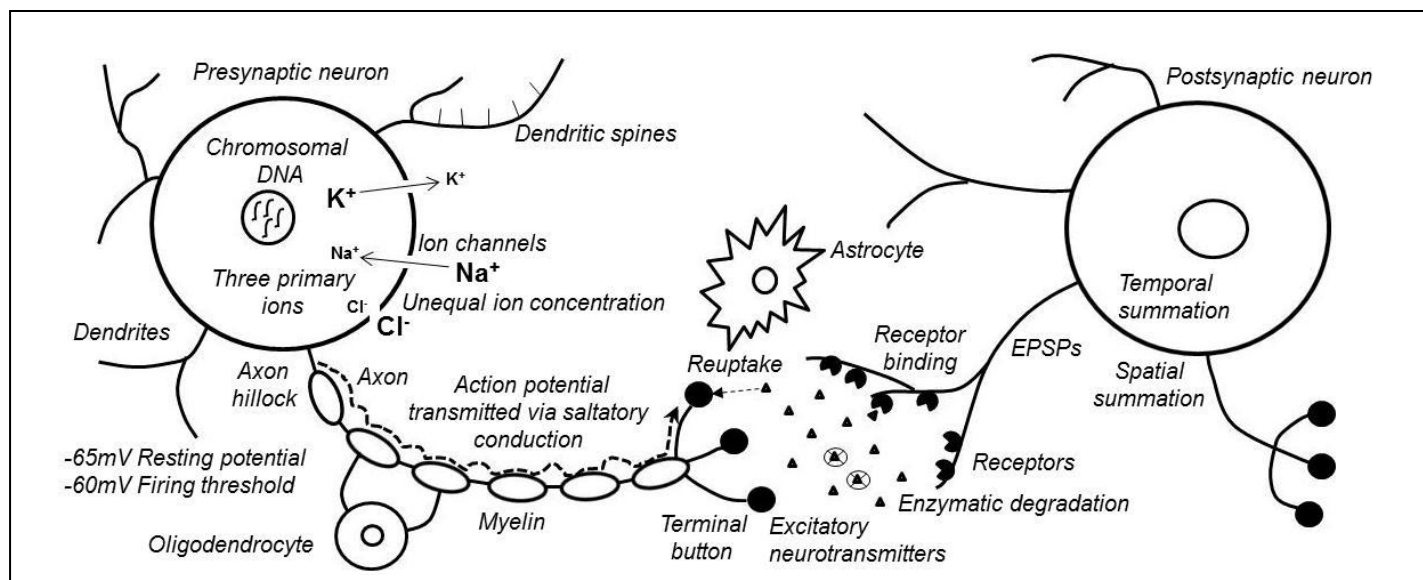

Figure 1. Sample Neurotransmission drawing. Twenty five terms/phrases, relevant to neurotransmission, were required. Additional terms/phrases beyond those represented in this schematic were also accepted for credit (i.e., soma, depolarization, hyperpolarization, IPSPs, nodes of Ranvier, absolute refractory period, etc). Solid arrows depict the direction of ion flow through the membrane.

neurotransmission using a two-neuron model circuit. At the start of the following class period, students were required to work together without notes to recapitulate the process of neurotransmission on a whiteboard.

2) The "PowerPoint Approach" (PPT; n=175) was implemented in different sections of the course. Students experienced the CA, but were also required to complete a group PowerPoint project. Groups of four students were required to choose and research a neurological disease outside of class and lead a fifteen minute class discussion emphasizing how neurotransmission was related to its etiology and treatment.   Each group constructed PowerPoint slides that defined and described their disease of choice and accurately depicted how those symptoms could have resulted from compromised neurotransmission. Student audience members were required to ask questions of each presenting group as part of their grade. Following the presentation, all members of the group were required to evaluate the effort and effectiveness of each group member (including themselves) as part of their grade. All comments were confidential.   The duration of the group project was five weeks.

3) The "Digital Video Approach" (VID; n=27) was implemented in a different section of the course.   It provided an additional supplement to PPT and required individual students to create a three to five minute long video breaking down the process of neurotransmission and applying it to a topic of their choice. They were required to use video-making freeware that was typically already installed on their laptops and free to download if not. For PCs, students used Windows Movie Maker (Microsoft) or Windows Movie Maker Pro (Microsoft) and for Macs they used iMovie (Apple). One primary learning objective for the course was that students demonstrate their ability to simplify complex information so that it was relatable to a general audience. For the digital video project, this was achieved by meeting the following goals: Link and apply neurotransmission to a topic relevant to neuroscience, Organize a logical and creative video, Develop "detail" skills with effectively constructed frames and use of music.

There were four phases to this project (see below) and students were given a total of five weeks to complete it outside of class.

Four Phases of the Digital Video Project
The digital video project has been used with success to teach several science concepts and this initiative has been described more thoroughly elsewhere (Jarvinen et al., 2012). Briefly, in Phase 1 (lasting one week), students were informed of the video project and trained in its use. They created a "10 second" video clip that contained at least one of the following: an image, a piece of text, a musical selection, and an animation.   This was an important exercise that required the necessary trial and error needed to learn the freeware program. In Phase 2 (lasting three weeks), students shared their topics with the professor, sought advice if needed, and created their videos. At the end of this phase, all videos were submitted to the professor for grading. In Phase 3 (lasting one week), students submitted a response paper detailing their

perceptions of the video project. No video scores were released until all response papers were submitted.   In Phase 4, all students completed a cumulative final exam that contained embedded assessments of neurotransmission.

Design
We evaluated whether PPT or VID provided any additional benefit to student learning of neurotransmission as compared to CA.   To do this, individual sections were taught neurotransmission using either the strategy of CA, PPT, or VID.   Direct measures of assessment included embedded neurotransmission questions on the final exam. These questions evaluated learning at the "Remembering" and "Understanding" levels of Bloom's revised taxonomy. In evaluating "Remembering", we measured the number of multiple choice questions that were answered correctly. These questions asked students to differentiate between concepts related to neurotransmission (synaptic cleft, resting potential, action potential, saltatory conduction, myelination, depolarization, absolute refractory period, "all or none", firing threshold, sodium-potassium pump, and neurotransmitters) and neuroanatomy (dendrites, axon, soma, axon hillock, terminal buttons).   We evaluated "Understanding" by having students create a sketch that summarized   neurotransmission   (See   Figure   1). Appropriate use and placement of twenty-five terms was expected, along with arrows showing where in the schematic that term was relevant. For each term omitted, placed wrongly, or used inappropriately, one point was deducted.   Reasonable spelling was expected.   For instance, if a student created a diagram using 23 "neurotransmission" terms, and eight of them were placed wrongly, they earned 15 out of 25 points.   Indirect measures of assessment included items from the response paper.   All final exam scores were analyzed and graphed with GraphPad Prism 5 for Windows (GraphPad Software Inc., La Jolla, California). Differences in student learning (Remembering and Understanding) of neurotransmission were evaluated by one-way ANOVAs with pedagogical strategy (CA vs PPT vs VID) as the between-subject variable, $p < 0.05$ was considered statistically significant. Post-hoc pairwise comparisons using a conservative Bonferroni adjustment were conducted to determine differences between means.

RESULTS
Through the years, as part of PPT, student groups have presented on many neurological diseases and mental disorders including Alzheimer's disease, amyotrophic lateral sclerosis, multiple sclerosis, Parkinson's disease, Huntington's disease, schizophrenia, and bipolar disorder.

Interestingly, despite the many possible applications for neurotransmission, students in VID had a strong tendency to choose topics related to drugs of abuse including alcohol, ecstasy, marijuana, nicotine addiction, morphine and cocaine.   A subset of created videos related to Alzheimer's and Parkinson's diseases. Musical selections transcended many genres.   We have included one

example of a student video as Supplemental Information.

We compared the three teaching approaches (CA, PPT, and VID) using direct measures of student learning of neurotransmission questions embedded in the final exam and found significance for both Remembering ($F_{(2,254)}=5.70$, p=0.0039) and Understanding ($F_{(2,254)}=4.86$, p=0.0085). Specifically, VID students had significantly better performance on neurotransmission "Remembering" (multiple choice; $p<0.05$) and "Understanding" (sketching; $p<0.05$) questions compared to CA or PPT students (see Figure 2, Left Panel). This equated to the VID students correctly answering approximately one more multiple choice question and including three more terms. Importantly, there were no differences in how each section performed on the cumulative portion of the final exam (~76%; $p>0.05$). We note that we conducted an additional analysis to account for unbalanced sample sizes, due to the large number of students in the PPT group. In short, we randomly selected two PPT sections (54 students) and compared student learning to that of the CA (55 students) and VID (27 students) groups. This analysis yielded the same findings.

A higher percentage of VID students compared to CA or PPT students earned full credit on multiple choice (37% versus 9% or 25%) and sketching-type (59% versus 24% or 46%) questions. The elevations that we observed in VID student learning was not due to students having neuroscience-related career aspirations ($p>0.05$; see Figure 2, Right Panel).
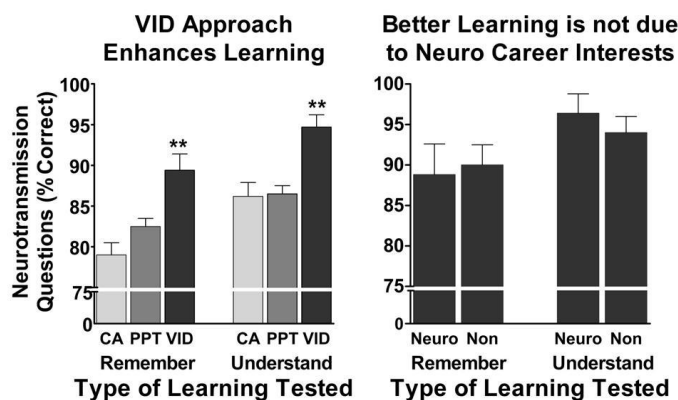

Figure 2. Comparison of teaching approaches. *Left Panel*: The Digital Video Approach (VID) yielded significantly elevated learning (** = $p<0.05$) compared to the Conventional (CA) and PowerPoint (PPT) Approaches as measured from embedded neurotransmission multiple choice (Remembering - Level 1 of Bloom's revised taxonomy) and sketching (Understanding - Level 2 of Bloom's revised taxonomy) questions. *Right Panel*: The elevated learning observed from VID was constant across career aspirations. Students indicated their future career interests on their response papers. Careers were grouped into Neuroscience (Neuro) and non-Neuroscience (Non) careers.

Student perceptions of VID were collected from their response papers. They felt that simplifying neurotransmission was the most challenging part of the video project (see Figure 3). A high percentage of students felt that they met this challenge and reported

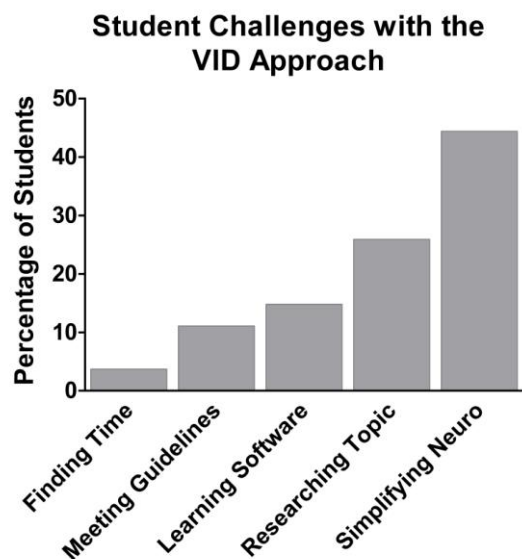feeling comfortable applying neurotransmission to another course.

Figure 3. Student difficulties with the five-week VID Approach. We note that a few students also disclosed using Final Cut Pro (Apple) as a video software program that required additional time for them to learn. Abbreviations: Neuro = neurotransmission.

DISCUSSION

In this study, we report three main findings. First, students who were required to apply their understanding of neurotransmission through the creation of a video significantly outperformed those who learned the concept from more conventional approaches. Second, this learning transcended several levels of Bloom's revised taxonomy. Third, students reported that it was challenging to simplify the process of neurotransmission, yet afterwards, felt more confident in their ability to apply neurotransmission in future classes. Cumulatively, these results support our hypothesis and provide evidence for the effective use of social media tools to teach the concept of neurotransmission.

Interestingly, VID students showed clear improvements at various levels of Bloom's revised taxonomy compared to their peer counterparts. Improved performance on the embedded Remembering (multiple choice) and Understanding (sketching) neurotransmission questions underscored the impact of our approach. This contrasts to perceptions of video-making as a passive approach. We eliminated alternative explanations for these findings including possible effects due to unbalanced sample sizes (additional analyses) or higher performing students in the VID section (equivalent scores on the cumulative portion of the final exam). While beyond the scope of this study, it would have been very interesting to evaluate whether there was improved learning of the individual topic chosen by each student.

Student self-reporting allowed us to indirectly gauge the level of interest and perception of the skills they gained from the VID experience. Based on the information that

they provided, we note that the successful performance on the embedded neurotransmission final exam questions was not due to student aspirations to pursue careers in neuroscience. This was surprising to us because, in our experience, students tend to perform better on a given topic if they have an inherent interest in that field of study. This thinking is supported by educational research (Ainley et al., 2002). However, it was clear, from the test results, that VID students who had little interest in pursuing neuroscience did as well as those who declared their intent to pursue that field. This was encouraging to us as it indicated that the process of creating the video (choosing images, text, animation, and music) may have engaged students in a way that we had not observed using a more conventional approach. In the end, the product created by the students was valuable to them: they felt that other students would learn from watching their video perhaps because they had learned from making their own video. Whether this would actually be the case is likely dependent on the level of interaction expected of the students that view the videos (Grabe and Grabe, 1998).

Our digital video project served as a "proof of principle" that it could be an effective active learning activity that engaged the students. It allowed students to express their understanding of a difficult concept in a unique and individualized manner. They were able to connect with the concepts because they chose the music, images, and text that they felt best represented their understanding. We believe that students felt engaged because the project required that they use multiple types of technologies that they use every day to communicate within their social circles.

Additional unexpected strengths of the approach are its high level of flexibility, such that it could easily be incorporated into any class at any level. Also, while the specifications of the assignment are concrete, it can challenge students of all abilities and interests. Whether this innovative approach could be expanded to include a film festival at the end of the semester---technology's version of a poster session---whereby each student introduces their video and plays it for the class remains to be seen.

CONCLUSION

Technology has changed the ways in which we communicate and it has affected the way in which today's undergraduates respond to incoming information. It may be challenging yet beneficial to incorporate aspects of these technologies to approach the teaching of difficult concepts. There are now numerous possibilities for novel pedagogical initiatives that can lead to impressive learning outcomes. The digital video project described in this study is an example of such an initiative. Structured at the "Creating" level of Bloom's revised taxonomy, it challenged students to validate their understanding through a unique demonstration intended to depict mastery of the concept of neurotransmission. In the end, this approach yielded an increased learning of neurotransmission that was accompanied by high levels of student confidence in their ability to apply this information in later classes. We believe

that this was due largely to their personal engagement with this multimedia project since it used elements contained in social media platforms with which they routinely engage.

There is a tremendous amount of potential in using this approach to teach a variety of difficult concepts for many types of courses. It yields higher levels of learning of those concepts because it forces the student to identify the basic components that frame the complex story. The process of creating it helped them to reduce the complexity of the concept to its most salient features. This data, taken together, suggests that a teacher could, with the appropriate permissions, eventually generate a peer-library of digital video, created by current students for future students. Ultimately, we offer a strategy to personalize and supplement conventional approaches to teaching by using technology that students can easily relate to.

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