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Learning Physics in the Millennial Age

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Abstract

Physics is a subject area that, like many others, requires a specific and rather well-defined skillset. This skillset includes the ability to solve problems which involve, at minimum, an understanding of basic algebra. The level of mathematics required often depends upon the population of students a particular physics class is geared for. Non-majors studying physics typically need to have a working knowledge of basic algebra, while science, technology, engineering and mathematics (STEM) majors need to have some basic calculus under their belts. To promote deeper learning in physics, educators and researchers have developed a variety of active-learning strategies that have one primary goal; namely, to enhance student learning. In addition, many research studies in physics education have looked at factors that affect learning in physics. Oftentimes these studies have focused on specific subsets of populations of students in classes such as introductory courses for non-majors or for specific non-STEM populations such as music or elementary education majors. Additional studies have focused on student learning in courses designed for physics and other STEM-related disciplines. Several studies, for example, have focused on the conceptual and reasoning difficulties novice students often encounter in an introductory physics course. Physics educators know that students don't enter the classroom with a tabula rasa – rather they bring with them a minimum of about 18 years of life experiences that directly and indirectly impede or enhance their ability to learn physics. Within the introductory physics course, one might argue that there are more similarities than differences in terms of factors that impede or enhance student learning across various subsets of student populations. For example, studies have shown that an alarmingly large number of students across the entire introductory spectrum of courses have similar difficulties in terms of the preconceptions and misconceptions they bring with them into the classroom. In the roughly 50 years that formal research in physics education has been conducted, we have uncovered, time and time again, that our students come into our classes with issues that have a direct or indirect bearing on their ability to learn physics. One central question this paper aims to address is: Are the factors that impede or enhance student learning in physics any different in the millennial age?

Introduction

Today's classrooms are largely populated by millennials. For the past two decades we have seen increased use of variety of terms used to describe them. The millennial is often considered to be an individual born sometime between approximately 1980 and 2000. We often refer to this subset of the population as Generation Y or Gen Y. Other names given to this group of individuals include Echo Boomers and 24/7's. Throughout this paper we will use the terms Gen Y and millennial interchangeably. In contrast, The Generation X or Gen X constituency is typically considered to be individuals born between approximately 1965 and 1980. Other names given to this group of individuals include Post Boomers, the 13th Generation, and The Doer's. Baby Boomers are typically considered to be those individuals born between 1946 and 1964 and are sometimes referred to as the Me Generation, or the Moral Authority. Many Baby Boomers are now parents of children born in either Gen X or Gen Y.

Beginning with Generation X we have seen an explosion in the availability of internet- and technology-based learning tools. However, it is not just an explosion in internet- and technology-based learning tools that is occurring. In fact, those in Gen Y have literally grown up with the internet and a wide range of other technology-based tools for learning, entertainment, etc. at their fingertips. Students entering the college classroom today were immersed in computers, smartphones and tablets from the youngest stages of their intellectual and emotional development. They don't know another way.

There are many differences between Gen Y and Gen X learners. For example, Gen Y learners are often swarmed with technology both in and out of the classroom and are almost always connected to one another through texting, tweeting, social media applications, etc. A recent study highlighted this difference between Gen Y and Gen X[1]. In this study it found that within a twenty-four-hour period, a third of millennials had watched video content online compared to only a quarter of Gen Xers. The reality is, most millennials don't even realize that they're as "plugged in" as they actually are. As a result, one could even go so far as to dub them as kings and queens of *subconscious multitasking*. In fact, they tend to engage in multitasking activities in virtually all facets of their lives.

These learners are also very used to having whatever information they want instantaneously. The fast-paced ease with which they can access information has also resulted in their being called high speed stimulus junkies. Constantly in front of a digital screen, some studies have pointed to a new form of addiction, namely, a digital one[2]. Why should they read the book when they can just use Google? Gen Y learners also tend to be ambitious, but not always focused. One might argue that perhaps this is due to their shorter attention spans. On the other hand, a perceived lack of focus may not be due to a short attention span at all. Some movies and television shows today have very complex story lines that span several weeks and even months – and millennials eat it right up. So an alternative conception may simply be that millennials don't lack focus; rather, they focus their attention on things that matter to them and that they perceive to be worthwhile to them and their lives. This fact alone may present a difficult issue in the classroom. In addition, a teacher may present what they feel was a great lecture; however, their millennial students may not feel the same way. Facts and figures and physics problems alone are not going to ignite the interest of many millennials. Real life connections to the material being covered may be critical to motivating a millennial leaner to eat it up. Instant access of digital information and lack of real life connections may also be one reason why Gen Y seems to be spending less time reading their textbooks.

Millennials are used to being the focus of attention and do very well in student-centered classrooms; and, they want to actually experience the content of a course rather than just read and/or be told about it. Active learning approaches have already been established as being effective ways to teach physics as well as other STEM courses. Perhaps an enhanced emphasis on active learning approaches in the classroom along with a more well-defined link to practical applications of the material being studied may be an effective approach to working with millennials.

So how does Gen Y fit within the "traditional" classroom and what impact does it have on student learning? What changes should be made to the traditional classroom in order to ensure that this new generation of learners remain excited and engaged so that true and robust learning can take place? From a learning standpoint, one must ask: *are these types of tools impeding or enhancing student learning … or perhaps both?*

Literature Synthesis

When we think of the "traditional" classroom, perhaps the image that first comes to mind is that of a teacher in front of the class lecturing to a group of students. A significant amount of research has shown, however, that traditional techniques often put students in a role of passive rather than active learning and are often very inadequate in terms of promoting deep learning and long-term retention of important concepts [3-11]. Passive learning routinely results in rote learning and regurgitation of the lecture. A discouraging fact is, after instruction, students often emerge from our classes with serious misconceptions[12-19]. The research on learning in physics has made one thing very clear. Namely, learning is enhanced within an activity-based learning environment[20-27]. For the millennial learner, an activity-based approach may be even more important. Learning itself is an active process. In a broad sense learning might be considered to be a net gain in understanding, experience, skill and/or expertise pertaining to a particular knowledge set. Adapting their definition from Mayer[28], Ambrose, et al.[29] describe learning as a *process* that leads to *change*. The active process of learning is not something we "do" to students. Rather, learning is something students do themselves, sparked by a good teacher's efforts to provide robust opportunities. One might argue that true learning begins with effective instruction. Wieman and Perkins suggest that effective instruction in physics is instruction that changes the way students thinking about physics and physics problem solving[30]. In addition, effective instruction is instruction that causes students to think more like experts (i.e. practicing physicists).

Are today's physics classrooms keeping up with the needs of their students? Millennial students have essentially grown up with technology while many of their teachers did not. Prensky[31] devised the terms *digital native* and *digital immigrant* (i.e. non-digital natives) in part to address the apparent mismatch between teaching methods and the needs of today's learners. Students in Gen Y are digital natives. Many Gen X and Baby Boomer teachers might be considered digital immigrants. Prensky suggests that the swift pace of digital technologies has in fact, changed the way learners think and process information. In other words, it is difficult for a digital native to achieve academic success in a classroom that is taught by a digital immigrant. Digital natives often tend to need a media- and technology-rich learning environment to hold their attention. Active engagement of the digital learner is necessary to promote learning. In the past decade or so, many STEM educators have found the use of rapid response systems using "clickers" to be particularly useful[32].

So what about effective instruction and learning in the age of the millennial? Are the learning styles of Gen Y really that much different than those of the Baby Boomers or Gen X? Emerging research is telling us that the answer to that question is a definitive YES. Jones[33] suggests that the millennial generation tends to rebel against the traditional styles of the previous generations. In fact, she posits that millennials demand learning experiences that are technology-rich and feedback that is supportive so that it assists them on their individual learning pathways. Jones argues that today's millennial learners "want to *do* the content and not just *learn* it" (p. 17).

Rainer and Rainer[34] also present the importance of technology-rich learning experiences for millennials. In terms of the workplace, these researchers posit that millennials may also need more attention and feedback than other older-generation employees do. Rainer and Rainer found that about three-quarters of individuals of millennial age want direct mentorship from a leader or other authority figure. In addition to being a technology-rich generation, Gen Y is one which wants to know that what they spend their time on is significant to the world around them. In one study, the vast majority of millennials surveyed agreed that they believed it was possible for them to do something great and perhaps make a positive impact for the common good of society. In this way, Carpino, Ugalde, and Gow argue that the expectations of today's millennial-age college students are much different than previous generations[35]. These researchers suggest that when a millennial enters the classroom they want to know that there is a practical application and use to what they are learning, and that they prefer active over passive learning. Based on a study of 15 psychology teachers and 120 undergraduate students, Kraus and Sears suggest that teachers may want to focus their time on activities that serve to build connections between the academic material being studied and the students' lives[36].

Millennial learners also tend to take a natural interest in civic and community issues. Within the classroom the community of millennial learners has also become increasingly diverse. It is important to note that millennials see the diversity of their generation as one of their greatest strengths. However, this increase in diversity within Gen Y leads to an increased variance in the kinds of preconceptions, misconceptions and perspectives that they are bringing into our classrooms. Brown, Hansen-Brown, and Conte suggest that incorporating an experiential learning-community type of approach can be an effective way to engage an increasingly diverse population of learners[37].

To address the questions posed thus far, a synthesis of a short set of preliminary surveys given to introductory students in two different physics classes at American University during the fall 2016 semester will be presented. Before the survey data is presented, a brief overview and description of the two classes of introductory physics students included the study will be shared in the upcoming section.

The Millennial Learner in Introductory Physics

Two classes of introductory physics students participated in the current study. Each class was populated heavily by non-majors and a brief overview of each is presented below.

<u>Physics 100 (Physics for the Modern World)</u>

The Physics for the Modern World course is an introductory physics course designed for non-STEM majors. The course also includes a laboratory component. Students that enroll do so to satisfy the university's Natural Sciences requirements towards graduation within the general education core of classes. Non-majors who enroll are typically studying such areas as international relations, business, history, philosophy, literature, the visual arts, communications, and political science. The course covers essentially the same span of topics as are covered in the first-semester calculus physics course for STEM majors. The only difference is simply the level of mathematics used. The Physics for the Modern World course is algebra-based. The fall 2016 class consisted of 50 students (22 females and 28 males). While there are a few junior and senior students who enroll in the class for one reason or the other, the vast majority of the students enrolled are freshmen and sophomores.

The textbook used in the Physics 100 course is the 12th edition of Conceptual Physics by Paul Hewitt[38]. While the focus of this book is learning physics through conceptual means, there is a level of problem solving required at the algebra level. In addition, the instructor prepared additional algebra-level problems that the students were also required to solve. In physics, both conceptual as well as numerical problem solving are important. Students in the Physics 100 class were exposed to a good deal of both types of problem solving. For conceptual problems students had to write complete explanations to demonstrate their understanding of a particular question. For the numerical-based questions, students were taught to solve a problem in what might be considered a standard format by first identifying the given information, drawing and labeling a diagram, and determining the key physics relationships that are involved in the question. Once the student has identified all of the given information they had to apply the physics relationships to solve for one or more unknown quantities. This is a pretty standard method in most physics classes.

Physics 230 (Changing Views of the Universe)

The Changing Views of the Universe course is also taken by students to satisfy the university's general education requirements towards graduation and is subscribed to by both STEM majors and non-majors. However, this course is unique as it does not fall within the Natural Sciences portion of the general education core of courses. Rather, it falls with the Traditions that Shaped the Western World portion of the core. The STEM majors are typically pursuing such areas as computer science, public health, biology, environmental science, mathematics, chemistry, or physics. The fall 2016 class consisted of 45 students (26 females and 19 males). Approximately 80% of the students who enrolled were not majoring in a STEM-related content area. In addition, the course was populated by a fairly even distribution of freshman through senior level students with perhaps a slightly larger concentration of freshmen and sophomores.

The textbook used in Physics 230 course is Coming of Age in the Milky Way by Timothy Ferris[39]. The Ferris book is not a traditional physics book in the sense that its focus is not on problem solving. Rather, it might be considered to be more of a history of science type of book. In fact, because of the unique nature of the course, there was very little problem solving required. Any numerical-type problems that were assigned to the students, while algebra-based, did not come from the textbook; but rather, they were written by the instructor.

The data collected in this study comes from 3 short qualitative surveys given in fall 2016 in both of the classes outlined above. The same surveys were given to both classes. The following section provides a look at a preliminary subset of the data collected.

Data

One of the surveys presented to both groups of students involved having them rank order the learning tools that they felt were "essential" when they prepared to study for a college class. Students were not asked to think about physics class specifically, but were encouraged to think about what learning tools they tended to require when they studied for any class. This particular question was posed in a general manner and students were encouraged to simply think about the learning tools that they feel they regularly need in order to study. Most students rank-ordered approximately 6 – 10 items that were important to them as they prepared to study for any course.

Students were also asked to describe how they used each learning tool they identified. For the purposes of this paper, Tables I and II illustrate the students' number one item on their rank-ordered lists.

Table I. Physics 100 (n = 43)
Most Essential Learning Tool Needed to Study

Number 1 Learning Tool	Number of Responses	% of Responses
textbook, class notes	12	27.9
comfortable work place/quiet	11	25.6
computer	6	14.0
notebook paper, pen and pencil	4	9.3
coffee or other beverage	2	4.7
flashcards	1	2.3
having a to-do list and study plan ready	1	2.3
knowing what's expected and what's being assessed	1	2.3
access to Blackboard/class PowerPoints	1	2.3
must be alert and well-rested	1	2.3
chewing tobacco at the ready	1	2.3
music	1	2.3
access to online quizlets	1	2.3

Table I indicates that the number one ranked learning tool by just over 25% of the Physics 100 class was the textbook or the students' class notes. Perhaps the students view their class notes as an extension of the textbook. Of this group of students, some said they preferred non-digital study tools because they were easier to make notes and markings in. Others indicated that they liked to refer to the textbook to look up definitions and key concepts and examples. We note that in this class, the computer was the number one ranked learning tool by 14% of the class.

Table II. Physics 230 (n = 43)
Most Essential Learning Tool Needed to Study

Number 1 Learning Tool	Number of Responses	% of Responses
notebook paper, pen and pencil	14	32.6
computer	8	18.6
comfortable work place/quiet	6	14.0
textbook, class notes	5	11.6
coffee or other beverage	2	4.7
access to Blackboard/class PowerPoints	2	4.7
take a walk	1	2.3
having a to-do list and study plan ready	1	2.3
eyeglasses	1	2.3
lamp	1	2.3
turn off phone	1	2.3
music	1	2.3

Table II shows that the number one ranked item by about 33% of the Physics 230 class was simply a notebook and pen and pencil. This might be anticipated given that the students felt they needed to take notes while reading the textbook. Of this group of students many indicated the importance of taking good notes.

One question that we felt important to ask relates to how millennials make use of their textbook. Are they reading them? Is the Gen Y group spending less time reading and more time accessing information digitally?

We began our exploration of these questions by surveying the students to find out just how many students were in possession of a textbook for their physics class. If they were not in possession of a textbook they were asked to explain how they accessed a copy of the textbook to complete the required readings and homework assignments. Tables III and IV show the number of students in each class that were or were not in possession of a textbook.

Table III. Physics 100 (n = 41)
Course Textbook

In possession of textbook?	**Number of Responses**	**% of Responses**
Yes	33	80.5
No	8	19.5

Of the 8 respondents that were not in possession of a textbook, 6 indicated that they regularly checked out a copy of the book using the library's course reserves. One student said they borrowed a friend's book and another said they used a copy of the book available during the instructor's and TA's office hours. Many of the students in the Physics 100 class said they used the textbook to help them answer homework questions. While the textbook was the number one ranked item on the list of learning tools, very few of the students surveyed actually said they sat down and read the book when they were studying. Most of the respondents indicated that they used the textbook as a reference for doing their homework.

Table IV. Physics 230 (n = 44)
Course Textbook

In possession of textbook?	Number of Responses	% of Responses
Yes	40	90.9
No	4	9.1

Of the 4 respondents not in possession of a textbook, 2 indicated that they checked the book from the library's course reserves and 2 indicated that they had access to a free online pdf of the book. Many of the students in the Physics 230 class surveyed said that they read the book using a variety of different styles. For example, some said they first skimmed the chapters looking for key names and dates. These same students would then go back and read the chapter in detail. Others indicated they took notes or highlighted passages from the book while reading it carefully.

Preliminary Results

One aim of the surveys we designed was to attempt to tease out factors that are affecting learning in physics by our millennial-age students. An additional aim was to look at the general perceptions millennials have towards learning in general; and, more specifically towards learning physics. Using the results of the preliminary surveys, we present some emergent themes; and, use them to try to paint a clearer picture of what tools and techniques best serve the millennial learner in the physics classroom.

Interestingly, the data show that the computer was not the number one ranked learning tool by either class of physics students. Students in the Physics 100 class ranked the textbook and their class notes as most important with the computer being fourth on their list. Students in the Physics 230 class indicated that notebook paper and pen and pencil were the most important learning tools. However, the computer was ranked second on their list. The difference in rankings between the two classes may simply be due to the different nature of the textbooks used for each class.

In terms of the textbook our results show that most students were in possession of a book. Students that were not in possession of a textbook had direct access to one either through a classmate or through the library's textbook reserves. Students in the Physics 100 class noted that they primarily used the textbook to help them with their homework. In fact, very few of these students actually indicated that they read the book. On the basis of our surveys, it appears that students in this class see the textbook as a means to an end with the end being getting their homework done. In contrast, many more students in the Physics 230 class indicated that they read the textbook. These students also indicated that they either highlighted key passages and/or took notes while reading the book.

Summary and Recommendations for Future Research

One question that we presented focused on whether the factors that impeded or enhanced student learning were somehow different for millennial-aged students. While one could argue that getting students to read their textbooks is an issue that has always been present throughout all generations of learners, we contend that there are issues facing the millennial or Gen Y group of students that are new and different from previous generations. The millennial student is the first generation of learners that has grown up in a predominantly digital environment and thus an inquiry into factors that affect their learning is imperative in order to best reach them both in and out of the classroom.

We also asked the question of just how does Gen Y fit within the "traditional" classroom and what impact does it have on student learning? Moreover, what changes could and should be made to the traditional classroom in order to ensure that this new generation of learners remain excited and engaged so that true and robust learning can take place? In terms of learning in the millennial age, we wanted to know about what learning tools these students found critical to their success as well as what tools might be impeding or enhancing their learning. While we were surprised to see that neither group of physics students ranked the computer as their number one learning tool, we feel that we have just begun to scratch the surface of answering the questions related to millennial learners. These questions are important and their answers may have many implications not only in physics but also within STEM classrooms in general.

To more fully answer the questions posed, we are presently crafting new and more detailed surveys to get at the questions related to the factors that impeded or enhance learning. These questions relate to the type of textbook students are using. For example, do students make more use of hard- or digital-copies of the textbook? And, for each type of textbook are there different strategies students find most useful? We also plan to make use of focus group interviews in future studies to find out more about not only textbook usage but about issues like multitasking. We are interested in hearing from the students to find out more about whether or not they have their smartphones near them when they are studying and if so, if they are on or off. Furthermore, if their phones are on, do they allow things like texting and social media to interrupt their study time or do they set them aside to create a distraction-free environment? Productivity apps on smartphones have now become popular. Are millennials using them to maximize and optimize their study time?

An issue that repeatedly came up in the literature focused on how millennial students wanted to be able to see the practical side of what they were learning and how what they were learning had an impact on their lives. In addition, the millennial also wants to know that what they are learning can somehow be connected to making society and the world a better place. This is primary issue for millennials and one we feel is not necessarily addressed or addressed in detail in the classroom. Hence, our future efforts will more closely focus on how learning in physics and STEM can be better linked to societal and global issues. We feel this may have a motivational effect on the millennial learner which in turn will serve as a factor which can enhance their learning within the physics and broader STEM classrooms.

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