



Collaboration in Assessment and Individual Validation for the 'Digital Native'

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Collaboration in Assessment and Individual Validation for the “Digital Native”

Abstract

Collaborative problem solving is a valuable skill encouraged in many engineering classrooms. This collaborative problem solving is an ABET requirement as well as a characteristic of the National Academy of Engineering’s “Engineer of 2020”. Course grades, however, are assigned individually, and the institution, which bears the ethical responsibility to validate baseline competence in the engineering profession, uses these grades to confer degrees to individuals and not groups. By observation and anecdote, “digital natives” (people who have lived their entire lives with easy access to information technology) approach learning and the propriety of knowledge differently than previous generations. To the digital native, “individual work” may mean that an assignment is submitted individually but its preparation can be collaborative. Upon submission, the instructor wrestles with validating a student’s individual understanding of course material while still encouraging synergistic peer-learning and the use of digital technology both in and out of the classroom. How can the framework of engineering courses change to meet how digital natives interact with information, maintain the integrity of the educational assessment process, and foster appreciation for individual ethical responsibility in the engineering profession? In a 3-year longitudinal study, the authors examined student performance and experimented with alternate assessment models in an introductory environmental engineering course for juniors with multi-disciplinary enrollment. This longitudinal study was designed to indicate better assessment and academic validation of digital natives while enhancing valuable peer-learning. Individual and course-wide grades as well as student feedback are used to assess student performance. Comparison of course-end comprehensive exam results (assumed to demonstrate individual material mastery) were compared with term grades (which will be influenced by collaboration on out-of-class assignments) using a Mastery of Material Indicator (MMI). Our study indicates that the traditional course assessment model still requires more maturation to provide targeted student learning feedback but a qualitative analysis establishes the digital natives respond favorably to an assessment model that deliberately emphasizes individual feedback both in terms of grades and instructor comments.

Introduction

Mark Prensky, the noted education author, speaker and futurist, famously coined the term “digital native” in his 2001 article, “Digital Native, Digital Immigrant”. In this publication, Prensky claimed that students at the time were “no longer the people our educational system was designed to teach” [1]. Prensky noted that contemporaneous students represented a singular generation that had grown up with digital technology, which had fundamentally changed how this generation thought and processed information.

The STEM education world took note of Prensky's observations and began to discuss ways to meet the needs and thought processes of digital natives. In 2004, the National Academy of Engineering (NAE) published a report entitled "The Engineer of 2020: Visions of Engineering in the New Century". In this report, NAE recognizes that we are progressing in age of extraordinary technological growth and sets forward ideal attributes for the next generation of engineers. The author committee predicted that:

- "The world in which technology will be deployed will be intensely globally interconnected.
- The population of individuals who are involved with or affected by technology (e.g. designers, manufacturers, distributors, users) will be increasingly diverse and multidisciplinary.
- Social, cultural, political, and economic forces will continue to shape and affect the success of technological innovation,
- The presence of technology in our everyday lives will be seamless, transparent, and more significant than ever" [2]

Since that time, the NAE authors' predictions have been borne out, most notably in the information technology realm. The next generation of engineers is now with us, sitting in our lecture halls, and preparing for their professional careers. This next generation of engineers has lived their entire lives as beneficiaries of the information technology revolution. They are skilled in instantaneously researching a topic on the internet and making global connections with a few swipes of their fingers. These skills give digital native students awareness of the multidisciplinary facets (social, cultural, political, economic, and technical) of contemporary engineering problems as well as prime their penchant for team integration [3], [4].

ABET, the higher education accrediting body that helps set an engineering student onto the road towards professional licensure, also recognizes that multi-disciplinary teamwork is a requisite skill for the modern engineering work force and encourages teamwork in the development of digital natives engineering related skill set. As part of General Criterion III (Student Outcomes), ABET asks for students to graduate an engineering program with an "ability to function on multidisciplinary teams" [5].

Institutions, too, have responded both to the increasing complexity of engineering problems and to digital natives' approach to learning. Digital technologies and platforms are increasingly assimilated into the curriculum [6]. Collaborative problem solving, too, is a valuable skill encouraged in many engineering classrooms. This approach enhances student learning by allowing a student to observe different problem-solving approaches, analyze these approaches, and negotiate with their peers on the best way forward [7]. Collaborative problem solving also permits the opportunity for peer-coaching, which may synergistically lead to deeper, more innovative learning for both the tutor and the tutored than classroom instruction and individual

problem sets alone. Practicing engineering learning in this way prepares a student to integrate with real-world teams and work to solve complex, multi-faceted problems upon graduation.

However, the incorporation of digital technology in the classroom is not enough to keep college education relevant in the long-term to digital natives and the increasingly-digital society. Nor is collaborative problem solving a triple win for the digital native student, the school, and society. The institution (the school) bears ethical and chartered obligations to society to graduate qualified individuals technically-ready and ethically-primed to enter into professional life. The institution must choose to confer a degree based on course grades (and GPA in relevant coursework). Course grades in turn should reflect *individual student mastery* of course material. How, then, should an assessment model be structured to selectively promote collaboration and still maintain the integrity of the individual educational assessment process? We seek to answer two questions in this assessment. How do we adjust the course assessment model (types of assignments used/points allocated) to best teach a classroom of digital natives with varying degrees of digital nativeness? How do we adjust the course assessment model (types of assignments used/points allocated) to best assess course mastery in a classroom of digital natives with varying degrees of digital nativeness?

In a longitudinal study, the authors examined student performance and experimented with alternate assessment models in an introductory environmental engineering course for juniors with multi-disciplinary enrollment. This longitudinal study was designed to indicate better assessment and academic validation of digital natives while enhancing valuable peer-learning. Individual and course-wide grades as well as student feedback are used to assess student performance. Comparison of course-end comprehensive exam results (assumed to demonstrate individual material mastery) with term grades (which will be influenced by collaboration on out-of-class assignments) indicates that the traditional course assessment model still requires more maturation to provide targeted student learning feedback that reflects accurate assessment of knowledge demonstrated by digital natives.

Reflection on Classifying the Digital Native

Categorizing digital natives can be difficult, especially as technology evolves quickly. Prensky's original bracket of digital natives (kindergarten thru college age in 2001) may seem broad to us today. The interaction with digital technology, especially information technology and digital social networking, is much different in 2018 than 2001. It is worth examining these differences and speculating how digital native students (and the educational system they grew up in) continue to develop.

Prenskian digital native college students had different information technology experiences than digital native kindergarteners in 2001. While both groups may have grown up with pocket calculators as opposed to slide rules, the older group more readily will remember typewriters, the Dewey decimal system, and encyclopedias. In fact, in 1995, when the older Prenskian digital

natives were in high school or junior high school, only 14% of American adults (a proxy for digital native internet access at the time) used the internet, and all internet access had to be via computer (63% of people had a home computer at the time) [8]. At a similar age, Prenskian digital natives who were in kindergarten in 2001 went to high school in a world where 79% of American adults had internet access and 35% of American adults owned internet-capable smartphones [8]. Clearly, such disproportionate access to digital information technologies at formative times in students' lives influenced the education systems they grew up in (affected by technological inertia as well as advancement), their access to information, and sense of proprietorship of intellectual property. With the swift evolution of the digital environment, younger digital natives are even more plugged in to technology than older Prenskian digital natives. As the doubling time of technology continues to decrease, the turnover of digital natives that are more technologically entwined will also continue to decrease.

To better understand the population of digital natives currently sitting in our classrooms, it may be helpful to set certain technology saturation benchmarks as points of inflection. Three qualifying benchmarks can be defined to evaluate the shades of digital nativeness in recent year groups of students. Figure 1 may provide some insight into the digital native's experience and how it formatively will change with almost every year group moving into the future.

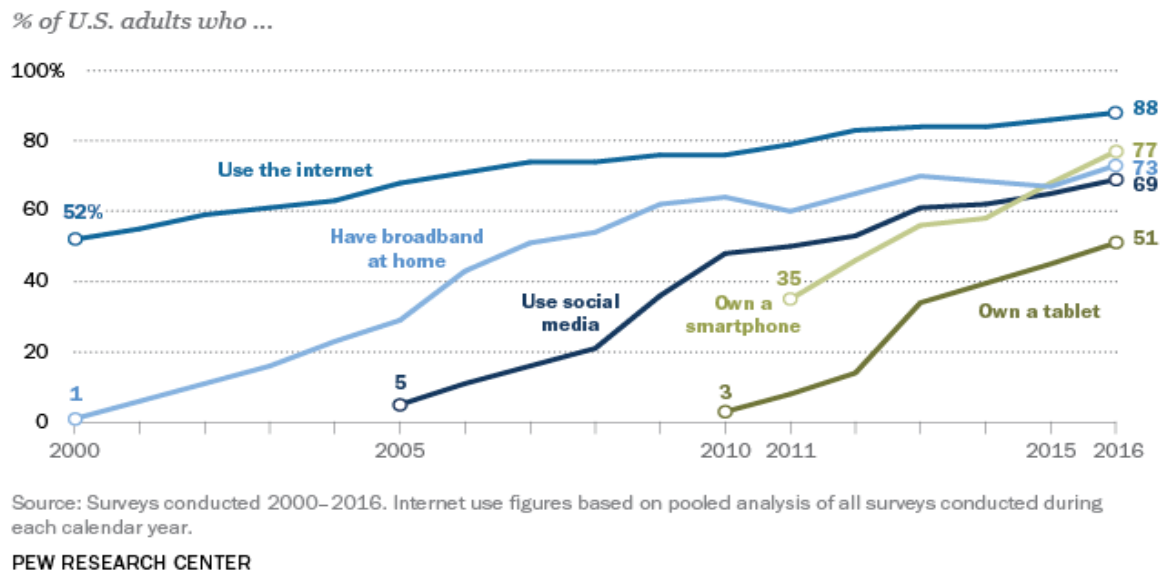


Figure 1 The Evolution of Technology Adoption and Usage [9]

Imagine a child who is just learning to read and has home internet access. Learning to read and write are milestones in individual intellectual development. These skills open up a new world of self-development. Coupled with the ability to now formulate their own web query at home, the reading child's potential for information acquisition has increased tremendously. A benchmark for contemporary digital nativeness, then, can be that a child learns to read (around age 6) and is capable of performing their own web searches in a household that more likely than

not has home internet access (e.g. >50% of the population has home internet access of some type). This most likely occurred sometime in 2002 [9]. In other words, this benchmark best describes students born after 1996.

This demographic closely corresponds with the Prenskian 2001 kindergartener, a student who is now an undergraduate. This individual will have a special relationship with information management. They grew up with access to a digital commons of knowledge. This individual perhaps will rely more on data query rather than data recall; they will be good at data aggregation and can quickly filter validity of information by consensus within search results. This latter skill, though, can serve as a limitation stifling broader creativity and critical thought. This individual, too, will be able to manage and manipulate multiple large datasets simultaneously using powerful digital tools like Microsoft Excel or MathLab.

A second benchmark in the evolution of digital natives is the discontinuation of the printing of reference books. The transition from printed to digital reference can be said to have occurred in 2012 when, after 244 years of printing, *Encyclopedia Britannica* ceased producing its heavy tomes. Once a necessary part of middle school book reports, sales of this encyclopedia line peaked in 1990 before the widespread adoption of the internet [10]. By 2012, free online crowd-sourced knowledge repositories such as Wikipedia had consigned printed encyclopedias to the way of the buggy whip. It is assumed that individuals who were in middle school (around age 10) at the time of *Encyclopedia Britannica's* demise relied solely on digital sources during their early research years. In other words, a student born after 2002 is a member of a population of digital natives that do not voluntarily need to seek out or perhaps even value printed reference books (books are seen as quickly being dated, which may be true in some cases). By researching online within the state of the science, the digital native's capacity to leapfrog within a field of study grows. However, this individual may have a more "net neutral" view (e.g. the query is important, but the quality of the query results may not be valued) of accessible information (digitized or otherwise) different than their predecessors, complicating their scholarly development.

A third benchmark may be the saturation of smartphones amongst the student population. In 2016, 77% of American adults owned a smartphone. However, amongst the 18-29 year old demographic, 92% of young adults owned smart phones. Simultaneously, 86% of this group was social media users [11]. This saturation of phones come from the developing economy and evolution of lifestyle permeating society. Children get phones earlier because parents want to keep in touch and it is not cost prohibitive to add them to the family phone bill. This provides mobile access to the worldwide web and assimilation into digital social networks which strengthens the digital native's collaborative instincts and further cements their egalitarian attitude towards the application of knowledge. With nearly 100% of digital natives born after 1987 being smartphone users, the instructor has to be prepared for instantaneous fact checking, recorded lectures, and different modes and definitions of cheating.

As these benchmarks occur over one another as shown in Figure 1, it is clear the levels of digital nativeness cannot only vary considerably within a classroom, but the overall classroom will change year to year as well. We receive a new population of students each year, but potentially a different generation of digital natives every 3-5 years. This is where diligent attention must be paid to ensure our instruction and assessment stay relevant to a dynamic student population.

Future benchmarks for digital natives may include students who more likely than not interacted with smart phones since they were babies (born after 2013) or the saturation of use of voice activated digital assistants, like Apple’s Siri or Amazon’s Alexa. Both of these events will have an impact on how students learn and value educational techniques such as closed-resource exams testing informational recall rather than informational query.

The Assessed

In this study, the assessment model of an introductory environmental engineering course entitled “Environmental Engineering Technologies” (EV350) is adjusted to accommodate the perceived needs of digital natives and then evaluated. EV350 is offered in the spring for juniors. Typical enrollment ranges from 160-200 with 11-14 sections (15-20 students per section). This course is the second in a three-course environmental engineering sequence (all students are required to take an engineering sequence at the authors’ institution regardless of their primary major) for non-engineering majors (e.g. History, English, Political Science, Math, Leadership, etc.). EV350 is preceded in the sequence by an environmental science course and is followed by an environmental engineering design course. EV350 course outcomes are:

Table 1 Course Outcomes for EV350

1	Design engineered systems to solve fundamental environmental problems in drinking water, wastewater, air pollution, and solid/hazardous waste.
2	Develop models for analyzing environmental problems by applying mathematics and basic science.
3	Apply the environmental engineering design process to an environmental problem to safeguard the environment and human health.
4	Conduct lab experiments as a member of a problem-solving team and integrate with infrastructure applications.

Over the course of this study, all EV350 students could be labeled as digital natives meeting the benchmarks described above to varying degrees. Table 2 shows the ages of students at different benchmarks discussed in the previous section. The authors suggest that their institution has not yet seen full saturation of digital natives per the benchmarks previously set, and this saturation will occur with overlap of future benchmarks in digital nativeness. The institution can expect further evolution of student attitudes, expectations, strengths and shortcomings in their programs, all the more so as digital natives return to the academic setting as instructors.

Table 2 Ages of EV350 Students Relative to Digital Native Benchmarks

EV350 Year Group	Birth Year Range of Students		Age at Benchmark 1 (>50% American homes with home internet access, 2002)	Age at Benchmark 2 (Cessation of physical publication of <i>Encyclopedia Britannica</i> , 2012)	Age at Benchmark 3 (>90% saturation of smartphone ownership in adults aged 18-29, 2016)
2017	1997	1991	11-17	15-21	19-25
2016	1996	1990	12-18	16-22	20-26
2015	1995	1989	13-19	17-23	-
2014	1994	1988	14-20	18-24	-
2013	1993	1987	15-21	19-25	-
2012	1992	1986	16-22	20-26	-
2011	1991	1985	17-23	21-27	-

For the purposes of assessment, by observation, the digital native students were highly collaborative and displayed an “open source” propriety of knowledge different from previous generations. At the authors’ institution, students are required to document all sources and collaboration used on out-of-class assignments. This documentation led to interesting insights into how students worked, learned, and demonstrated knowledge. Most notably, evidence of heavy collaboration in documentation showed that valuable peer learning was taking place outside the classroom. Detrimentially, however, this evidence also revealed that, to a digital native, “individual work” often meant that an assignment is submitted individually but its preparation can be collaborative. Some example statements of documentation are below:

- *“Assistance given the author, verbal discussion and review of written work. Student X and I jointly discussed the methods and equations used on every problem in the homework set. He assisted me in solving the problems by checking my solutions against his own, which he had completed prior to our meeting.”*
- *“Assistance given to author, collaboration. Student X and I worked together on all problems. We worked collectively to figure out how to solve them and calculated them separately using a calculator and then compared.”*
- *“Assistance given the author, verbal discussion. Student X checked my work and told me how to correct problem 2.”*
- *“Assistance given the author, verbal discussion. Student X helped me set up my equation to find the Darcy Velocity on number three when I was confused on which value to use for r.”*
- *“Assistance given the author, verbal discussion. Student X helped me with my mass balance equation on problem 1b by helping me understand the units that my K value needed to be in. Additionally, Student X helped me set up the K_{sp} equation on problem two by helping me figure out where to get the pH levels from and how to solve for Fe.”*

Students also leveraged technology as opposed to textbooks. In fact, many digital natives learned best through virtual experience. Several students commented to their instructors that they watched online videos about treatment technologies discussed in class. Other students stated that they watched online videos on how to solve problem types presented in lecture. In both cases, students felt they understood course content better after watching this online content. This could serve as an opportunity to better instruct digital natives in a way they are willing to interact with the material and could lead to better learning.

However, the students sometimes over-relied on technology. One interesting phenomenon encountered by an author hit upon the worst stereotype of the digital native. One student responded to a problem by writing that they had entered the problem's main question into a web search engine and could not find an answer. Due to this, the student did not consider the question legitimate and gave up on the question.

The Evolution of the Course Assessment Model

To this point, the authors attempted to understand digital natives, how they work and learn, and place a larger context on how those work methods are challenging how institutions function. Shifting focus, EV350 will be used as a case study to examine the assessment model research question.

No major revisions to EV350 course content occurred between 2011 and 2016. The course ends with a course-end comprehensive exam known as a Term End Exam (TEE). We chose the TEE as a point of comparison due to program policy that we do not radically change the TEE thus maintaining its applicability for longitudinal assessment. The TEE did not change significantly in content or format over these years either. The biggest change during this time period was the aggregation of course outcomes in 2015 to be less topical and more general in nature. Figure 2, though, shows marked deviation between TEE averages and semester course averages (minus the TEE, 20% of the overall grade) after 2012.

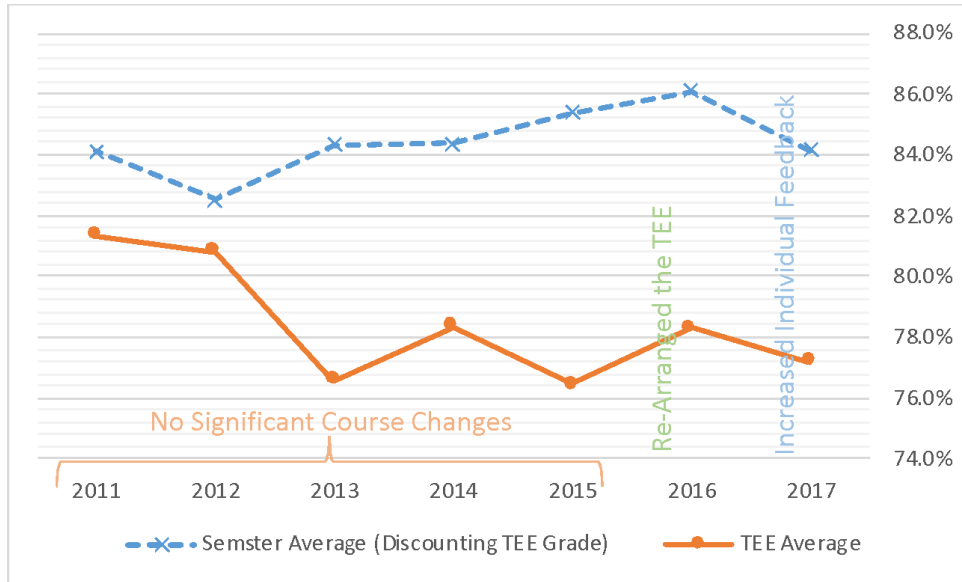


Figure 2 Comparison of Grade Averages Earned Throughout the Semester versus on the TEE in EV350, 2011-2017

The lower TEE averages after 2012 seen in Figure 2 were largely mathematically driven by sharp increases in the D and F letter grades earned. Our thoughts were that the change occurring in the year 2013 may be due to a shift in digital nativism affecting how digital natives learn, collaborate, and test.

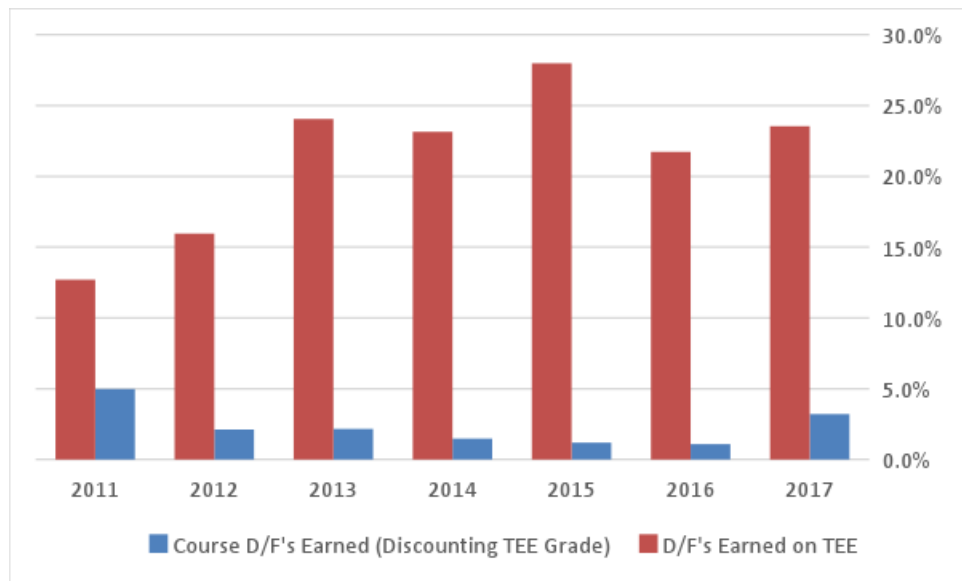


Figure 3 Comparison of D/F's Earned Throughout the Semester Versus on the TEE in EV350, 2011-2017

Taken together, these grade trends do not present a consistent picture of a successful assessment model. A successful assessment model should consistently inform the instructor and indicate to the student how well the student understands and can demonstrate knowledge of course material. The assessment model had largely been successful through 2012; TEE scores (reflecting individual mastery) closely followed course grades. However, after 2012, a

divergence occurred between course grades and TEE performance, as seen by the rise in the red bars in Figure 3. As a result, my students' final grades may have been inflated by half a letter grade relative to TEE performance. Going into the TEE, the last graded event of the semester and an in-class, individual event without the benefit of collaboration, students may have been over-confident and unprepared.

The divergence of TEE grades and non-TEE semester grades as well as the percentage of students earning a D or an F on the TEE hit a high-water mark in 2015. Consequently, in 2016, the TEE was re-structured to enhance data recall. Primarily, the TEE was re-organized to topically mirror the progression of the course. Additionally, multiple choice questions testing conceptual knowledge were partially de-valued (3 points to 2 points per question). Multiple choice questions historically had been a major source of lost points. Re-allocated points went to new short answer questions highlighting process flow in water and waste water treatment trains, the conceptual differences of which had been problematic for students even as they walked away from the course. Lastly, sub-parts of quantitative questions were made independent of one another to prevent "follows credit" confusion for both the students and the instructors.

The following year, in 2017, the assessment model was adjusted to increase individual feedback to students. This was done by increasing the number of assignments, focusing the in class tests given throughout the semester on specific topics and shifting points between graded events. We did this because of the collaborative nature of the students, to give them more individual feedback on their learnings and also more assessment for course points on in-class individual work.

One large consideration in modifying the assessment model was the percentage of group-earned points to individually earned points. Past senior instructors commented that the high lab and Engineer Design Problem (EDP) grades, both group events, artificially bolstered student grades. In 2017, to better reflect individual student effort and performance while still tipping the cap to the importance of group work in problem-solving, 9% of distributed course points were shifted from points earned with a team and points earned individually.

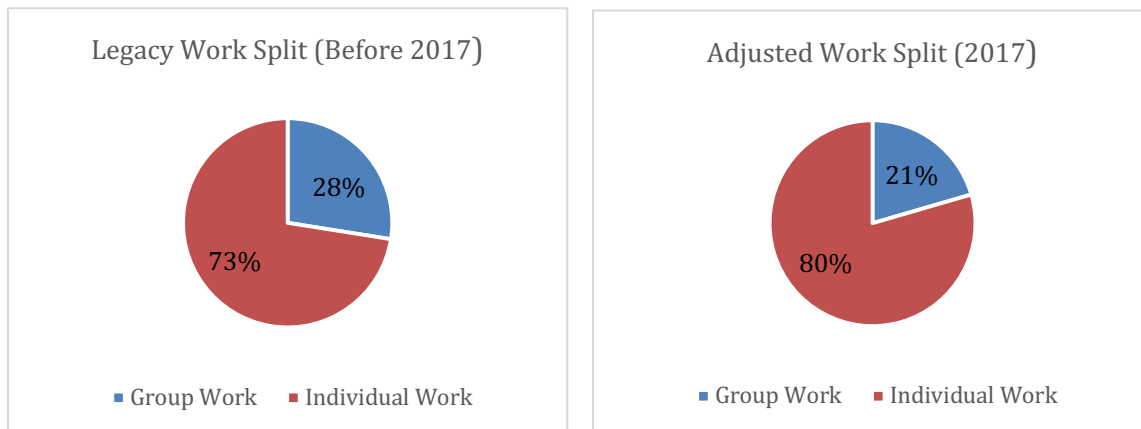


Figure 4 Percentage of Allocated Group-Earned Points Versus Allocated Individually-earned Points in the Course Assessment Model

The primary factor in apportioning points under the adjusted 2017 assessment model was not individual points earned, however. Individual points earned tell only part of the story. As noted earlier, instructors noted extensive and pervasive collaboration on out-of-class assignments, including on intended individual assignments like homeworks. To more accurately grade the students' learning (and give accurate feedback) throughout the semester, the allocation of in-class versus out of class points were also adjusted.

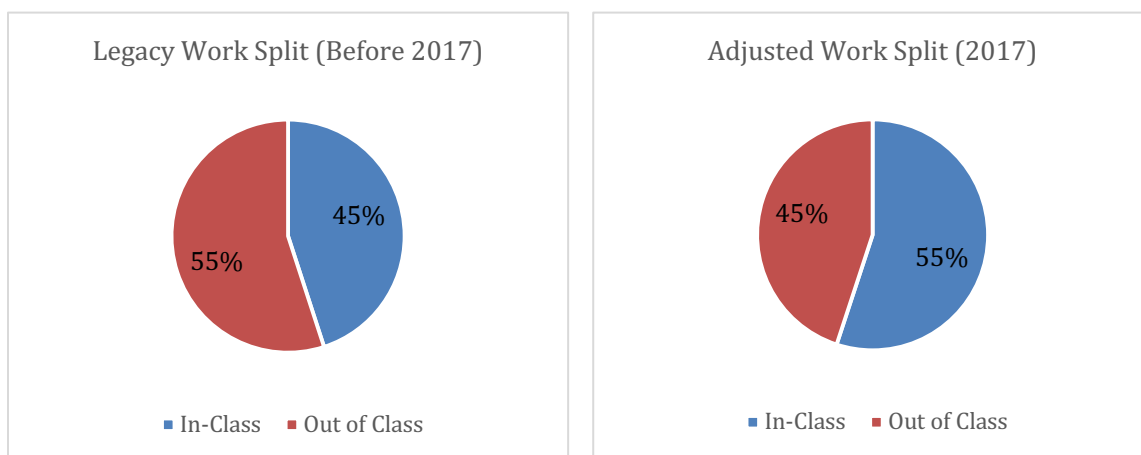


Figure 5 Percentage of Allocated Points Earned In-Class Versus Out of Class in the Course Assessment Model

The Adjusted (2017) Course Assessment Model, In Detail

The goal of the assessment model adjustments in 2017 was to more closely match knowledge retention, as demonstrated by TEE performance, to course grade performance through increased individual feedback. To support this goal, several changes were made to the course in 2017:

- Incorporated three new in-class demonstrations to give the students the opportunity to visualize concepts past students have had trouble with (mass balance, acid/base

neutralization with associated problem, and solubility) and tied them to in-class problems.

- Created space on the syllabus for extra lecture and problem solving lessons for problematic topic areas like mass balance, chlorine disinfection, and BOD.
- Better coordinated the graded events so they would not overlap, thus the students could focus on one at a time. The EDP and Lab reports were the exception.
- Added more frequent feedback by increasing the number (and shortening the length) of graded events from 16 events in before 2017 to 21 events in 2017.
- Created more variation in graded events, including more in-class graded events, to curb some excessive collaboration and pull in different types of learners. These events included:
 - 3 quizzes for quick, in-class evaluation
 - 3 on-line quizzes (Blackboard assignments) with hints as feedback (one question used with minor modifications as a TEE question)
 - 4 numbered homeworks (one fewer than 2016) of shorter length with more points associated with them
 - Streamlined (shortened and presented in multiple, successive parts to highlight problem solving frameworks) Streeter-Phelps homework and group engineer design project from previous years
 - 3 group lab assignments worth less points than previous years (cut 20 points from each report submission; the hands-on portion remained the same)
 - Qualitative reflections with guided calculations to accompany field trips to the drinking water treatment plants (WTP) and wastewater treatment plants (WWTP) (students in the past have confused the two treatment trains greatly)
 - 3 (as opposed to two) in-class exams of shorter lengths and aligned with specific course blocks and topics
- Shortened the TEE (one less complete quantitative question, less sub-parts in two other questions, and five less multiple choice questions).

Summaries of the legacy (pre-2017) assessment model and the adjusted (2017) assessment model are found in Tables 3 & 4.

Table 3 Legacy Assessment Model (pre-2017)

Event	Points	Course %	Notes
Homework Sets	250	25.0%	5 @ 35 points, 1 @ 75 points (Streeter-Phelps)
Laboratory Work	150	15.0%	3 @ 50 points each
Engineering Design Problem	125	12.5%	Wastewater Treatment Plant Design with Cost Analysis
In-Class Exams	250	25.0%	2 @ 125 points each
TEE	200	20.0%	Comprehensive
Instructor Grade	25	2.5%	Class Participation / Peer Evaluations
TOTAL POINTS:	1000	100%	Total Number of Assignments: 16

Table 4 Current Assessment Model (2017)

Event	Points	Course %	Notes
Blackboard Assignments	30	3.0%	3 @ 10 points each
Homework Sets	210	21.0%	4 @ 40 points, 1 @ 50 points (Streeter-Phelps)
Laboratory Work	110	11.0%	3 Labs @ 30 points each, 2 field trips @ 10 points each
Engineering Design Problem	95	9.5%	Wastewater Treatment Plant Design with Cost Analysis
Quizzes	45	4.5%	3 @ 15 points each
In-Class Exams	300	30.0%	3 @ 100 points each
TEE	200	20.0%	Comprehensive
Instructor Grade	10	1.0%	Class Participation / Peer Evaluations
TOTAL POINTS:	1000	100%	Total Number of Assignments: 21 (3 computer graded)

Blackboard Assignments. (Individual/Out of Class Assignments) Blackboard assignments were on-line quizzes that plugged the gap between homeworks, in-class quizzes, and in-class exams. These assignments covered block material that the students did not have an opportunity to receive feedback on (usually the last in-class lesson) before a test. These assignments are worth 10 points each and consist of both multiple choice and calculation questions. There is at least one conceptual multiple choice question on each assignment to maximize the chance for students to receive points, encourage them to open their textbook, and prepare them for in-class exams. Calculations, too, are broken up into as many sub-parts as possible to again maximize earned points as well as highlight problem solving methodology. Students have two chances to work through a solution. After each submission, students receive very pointed hints to either drive them to a fuller understanding of the question or to seek additional instruction with their instructor.

Homework Sets. (Individual/Out of Class Assignments) In the past, students commented that homework sets required too much work for too little points. The homeworks in 2017 were shortened (legacy questions were pushed to quizzes and Blackboard assignments) and valued at 40 points as opposed to 35 points making the assignments more gradable (more granularity in points-based feedback). One less numbered homework was offered in 2017 in comparison to previous years.

Lab Assignments. (Group/Out of Class Assignments) EV350 is not primarily a lab course and places rigorous emphasis elsewhere. Labs are great exercises in hands-on, applied classroom theory. Labs in EV350 are meant to be tactile self-discovery and peer-learning experiences. In 2017, points were adjusted to incentivize lab participation but not inflate course grades, a historical problem. In the graded portions of the labs, lab groups interpret and report on their data and answer a set of related questions. The questions are geared towards simple

performance analysis of an environmental engineering system or research on current topics or technologies related to the lab.

Treatment Plant Tour Reflections. (Individual/Out of Class Assignments) In past years, students have left EV350 without distinguishing between or confusing water and wastewater treatment process flows. To remedy this shortcoming, in 2017, students completed a graded reflection following tours of a drinking water treatment plant and a wastewater treatment plant. The reflection included stating the objective of each treatment train then list the purpose of each component process as well as conducted guided calculations of the plant process flows matching in class instruction. Instructors comment on students' responses.

Engineering Design Project. (Group/Out of Class Assignment) The EDP was very similar to one of the homework sets and centered on the design of a wastewater treatment plant given a set of constraints. Students either found it useful or the bane of their existence. In 2017, the EDP was cut in size and stream-lined to highlight problem-solving methodology.

Quizzes. (Individual/In-Class Assignments) Each quiz consists of choose-your-answer questions (usually a True/False and a multiple choice question) worth a total of 5 points and a calculation question worth 10 points. The quizzes complement the numbered homeworks by covering and providing pedagogical feedback on topics not otherwise tested before the administration of in-class exams during a semester. The quizzes were placed during lessons expected to be less busy.

In-Class Exams. (Individual/In-Class Assignment) In 2017, three in-class exams were administered as opposed to two in previous years to increase graded feedback for students. An exam fell at the end of each of the first three blocks (environmental chemistry & mass balance; water treatment; wastewater treatment) of the course. Each in-class exam was worth 100 points, 25 points less than a single exam offered in previous years. An effort was made to link each question to a lesson objective with comprehensive coverage of the block tested. Each exam was structured similarly: five multiple choice questions, two short answer questions, and three calculation problems.

Instructor Points. (Binned as an Individual/Out of Class Assignment) Instructor points incorporate weighted averages of peer evaluations (a self-policing mechanism for free-loaders) from lab group and EDP partners as well as a subjective instructor score for class participation. Given the subjective nature of these points, their value was greatly reduced in 2017.

As much as possible, graded events of the same type were structured and valued very similarly and predictably. Comprehensive graded events, particularly the TEE, followed the syllabus in topic presentation.

Instructors did their part to enhance the structural changes to the course. Instructors discussed and coordinated understandings of event grading rubrics to ensure consistent

application across the board. Additionally, in-class exams and the TEE were team-graded to maximize consistency.

Examination of the Efficacy of Assessment Model Adjustments

The efficacy of the adjusted assessment model will be examined both quantitatively and qualitatively.

Still assuming that the TEE is a comprehensive measure of course material mastery, a mastery of material indicator (MMI) can be formulated to quantitatively indicate how well course grades for a given year group reflect course mastery. This MMI, then, can be used to evaluate the assessment model.

The MMI can be calculated using the following:

$$MMI = (Course\ Average\ Excluding\ the\ TEE - TEE\ Average) * 100$$

The MMI will reflect the proportional spread between the TEE average and a year group's performance during the majority of the semester.

The MMI average is not a perfect tool; it rests on several assumptions. These assumptions include the fair structure and assessment of the TEE as well as consistent levels of ability and effort between year groups. However, as a tool, it can be used to better evaluate trends in course performance than course averages alone.

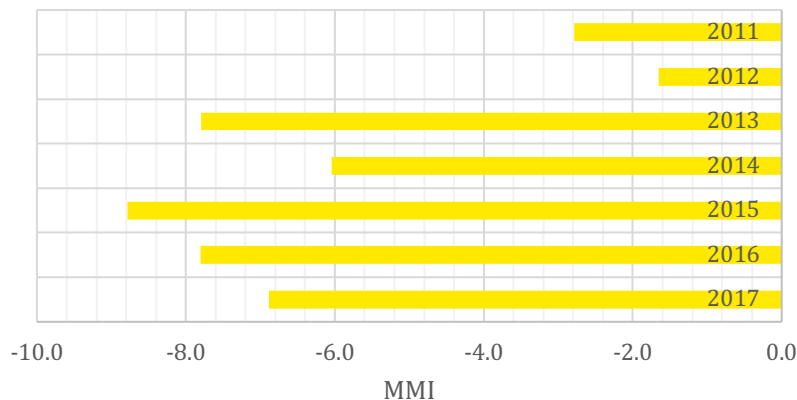


Figure 6 Annual Average Mastery of Material Indicator (MMI) for EV350, 2011-2017

Figure 6 shows that changes made in 2016 (re-arrangement of the TEE) and 2017 (increased individual feedback) had a limited though positive effect on MMI; in short, the trend is in the right direction. These changes were made with the understanding that our students are a changing generation of digital natives and perhaps our changes are working towards their needs.

If we continue to pursue a learning environment conducive to digital natives, hopefully the MMI will continue a positive trend.

However, what would be a threshold average MMI value to indicate a healthy course assessment model? The 2011 and 2012 year groups may be indicators. An MMI average in the threshold range of -3 to -2 may reflect a healthy assessment model with some realism that underachievers can throw off the TEE average.

The short answer section on the 2016 and 2017 TEEs is a case in point of underachievement on the TEE. The short answer is worth 15 points, 8% of the TEE, and asks students to outline a conventional water or a wastewater treatment train. Students performed very poorly on this section in 2016. However, even with required treatment plant tour reflections, students performed little better on the TEE short answer. It has been suggested that this learning may require more direct reinforcement in the classroom; data collected during the treatment plant tours can be used to evaluate treatment plant process efficiencies as in-class problems.

Table 5 A Glimpse at Student Synthesis of Treatment System Process Flow

	2016	2017
WWTP Tour Reflection Score (10 points)	<i>N/A</i>	77.7%
Primary TEE WWTP Reflection Score (15 points)	62.1% (n = 144)	62.4% (n = 175)
WTP Tour Reflection Score (10 points)	<i>N/A</i>	73.2%
Alternate TEE WTP Reflection Score (15 points)	63.0% (n = 40)	55.6% (n = 12)

Turning to subjective measures, survey results are used as metrics. At the end of each semester, students and instructors are surveyed about various aspects of the course. In part, the students are asked how well they can achieve the course outcomes (presented in Table 1) after taking the course. Instructors are asked how well they think their students can achieve the course outcomes. The respondents can choose from a Likert scale with responses ranging in value from 1 to 5 (5 being the highest level of confidence that students can achieve an outcome).

Table 6 Subjective Scores Based on Student and Instructor Exit Surveys, 2016-2017

Course Outcome		2017	2016
1	Design engineered systems...	4.16	4.33
2	Develop models...	4.12	4.14
3	Apply the environmental EDP...	4.09	4.12
4	Conduct lab experiments...	4.21	4.06

Table 6 shows that the averaged subjective scores for three out of the four course outcomes, including for Outcomes 1 & 2, which encompass $\frac{3}{4}$ of the points offered in the course, are lower in 2017 than in 2016. Interestingly and unusually, students scored themselves lower than

instructors for these outcomes in 2017. Furthermore, like-scaled performance-based scores show that students underperformed their expectation in only one of these course outcomes (Course Outcome 1, and then only by hundredths of a point) in that year. Rather than showing lack of confidence, this result may indicate heightened self-awareness, critical thought, and the recognition that there is more to learn than what is mastered (i.e. need for life-time learning), all desirable variations of ABET General Criterion III (Student Outcomes). McGlynn writes that learning activities (and, by extension, assessment tools as learner feedback) should be designed to: nest within a discipline's body of knowledge; support the institution's academic charter; and create opportunities for individual student growth [12]. In this way, the adjusted assessment model was partially successful.

Conclusions

Quantitative analysis demonstrates that the EV350 assessment model still requires more modification to accommodate digital natives. However, a qualitative analysis establishes that digital natives respond favorably to an assessment model that deliberately emphasizes individual feedback both in terms of grades and instructor comments. The MMI served as a good indicator of the perceived difference in course success and subject mastery. It is worth continuing to work towards course instruction and assessment that lead to a small MMI, bringing success and mastery in tune with each other.

A successful assessment model will balance collaborative opportunities with targeted individual assignments completed both in and out of class. The EV350 case study indicated that a successful assessment model will most likely feature:

- Majority online platform-based (in our case, Blackboard) homeworks to meet digital natives where they are. These homeworks will pull questions randomly from topical pools to minimize collaboration on assignments of this type. Students will have the opportunity to press the literal reset button for multiple (but limited) attempts to continue the learning. The instructors "capital expense" of time in preparing these pools of questions will have a quick payback period in terms of grading.
- Limited number of hard-copy homework assignments emphasizing thorough, transparent, and neat communication of an engineering solution. Ensuring emphasis on quality and thoroughness of work over sheer amount of problems, understanding many digital natives will approach these collaboratively and result in peer learning.
- Periodic, low-risk (lowered point value) in-class exams with a predictable structure, which mirrors course progression, reinforces proven problem-solving methodologies, and checks conceptual understanding. A predictable structure may help reduce exam anxiety and have an algorithmic-like feel for digital natives.
- Deliberately collaborative modular design projects with stated project constraints requiring on-line literature reviews and creativity.

- Experiential learning including demonstration videos, site visits, and labs backed by in class flipped classroom problem-solving sessions.

Institutional programs, including the authors' own, will most likely always be playing catch-up with ever-evolving digital natives and rapid turnover of technology. To remain relevant, these programs must not just seek to impart professional skills particular to a certain discipline, like environmental engineering. Such knowledge can be found and gained in other ways, too. Rather, these programs must recognize and magnify their value in teaching digital natives critical thought as well. Even if a course assessment model is responsive, one that consciously incorporates an increased capacity for critical thought will be successful in its own way.

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