Replacing Knowledge with Experience; the Second Millennium of the University

or what I learned from Dungeons & Dragons

Alan Cheville, July, 2008

Higher Education in the Information Age

> *"…the fact remains that the university of the twentieth century is the lineal descendant of mediaeval Paris and Bologna. They are the rock whence we were hewn, the hole of the pit whence we were digged. The fundamental organization is the same, the historic continuity is unbroken." [1]*

The above observation that the organization of universities has not changed significantly since the Middle Ages was published in 1923. While in some ways the role of the university in society *has* changed—and at no time more rapidly than in the decades following the Second World War—undergraduate programs still operate under the assumption that students must come to the university for knowledge. Even the word "university", which originated around 1300, is shortened from the Latin phrase "*universitas magistrorum et scholarium*" which translates as "community of masters and scholars". The oral and written information transmitted by master to scholar was once an extremely valuable commodity that could only be obtained by face-to-face contact. The university as it currently exists arose as the fixed location that scholars *had to travel to* in order to obtain the information they needed to become educated; at the earliest universities information was passed on by scholars hand-copying their books.

With the advent of the information age in the mid-1990's, students may obtain information without a physical presence at the university. In an excellent article in *Science* Eli Noam makes the argument that the commodity of information is rapidly dropping in value, undermining the entire structure of the university system [2]. In the decade since this article came out it has become clear that information is, in fact, cheap; what is not clear is what will replace knowledge as the commodity the university must sell if it wishes to retain its identity as "*universitas magistrorum et scholarium*". Within my own discipline of engineering the first cracks are appearing as the historic model of higher education begins slowly to fail.

The university needs to change, but significant change, as wise men have always recognized, is difficult; particularly when the *status quo* had existed for a long time. With the fundamental structure of the university unchanged for almost a millennium, most students, faculty, and administrators do not think much about how ingrained treating knowledge as a commodity is to the university's structure. Change within the university has always focused on knowledge, a historical example is the emergence of courses and the curriculum in the 16th century [3]. The move towards videos and on-line courses as new channels of transmitting knowledge is a more recent example. Nearly all efforts at curriculum or course reform retain the primacy of knowledge and focus on methods to reorder, redefine, acquire, retain, and/or transfer knowledge. However if the commodity you are selling, in this case knowledge, loses its value then over the long run efforts at packaging and marketing will not keep your business afloat.

The idea of knowledge as a commodity suffuses the entire structure and culture of higher education, but like the naked emperor but this idea cannot withstand close scrutiny. One example is grades which serve as ratings or records of how much students learn. Grades, however, are not particularly accurate measures of learning; so much so that grades aren't by themselves accepted as measures of learning by most accreditation agencies. In other words, students are rewarded for learning by being given a rating that the university itself can't use to measure learning! Grades, however, remain the "coin of the realm" in academia and, except for praise and encouragement, the only mechanism by which faculty can reward students for effort (or punish them for lack of effort). The analogy of grades as coin may be particularly apt. Like most systems of fiat currency the actual value of grades rests, to a large extent, on the long-term perception of the stability and value of grades. In order to have value, grades must be backed by the university and accepted in exchange for something of value, typically a diploma. Unlike currency, however, earning low grades

doesn't directly translate into "less" degree, although low grades can reduce a student's job offers and potential salary.

Beyond Knowledge: the Future of Engineering Education

The university, modeled after millennial old institutions, functions to transmit knowledge to students and rewards performance through the fiat currency of grades. There is a growing concern that this system no longer works at the level needed to sustain modern society. The National Academy of Engineering (**NAE**) and other legislative and advisory bodies recognize that Science, Technology, Engineering, and Mathematics (**STEM**) education is in a critical state. A decreasing number of technically qualified graduates will likely have a severe negative impact on the United States' economy unless concerted action is taken. Multiple reports have addressed this issue and the reader will be spared another recitation of the fact that a problem exists; a compendium is attached as reference [4]. While the panel summaries and committee reports unanimously agree action needs to be taken, they leave vague what to do, particularly down in the trenches at the university or program level.

While it is not clear what the university of the next decades will look like, it is abundantly clear that judiciously selecting a method of teaching, or pedagogy, that supports a given education outcome can positively impact how and what students learn [5]. While a comprehensive review of STEM education would take several volumes, a (very) brief overview will highlight certain trends.

- One of the fourteen "grand challenges" put forth by the National Academy of Engineering is to "advance personalized learning". According to the NAE, advances in information technology are allowing lessons that address individual needs and styles, breaking away from the historic recitation-based model.
- Although our understanding of intelligence and learning is still nascent, advances in neurosciences and psychology are driving a renaissance in education. A broader definition of knowing and knowledge, the basis of the university, is developing. Multiple new theories of intelligence, the strong effect of motivation and environment on learning, and expanded taxonomies of learning support the idea of fundamentally different *types* of knowledge.
- Team-based approaches to learning, drawing on peer support an socialization, are highly effective when they are implemented correctly. Supporting effective teamwork requires substantial effort and training on the part of an instructor, however.
- Contextualizing learning around relevant or important problems—service learning is an example— improves students' education in STEM disciplines.
- Research has shown that effective use of techniques that actively engage students in their own development produces better results than methods in which students are passive learners. It is worth noting that utilizing these pedagogies invariably changes faculty as much or more than students; they transition from oracles to mentors[1].

Experience has shown how difficult it is to implement and sustain effective teaching methods within the millennial old structure of higher education. One wonders if the current university structure is not only holding back advances in STEM education, but whether a 21st century education is even fundamentally compatible with the knowledge-centered university. Realistically, however, it is neither prudent nor possible to tear down a thousand years of university culture and build something new on the ashes. In order to replace undergraduate programs in a knowledge-centered university new models must allow smooth transitions from the current system, support the important research and extension roles of the institution, and retain and build on traditional cultural values while integrating emerging values from the next generations of engineers.

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[1] Both these roles allude to classical Greek mythology/literature. The *oracle* served as a conduit from the wisdom of the Gods, while *mentor* is drawn from Homer. Mentor was the advisor and tutor of Odysseus' son, Telemachus [6], a friend and counselor to Odysseus, and also an avatar for Athena, the goddess of wisdom and heroic undertakings. In Homer's *Odyssey* Mentor prepared Telemachus for a traditional role; both stayed home while Odysseus voyaged. Extending the allusion to Homer a little farther one wonders if traditional mentoring will prepare students for the challenges of 21st century engineering, or rather teach them to be conservative caretakers of the *status quo*? Perhaps what is needed is a learning environment that allows "odysseusing", a perilous questing performed in parallel to mentoring. The basic idea is best captured by Tennyson in his classic poem *Ulysses* [7].

The remainder of this white paper discusses an alternative model for undergraduate engineering programs that, in my opinion, is a natural extension of existing curricula and merges historical with emerging social and institutional values. The reader is cautioned that this alternative model has potentially strong cultural baggage so it may be necessary to make an effort to suspend personal biases and judge the arguments on their merits (or lack thereof) rather than popular media perceptions.

Fixing the Knowledge-Centric University

The proposed model for higher education program is drawn from modern development of games. Games are common to all cultures throughout recorded history and have been shown to be powerful tools for teaching. The proposed model draws, in particular, from role-playing games and their modern descendants. Role playing games likely first originated in the early 1970's [8] and were a radical departure from existing games. For those who have participated in role-playing games (**RPGs**) no explanation is necessary. For those unfamiliar with RPGs a very abbreviated explanation is given below to provide context for the rest of this paper.

In a role playing game each participant, or player, takes on the role of a fictional character they create. Here the term "player" is used to represent the human playing the RPG while "character" is used to refer to the human's alter-ego in the game. The characters are set in a fictional milieu—usually a Tolkien-like fantasy world although futuristic, historical, or other contexts are sometimes used—and interact with each other and the world. One of the participants takes on the role of a game master (**GM**) who acts as a story teller and referee. The GM gives information and background about the situation the characters find themselves in within the story and the players, in the role of their characters, respond to the story and help create it. The GM, using a well defined set of rules, then determines the results of the characters' actions and their impact on the story and relays this information to the players. The players respond and the rule-supported role playing continues, often for many gaming session extending over months.

While there are hundreds of different variations of role playing games they all share certain common features:

- Action in role playing games takes place in a well defined context. The game is built around an overarching plot that give importance and urgency to the actions of the characters. Within this context game play revolves series of quests or tasks the characters must complete. A character's development is strongly influenced by both the context of the story and their choice of quests. Quests in role playing games draw from basic themes of literature [9].
- Role playing games involve teamwork. In almost all RPGs the characters team together to fulfill their chosen quests and support each other with unique skills; for example one character may have fighting skills, another healing, while another acts as a scout. Players also develop as a team, learning each other's styles, strategies, and areas of knowledge. Teamwork is a vital aspect of RPGs.
- Role playing games heavily emphasize and support the development of new abilities for a character. At the start of a RPG a player's character has few abilities, little experience, and can manage few challenges. "The novice kills rats, not the dragon." A character's ability is usually quantified as their "level"; a new character is "first level". As characters successfully accomplish tasks (quests) they are rewarded with "experience points". After accumulating enough experience the character advances to a higher level at which point they gain new abilities and so are able to take on more advanced challenges. The quantification of experience is the primary scoring mechanism of a RPG. One of the engaging and motivating aspects of the RPG is the immediate feedback and reward of a player's character advancing in levels and ability.
- Role playing games allow a player to choose how a character develops. Players select their character's skills, abilities, vocations, and attributes from a large number of possible choices. The ability of a player's character to cope with a given situation depends on these choices. Players are given great latitude in guiding how their character's abilities grow over time and how they wish their character to specialize. No character has all abilities.

The combination of these elements seem to have tapped a chord in the human psyche and made RPGs an extremely popular pastime. Over the last forty years this form of gaming has exploded in popularity; it is

estimated that over twenty million people have played *Dungeons & Dragons*® alone and sales of *Dungeons & Dragons*® merchandise top $US one billion. It is an interesting observation that many of the elements of RPGs listed above—framing action in an important context, teamwork, a strong link between experience and new abilities, and choice in one's own development—align closely with what is currently known about effective methods of education. In my own opinion the popularity of RPG's is connected to the sense of personal advancement they create; a function often unsuccessfully filled by education.

Role playing games have been much more effective than education at taking advantage of the power offered by the personal computers, visualization software, and the collaborative medium of the internet. On-line games—technically known as massively multiplayer on-line role playing games (**MMORPGs**)—replace the score keeping functions of a human game master with a software program. On-line RPGs, the best known currently is *World of Warcraft*® (**WoW**), allow individuals or teams of hundreds of individuals spread across the globe to interact in complex and visually rich virtual world. The popularity of such games staggers the imagination. Consider WoW, just one of many MMORPGs. With a July, 2008 population of 6.3 million active residents [10] WoW ranks as the 37th largest city in the world, just above Hong Kong. In the US only New York, Los Angeles, and Chicago have larger populations. Put another way, in any given month *fifteen times* as many people are playing WoW as are majoring in engineering at *all* US colleges and universities combined [11].

Researchers have begun to take interest in the learning environment created by games. Most of the research on games and education has looked at using, adapting or writing games to help teach. I personally question, however, how much sense it makes to try to fit a late 20th century technology to the knowledge-based university which remains at its core a 13th century institution. Some researchers have begun looking at what games have to teach us about learning. James Paul Gee is generally acknowledged as starting this movement with the publication of *What Video Games Have to Teach Us About Learning and Literacy* in 2003. He has shown that games can serve as nearly ideal learning environments for some skills. Dr. Gee's Games+Learning+Society research group seeks to understand "*how these design features* [of games] *might be leveraged to improve learning via the design of learning systems, and how organizations such as schools will need to respond.*" [12]

The remainder of this paper explores how a university could adapt some of the basic ideas of role-playing games to transform higher education. The basic arguments build on Dr. Gee's research by arguing that the ideas and culture that underlie role playing games form a much better model for 21st century STEM education in the age of "free" information than does the traditional knowledge-centered university. If the state of STEM education is as dire as it seems [4] then bold and daring ideas are urgently needed.

A Brief Look at a Game-Based University

Many of the (deserved) criticisms of role playing games and gamers is that they are not rooted in reality. Gamers devote many hours to a pursuit that has great personal, but little material reward and does not advance more real-world ambitions. While such criticisms are valid, the fact remains that RPG's, including modern computer-based versions, are highly engaging to exactly the same demographic university engineering programs seek to recruit. Practically speaking, there is no reason that the highly successful and engaging structure of RPG's shouldn't be adapted to teaching engineering.

The remainder of this paper discusses how a university engineering program could incorporate ideas from role playing games to solve some of the most vexing and persistent problems that face higher education. Rather than outline a complete reform program—an exercise that would need to be done by individual institutions—four specific changes to university norms, customs, and practices are suggested. The following paragraphs discuss how each of these changes can potentially improve how students learn as well as difficulties that may be encountered in transitioning from existing programs. Fictional scenarios involving students and faculty are used to illustrate how changes might impact individuals.

<u>Change #1: Keep Track of Learning Using Experience Points Rather than Grades</u>
Currently universities measure student achievement using grades. A students' grade point average (GPA) is used as a proxy measure of overall student performance while the grade in a class serves as a measure of the quality of a student's work and depth of their understanding. As pointed out earlier, grades are not good

measures of student learning. While universities measure performance by grades, role playing games measure performance using a quantitative measure of experience known as "experience points". Experience points (abbreviated "**XP**") are awarded for completion of a task. The number of experience points awarded depends on the difficulty of the task and how well a character performs the task. For example killing a dragon would earn characters many more XP than killing a rat.

In an RPG-based degree program students would earn experience points for work in a class rather than be given a grade. There are many similarities between grades and experience points which would aid in making the transition from grade to XP within a degree program. As an example, consider a class in which eight homework assignments contribute 25% of the final grade, three exams each account for 20% and a project is the remaining 15%. In the present system students work towards maximizing their grade, in the RPG model student would try to maximize earned experience points. The examples below highlight some of the similarities and differences:

Traditional Program

ENG207 is a required course for graduation at State University and has a reputation for being difficult. Joe hopes he will make a "B" in the course since his homework scores are above the class mean. He got a 56 on the first exam, just below the class average, and needs to do well on the second test. Unfortunately he receives a 42 while the class mean is a 61. Joe now needs to decide whether to risk getting a C or to drop the course to maintain his GPA. He learns from Pick-A-Prof [13] that while few students fail ENG207, the professor gives few A grades and a large number of B, C, and D grades.

RPG-Based Program

Joe Engineer is doing fairly well on his homework assignments in ENG207, and has gained 324 experience points so far. Joe hopes to earn another 100 XP by the end of the semester on homework. He hasn't done so well on the tests, however, only getting 112 XP on the first test out of a possible 200 and 84 XP on the second test. In talking with his friends Joe learns that most students earn 1200 to 1500 of the 2000 possible XP in ENG207. He estimates he will be able to earn another 500 XP by the end of the semester, enough to advance to 14th level before Christmas break.

In the current model students often have to make difficult decisions between extending the time they spend in college and their GPA and career prospects. Seymour and Hewitt [14] discuss the serious impacts such choices have on students. In the current system students must obtain a passing grade to move forward in the curriculum; should the student receive a failing grade the class counts *against* them regardless of what they have learned. In the RPG-based program, on the other hand, students gain experience points for a class regardless of performance. Poorly performing students simply do not earn as many experience points, advance much more slowly towards graduation, and have to retake classes or find other ways to gain experience. High performing students advance more quickly. Lets take a look at another impact of moving from grades to experience points, this time from the faculty perspective:

Traditional Program

Dr. K has taught ENG207 for eleven consecutive semesters. He believes the material provides some of the most important foundational material in the engineering program at State University and his grading policy reflects the fact that students need to master the content. Although the tests reflect what was taught in class and given on the homework assignments the class average is usually low. After a discussion with the department head several years ago Dr. K typically sets the mean score on the exams to correspond to a low B- or high C+ to ensure enough students pass. Several times he has had to award bonus points to the class after the final to "balance" the grades in his class.

RPG-Based Program

Dr. K tries very hard to make sure the tests and homework assignments in his ENG207 course are at a level that reflect the level of competence expected from students. While, most students only early about 1300 XP of the 2000 XP available in the course, the better students are able to earn 1800 or more. Several years ago Dr. K's department head noticed that students were not gaining enough experience points in ENG207. To help students Dr. K developed three quests available to 10th to 15th level engineers which students can undertake to earn additional XP.

As the example above illustrated there is little pressure on faculty to "curve" grades in an RPG-based program. Since experience points are rewarded based solely on performance, student learning is much more closely correlated with the number of experience points earned than is a grade. Thus in a RPG-based

program experience points, the replacement for grades, *can* be used for assessment. This fact alone would help reduce the workload of departments who need to implement and sustain assessment of student learning for ABET.

Another benefit of moving from grades to experience points is the effect such a change would have towards strengthening academic integrity policies. Under the current grade-based system, violations of academic integrity are usually punished by loss of credit for an assignment. Even if a student's grade drops due to being caught cheating, in most cases students pass and receive full credit for the course. In particularly egregious cases a student may fail a course, but such draconian measures are rare. In my opinion grade-based deterrents for cheating are generally ineffective. In a RPG-based program academic dishonesty would result in immediate loss of XP. Losing experience points has the direct effect of delaying graduation and may result in dropping to a lower level- described in the next section. This is certainly a strong deterrent.

Change #2: Replace the Curriculum with Graduation Based on Level

Measuring a students progress towards a degree changes under a RPG-based program. Currently, a student's status (i.e sophomore) is based on the number of credits completed. When a student has passed required courses in the specified order (followed the curriculum) and earned enough credit hours in a given subject they graduate. Student advancement is based solely on receiving a passing grade in courses. In contrast, under a RPG-based program a student gains experience points as they complete assignments. Cumulative experience points are used to determine a student's level, which is turn is used to determine a student's status and readiness for graduation. In a RPG-based program a student graduates when they become a 40th level engineer. The relation between status, level, and XP is illustrated by a fictional implementation in an undergraduate engineering program:

Traditional Program

Deb, in her third year at State University, is technically a senior with 94 credit hours due to AP classes from the magnet high school she attended. She had to drop a required course last semester when her sister got leukemia, and since it was a pre-requisite for other courses she will take at least nine semesters to graduate instead of the recommended eight. Since Deb loses her scholarship after eight semesters, she is considering reducing her course load to make time for a part-time job. Deb would like to keep her GPA above 3.6 to be more competitive on job interviews. In order to boost her GPA and also be able to enjoy her senior year more Deb plans to graduate after ten semesters and schedules a meeting with her academic advisor to see if her plans agree with the course flowchart.

RPG-Based program

Deb, in her third year at State University, is a 31st level engineer with 62,345 experience points; she needs 100,000 XP to graduate at 40th level. Deb earned some XP at the magnet high school she attended, and took on several quests to earn XP when she couldn't attend college one semester when her sister got leukemia. Since Deb wants to graduate in three semesters she plans to advance three levels each semester. Senior level classes and quests typically are worth 4000 XP (Freshman classes are 1000 XP, Sophomore 2000 XP, and Junior 3000 XP). Deb plans to really concentrate on school next semester both because it is her last semester with a scholarship and if she can get to 35th level she will be high enough level to join a capstone team and trade in her old laptop for the latest model. She saw her best friend just reached 33rd level when she read the department status board which is updated weekly with the names of all students who have advanced in level.

The example above illustrates several differences between the RPG-based program and the traditional university program. First, a level-based system for measuring student progress makes each student's progress through the program clear. Since students graduate at 40th level they advance eight to ten levels each year, on average once a month. Advancing through levels provides continual positive feedback for students. In current undergraduate programs a student's progress can be difficult to determine since few students follow the idealized four year course plan. Skipped, dropped, or failed courses result in wide variations from the planned curriculum. In my university a full-time staff member is needed to ensure students meet curricular requirements for graduation despite the fact that the students have little choice in what courses to take.

A second change would be how programs monitor student learning and progress towards graduation. While the RPG-based program provides students more direct feedback, it would likely present a much more

complex accounting challenge for the university. The inclusion of quests (discussed later), more freedom to arrange schedules, and potentially more ways for students to progress through the program could overwhelm existing resources. While this accounting presents a formidable challenge, existing role playing games and MMORPGs have developed detailed and robust systems that calculate character progress accurately and reliably. One research aspect of transitioning to an RPG-based program is examining existing RPG's and adapting the most suitable to a university degree program.

A third, and more daunting, aspect of the transition would be the process of eliminating grades, credit hours, and pre-requisite courses as a method of tracking student progress through a program. Under an RPG-based program rewards for academic performance are more substantial since students progress more quickly towards graduation, but there is no single number such as GPA to distinguish one 35th level engineer from another. In a RPG-based program grades and student transcripts would be replaced with a tally of how many experience points or levels students might have in different sub-disciplines or core requirements. This change could have several beneficial outcomes:

- Rather than grades, students would be differentiated by how much experience they had in different areas of engineering, mathematics, languages, and so forth. Identifying meaningful differences between students would become easier than under the traditional system where potential employers and graduate schools have to decipher the student's transcript.
- By choosing, within reasonable boundaries, where to concentrate their studies, the RPG-based system better allows students to "customize" their credentials. Currently students within a program are distinguished more by their grades, extra-curricular activities, and relevant non-academic experiences than by the degree program and curricular choices.
- Keeping track of how many XP students gain in key areas both simplifies accreditation and makes it more accurate. For example, ABET accreditation requires students have one year of math and science and one-and-a-half years of engineering topics. A program could more easily ensure all graduates met certain standards—for example 25,000 XP in engineering, 7500 in math, and 9000 in science—than design and implement measures to assess whether learning outcomes were met in courses outside a department's purview.
- Moving to a RPG-based model would greatly simplify determining and enforcing pre-requisites both for students and programs. For example a sophomore engineering course might have as pre-requisites that students must be 12th level with 4000 XP in mathematics and 2500 XP in physics to be eligible to take the course. The RPG-based system is potentially much more flexible towards pre-requisites which could have a positive impact on retention, particularly for non-traditional or minority students [14].
- A RPG-based program supports meaningful team design experiences, critical in engineering courses, by ensuring student teams have the range of experience to tackle complex design projects. To see how this might be implemented Deb and her friend sign up for a capstone design course in the example below:

Traditional Program	RPG-Based program
Deb, in her last semester, has completed all the pre-requisite courses and is taking the required capstone design electrical engineering course with her friend Megan. They have been assigned to a project team that is building a robot that can be remotely controlled by a cellular phone. Three other students are on their team, but only Megan has taken the digital signal processing elective. Megan is given responsibility for designing the tone-decoding circuitry. Deb, through Hobson's choice, ends up being responsible for the robot hardware, despite having little formal training to prepare her for this role.	Deb and Megan, both 35th level, are finally eligible to take the required capstone design quest. Together they go to the capstone lab to look through the available quests so they can be on the same team. A cellular phone controlled robot project looks interesting and the team is looking for someone like Megan with at least 4500 XP in signal processing. Unfortunately this project is also looking for someone with 12,000 XP in mechanical design; Deb's experience does not align with the needs of the project. The friends choose a project designing an infrared heads-up display needs someone with 2500 XP in image processing which Megan has, as well as someone with 7500 XP in microcontroller experience which is Deb's specialty.

One of the features of distinguishing students by level rather than grades I personally find most appealing is the inherent equality of students under such a system. In a RPG-based program all 30th level engineers are equal, distinguished only by the types of experience they have earned. I believe such a system could eliminate the subtle stigmas that arise from being a "C" student or unearned benefits that accrue to those who have the reputation as "A" students.

Change #3: Beyond the Classroom- Quests and Extracurricular Activities

In a traditional undergraduate program, progress towards graduation is measured by the number of credit hours a student has completed. In order for relevant student experiences—no matter how supportive of professional development—to count towards graduation they must be recognized by the university as a course. Most programs recognize how restrictive this requirement is, and offer one or more "independent study" or "special project" courses in their curriculum. In contrast, under the RPG-based program, allowing relevant experiences to count towards graduation becomes much simpler since a student can be rewarded experience points outside of a course. Beyond simply accounting for relevant experiences such as technical summer jobs and co-op experiences the RPG-based system would draw from the gaming world and offer a wide range of experiences to students in the form of "quests".

A quest is any activity outside the classroom by which a student could gain experience points. Currently a wide range of professional development opportunities exist at universities, but student participation is often limited since these activities don't directly count for "credit". Under the RPG-based program activities like attending technical talks, participating in the student chapter of the professional society, outreach activities, participating in national engineering competitions, serving at a mentor or tutor, or service learning activities would all allow a student to gain XP. For each of these activities a maximum number of experience points could be earned and the level of a student's participation would determine what fraction of the available experience points they earned. The RPG-based program gives real value to activities that support students' development as engineers.

Quests serve as valuable alternative pathways to gain experience points in the RPG-based program. Since XP are awarded based on performance, a "B" student (under the current system) might earn, on average, 80% of the XP available in a given class and thus gain levels and progress more slowly than an "A" student. To offset different rates of advancement faculty in an RPG-based program would offer quests to allow students alternative paths to advance towards graduation. Such quests might be independent study projects or labs associated with a course. Faculty who believe in the importance of solving large problem sets to master basic skills could offer problems sets outside of class for students to gain extra XP. Quests need not be directly related to course content. A department might develop, as we have done in our capstone design courses at Oklahoma State University, a set of training exercises in engineering instrumentation or processes that develop skills in specific technical areas. Since XP could be awarded in different areas of knowledge, quests would be another mechanism by which students could "customize" their credentials in an engineering program as illustrated in the fictional example below:

Student Viewpoint

Eric, a 27th level engineer, completed a summer internship and made up some of the XP he lost after a bad sophomore year. During his internship he peformed RF measurements and is interested in pursuing microwave engineering as a career option. Eric learns that there is a RF engineering course, but unfortunately he needs to be 32nd level and earn 2400 more XP in math and 3200 more XP in numerical modeling to take the course. When talking with the instructor, Dr. Diggs, Eric finds out three quests are offered that will let him explore how to use a spectrum analyzer, high speed oscilloscope, and vector network analyzer. To qualify for the quests Eric just needs to gain 520 XP in Matlab. He begins to look for quests that will allow him to get experience in Matlab.

Faculty Viewpoint

Jim Diggs teaches electromagnetic fields and researches the effect of electric discharges on RF systems. He has, for the past several years, offered research projects to undergraduates after he developed a series of quests that let students master the use of common RF instruments. About half of the students in his courses complete at least one of these quests to make up for the experience points they lose on the exams. One of Jim's colleagues has approached him about developing a series of quests jointly between aerospace and electrical engineering, but Jim had to decline since he is developing a new series of quests around finite difference time domain software. Jim hopes these quests will help him identify some potential candidates for graduate studies.

In summary, quests serve as ways for students who don't perform as well academically as peers to advance towards graduation at the same rate. Rather than stigmatizing such students with a low grade, the RPG-based model simply ensures that they gain other relevant experience that may fit better with their interests and career goals.

Change #4: Addressing the Dissemination Dilemma

By opening up alternative pathways to graduation through quests, the RPG-based model may help solve one of the most persistent and vexing problems in STEM education: the difficulty of disseminating material between universities. The present system stymies the spread of educational innovations in several ways. First, any new innovations need to be done within the framework of a course both to justify faculty time and reward students with progress towards graduation. Since a course represents approximately 1/40th of the student's educational experience, the current system ensures reform is coarse-grained and requires large investment. Second, since courses (theoretically) build on one another within a university's curriculum a course at University A, no matter how innovative and effective, can't directly transfer to University B since curricula differ between institutions. Third, faculty need to select, adapt, and interpret material for their course based on their own interests and biases. Thus there will always be additional faculty effort required to transfer innovations even if curricula were identical.

The RPG-based model bypasses some of these roadblocks to dissemination. Since in an RPG-based program both classes and quests move a student toward graduation, reform no longer needs to focus on creating or modifying courses. By focusing innovation on *quests* rather than courses reform becomes more fine-grained. For example, a university could develop a series of quests focused on getting students to develop engineering skills such as analyzing data, numeric modeling, or using test and measurement instrumentation. These quests, which a student could undertake independently to gain XP, fall outside the normal course structure and thus are independent of a given universities curriculum. A program could offer quests developed at other universities to students *as-is*, without the expense and time needed to modify the material.

Another advantage of the RPG-based program is that quests of any size, type, or complexity can be incorporated into a university's program. As a first example consider the utility of a small quest. Here, a student may need 200 XP in some area or sub-discipline to qualify for a class they wish to take or make up for poor performance on an exam. In this case the student would look for a simple quest that will gain them the needed experience points. In a student's junior year (20th-30th level), where nominally 3000 XP advances a student a level, this is 1/15th of the XP offered for a class or roughly one week of typical class work. A suitable quest in this case might be solving a large problem set, computer modeling of an engineering system, or development of a software algorithm. On the other extreme are quests worth as much as, or more than, courses. Significant extra-curricular experiences such as *Engineers Without Borders* or service learning projects are examples. Often in role playing games quests are sequential; completion of one quest qualifies one to begin another. The total number of experience point for completing a sequential series of quests could be more than those offered for a class. For example an instrumentation quest might have students debug a complex circuit in stages, learning the use of new measurement instruments sequentially.

Beyond simply allowing a wider range of more easily adopted reform projects, the RPG-based model fundamentally shifts the focus of reform from changing knowledge structures to development of engineering skills. I argue that this is a necessary shift if the calls for action to improve STEM education [4] are to be fulfilled. The reason change has been glacial—despite long-term and significant funding by the NSF and other agencies—is that changing a curriculum is simply too big a task for most programs. Beyond trying to change a culture that developed over a millennium, reasons it is nearly impossible to change a curriculum include: the heavy investment of many faculty in the current curriculum, deeply held beliefs about teaching and what students need to learn, the "not in my course" syndrome, the need to meet state or regents requirements, and the biases of faculty and administrators in determining what an ideal curriculum should be. Certainly these factors will hinder changing to the RPG-based model proposed here, but once implemented change becomes easier. One observation I have made, based on reviewing engineering education proposals, is that there is a shift in reform efforts to activities outside the curriculum for exactly these reasons. The RPG-based model simply provides a convenient method to reward students for engineering experiences.

What Next?

This white paper makes the argument that the thousand year old, knowledge-based structure of universities has difficulty creating learning environments that are effective for today's STEM students. Meaningful reform of STEM education will require equally meaningful (and difficult) reformation of university organization and culture. Role playing games, developed in the late 20th century, offer a model for future university programs that can solve some of the most pressing issues we face in reforming our educational system. Although such reform would face significant challenges, the knowledge and expertise that has developed around role-playing games can provide needed guidance for engineering degree program reform.

What next? There are several ways to test the assertions made in this white paper. One way would be for a university program to adopt the RPG-based model. Given my own experiences trying to implement less far-reaching change this option seems unlikely at best for an existing university program. A more practical alternative would be to offer an engineering summer camp for students to test the ideas of experience points, quests, and levels. Such a program would offer an educational test-bed to determine if the claims made in this white paper would transfer to practice. A more academic approach would be to conduct research on what aspects of successful role playing games or MMORPGs could be adopted by universities to improve student learning- see reference [12]. Such research could examine other aspects of role-playing games—such as acquiring items that help a character complete quests, multi-class characters, or the idea of character "attributes"—which can support meaningful learning [15].

I would like to conclude this white paper with a personal anecdote. After becoming PI of a large department reform project at Oklahoma State University, I was often asked to give talks on engineering education to engineers, educators, and students. One evening at the end of a talk to a group of engineering students I got one of those insightful, out-of-left-field questions that can stop a good presentation dead in its tracks. "*Of all the things you talked about tonight that need to be fixed in engineering education, what is the one single biggest problem?*" The question completely stumped me since like many in engineering education I have become used to repeating a litany of problems. After an uncomfortable pause I thought of a passing comment made by a colleague and answered, "*Somehow we have made it not fun anymore.*" Education is important, but so is having fun while learning. Perhaps by modeling our programs after successful, engaging games we can make learning fun again.

Bibliography

1. Haskins, H., *The Rise of Universities*. 1923, New York: H. Holt and Co.

2. Noam, E., *Electronics and the dim future of the university.* Science, 1995. **270**(5234): p. 247-249.

3. Goodson, I., *Chariots of Fire: Etymologies, Epistemologies and the Emergence of Curriculum*, in *The Making Of The Curriculum: Collected Essays*, I. Goodson, Editor. 1995, Taylor & Francis: London.

4. The National Academy of Engineering has outlined the critical need to reform STEM education in several detailed reports. The reports can be read electronically at the NAE website (http://www.nae.edu). The most widely read are:
   - *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (RAGS) calls for a systemic reform of both the research and education enterprises to enhance national competitiveness. RAGS emphasizes that both national security and economic security and prosperity will increasingly depend on technological innovation. Key recommendations are:
     - Improve K-12 education primarily by increasing qualifications and number of teachers.
     - Strengthen support of basic research.
     - Ensure US universities are world's best for undergraduate and graduate students.
     - Implement policy changes that support technology infrastructure
   - *The Engineer of 2020: Visions of Engineering in the New Century* (E2020) projects what the skills and knowledge needed by engineers in the next century should be by examining possible future scenarios. While speculative, E2020 challenges the engineering profession to define a broader, more inclusive vision for the future of engineering and work across disciplines bring about the vision.

- *Educating the Engineer of 2020: Adapting Engineering Education to the New Century* (EE2020) is a followup to E2020 on the steps needed to prepare students to face the engineering profession in 2020. A list of recommendations challenges universities change engineering education at the undergraduate level, but the challenges are purposely general rather than specific.
- *The Center for Advancement of Engineering Education Portal for Administrators* is available from the CASEE link on the NAE website has more material on policy reports that impact how engineering should be taught and the consequences of not addressing engineering education. (NAE→CASEE→Portals→Administrators)

5. National Research Council, *How People Learn: Brain, Mind, Experience, and School*, ed. J.D. Bransford, A.L. Brown, and R.R. Cocking. 2000, Washington, DC: National Academy Press.

6. The commentary on the role of Mentor was likely first published in the late 17th century. For a discussion see Andy Roberts' *Homer's Mentor: Duties Fulfilled or Misconstrued?* This work is referenced as being published in the November 1999 volume of *History of Education* but I was unable to find this citation. An electronic copy can be found at http://home.att.net/~nickols/homers_mentor.htm

7. Tennyson, A., *Poems by Alfred Tennyson*. 1862, London: Edward Moxton.

8. Bay Area Role Playing Society, *History of D&D*. This online document is available from: http://bayrps.com:8000/history_of_dungeons_and_dragons.htm

9. Barrette, P. *The Quest In Classical Literature: Structuralism And Databases*. in *Association for Computers and the Humanities and the Association for Literary and Linguistic Computing*. 1999. University of Virginia, Charlottesville.

10. The current population of WoW can be found on the web site *WarCraft Realms* at the internet address: http://www.warcraftrealms.com/census.php

11. Data on the number of engineering students was obtained from *Science and Engineering Indicators 2008*. 2008, National Science Board: Washington, D.C.

12. Several years ago I had the pleasure of introducing Dr. Gee when he spoke at a teaching seminar at Oklahoma State University. His talk was likely the stimulus that started this white paper. Although the commentary in this paper is drawn from my own experiences in engineering education reform, Dr. Gee's *Games+Learning+Society* research group has delved more deeply and more rigorously into the ideas expressed here than I have. More information can be found in his books or at: http://gameslearningsociety.org/index.php

13. Pick-a-Prof is a website where students can rate their professors. Although some students use the site to flame faculty, many of the ratings are informative. The site can be accessed electronically at: http://www.pickaprof.com/

14. Seymour, E. and N. Hewitt, *Talking About Leaving: Factors Contributing to High Attrition Rates Among Science, Mathematics, and Engineering Undergraduate Majors*. 1994, Bureau of Sociological Research, University of Colorado: Boulder, CO.

15. In role-playing games characters' abilities are enhanced by items, similar to enhancing an engineering design by having the right component. In the RPG-based model students could be given access to new tools, components, software, or computational facilities as they advance in level or XP. Such material rewards would help mark a student's advancement through the program as well as help students learn about options for components and tools. The idea of a multi-class character (two disciplines) is well developed in RPGs and could lead to meaningful cross-disciplinary programs. Character attributes in RPGs help determine what role a character plays: strong characters are fighters, intelligent characters are magicians, nimble characters serve as rogues, and so forth. While it is not easy to quantify a real individual's abilities the way a game can, it remains true that each individual has unique abilities and interests that steer their path through a university program. By supporting alternative pathways through engineering programs the RPG-based model more easily accounts for an individual's inherent strengths and interests as well as helping student learn where their own abilities lie.
