

Building Continuous Loop Learning Communities: An Engineering Outreach Case Study

Dr. Deborah Besser, Dr. Gerry Swan, Dr. Thomas Dziubla and Dr. Richard Eitel

Abstract – Declining numbers of students entering the science, technology, engineering and mathematics (STEM) disciplines is an issue that has captured the interest of the nation [9][10][7]. This attention has focused a lens on various facets of STEM education including educational methods, recruitment, and retention. Change, including cultural change, is an underlying theme of the many solutions proposed to the STEM challenge [13]. Parallel to the change issues is an attunement to diversity recruitment and retention programs. The authors of this paper report on an engineering outreach program, which seeks to incorporate the construct of learning communities on various levels as one method of STEM cultural change. The outreach program seeks to provide students with an introduction to engineering, faculty with an opportunity to design and test curriculum for both outreach and undergraduate education and a technology mechanism to design, deliver, share and assess outreach activities as part of integrated loop learning. Preliminary results of assessments, faculty reactions and software beta testing from the pilot program are presented in this paper.

Keywords: Learning Communities, K-12 Initiatives, Interactive Engineering Education, Diversity Recruitment and Retention Programs, Engineering and Engineering Technology Curricula.

I. PROGRAM NEED

What does the National Science Academies report *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, the National Governors Association report *Building a Science, Technology, Engineering and Math Agenda*, and the Kentucky Council of Postsecondary Education report *Kentucky's Science Technology Engineering Mathematics Imperative: Competing in the Global Economy* all have in common [9][10][4]? These reports and numerous others point to the need to improve science, technology, engineering and mathematics (STEM) education or risk further economic demise. The later, Kentucky based report, points to the acute need to modify practices in Kentucky. Of particular relevance to this study is the specific problem statement that “Collaboration among STEM professionals within P-20 [preschool through college] education is not currently sufficient to produce widespread improvement in Kentucky’s STEM performance. Improved collaboration between P-12 [preschool through secondary education] and higher education is critical to the creation of an adequate STEM pipeline within Kentucky.”[4]. Central to the authors’ pilot program was collaboration between higher education and teachers and students at the high school level.

Aligned with this need to strengthen STEM education and collaboration is a need to broaden and thus diversify the STEM education pool. A broader, inclusive education focus will foster greater numbers of high tech workers in an ever expanding global economy, will better reflect the full range of consumer demographics, is essential as the tremendous number of Sputnik-era engineering boomers retire, and is vital to synergy and innovation in the creative process [11]. The engineering field in general has lagged other fields in recruiting, admitting, and graduating racial minorities, with the exception of Asian/Pacific Islander. National Science Foundation statistics indicate the percentage of degrees awarded to non-Caucasian racial/ethnic groups in science and engineering groups is significantly outpacing science and engineering bachelor’s degrees awarded to Caucasian students. NSF reports that minority populations “are expected to be more than half (52 percent) of the resident college-age (18-24 years old) population of the United States by 2050, up from 34 percent in 1999” Additionally, “the greatest growth among minority groups is projected for Hispanics and Asians/Pacific Islanders” [12].

The attention to a diversified education focus results in enhanced education for all students. For example, the Center for Research on Education, Diversity & Excellence (CREDE) promotes best teaching practices which benefit all

students with the following practices “facilitate learning through joint productive activity among teachers and students. Develop students’ competence in the language and literacy of instruction throughout all instructional activities. Connect curriculum to experience and skills of students’ home and community. Challenge students toward cognitive complexity. Engage students through dialogue, especially instructional conversation” [3]. The authors of this study strove to address the issues of STEM educational issues with an attunement to diversity by beginning a pilot high school student pre-engineering summer program. This program based in the University of Kentucky, College of Engineering, allowed students, high school teachers, and college professors to collaboratively explore pre-engineering education in a low-risk and potentially high benefit setting.

UK BEST Design

The 2007 pilot offering of UK Building Engineering, Science and Technology (UK BEST) provided rising high school junior students who identified themselves as interested in contributing to the diversity of the engineering educational experience, the opportunity to simultaneously strengthen pre-engineering academic skills while discovering the varied opportunities available in an engineering profession. Previous research has parsed out psychosocial factors and correlated increased technical self-efficacy with experiential mastery experiences [5]. Thus this program included key experiential activities which allowed students to build self-efficacy while constructing their own understanding of how their talents and interests would best combine with an engineering degree to offer the individuals multiple engineering options.

The UK BEST program drew lessons learned both from best practices in science, mathematics, and engineering education, as well as, other successful programs with comparable goals including the Summer Preview of Engineering and Technology (STEPS), JETS—UNITE (The Uninitiates' Introduction to Engineering Program), and the UK Engineering Summer Program (ESP) [1] [6]. The UK BEST program daily schedule began with a math warm-up session which was related to the day’s project. The math warm-up sessions lasted an hour and often included a game or play component. The daily engineering projects were the core of the program and were completed in optimized teams of two. Time and space were included for discovery of science and mathematical lessons through exploration. Projects included construction and testing of model cars, microelectronics, composite material, model scale bridges, and flash programming. Project experience was complemented by relevant research laboratory and industry tours.

The following pictures illustrate some of the design projects and team building activities. The program website, <http://www.engr.uky.edu/outreach/2007UKBESTPHOTOS.html>, provides a full program pictorial review.



II. UK BEST LEARNING COMMUNITY

Figure 1 illustrates the connections between the various members of the UK BEST learning community. During the first implementation of the program the focus was on bringing in faculty members to work with the rising juniors. Based on this initial pilot we can begin to refine and develop the mechanisms for providing curriculum support for University Faculty and K-12 Educators. This section describes the experiences from the university faculty and K-12 student perspectives.

Faculty Experience

Unlike high school teachers, young engineering faculty typically have no formal educator training. With the risks of failing in class being too great, this results in a culture of learning that is slow to adopt more progressive teaching styles. While the department and college are encouraging, new professors, for fear of risking poor performance reviews, will normally implement the same lecture class format that they had during their education. UK BEST provided us an opportunity to try out techniques, such as active learning, in a safe environment. Therefore, we organized a lecture period where we discussed what chemical and materials engineering are, asking for their thoughts as to what we do or could do. This method allowed us to demonstrate the wide variety of work that our disciplines possess. Following this lecture, we gave a brief overview of polymer chemistry with an in class example of polymer properties (e.g., silly putty synthesis), to show how molecular properties determines the final material properties.

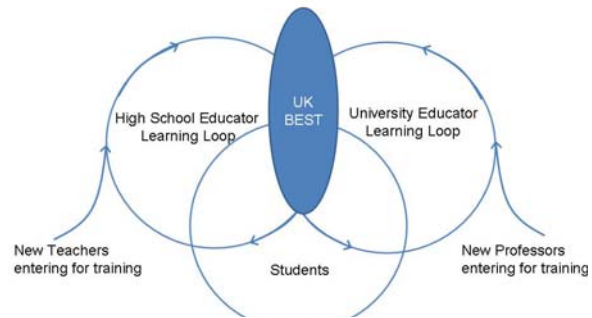


Figure1: UK Best Learning Community

The goal of this module was to provide each student the opportunity to solve a practical materials engineering design problem. Specifically, students were tasked with the design of energy absorbing composite structure. The ability to absorb mechanical energy without failure is key performance requirement for many structural applications. In order to assist students in the design of suitable composite a commonly used materials science paradigm was used, see Figure 2, which illustrates the interconnection between various contributions to a ultimate materials performance. By definition a composite material is made up of two or more materials typically having vastly different properties. Producing a composite structure requires an understanding of each aspect of the materials science pyramid; the properties of the individual materials, the structure of the composite (in terms of the physical arrangement of the various materials), and the way in which the materials are assembled will all impact the ultimate performance of the composite part.

A key contributor to the success of this module was the choice of materials familiar to the students and avoiding the use of any expensive or possibly hazardous equipment. The materials and supplies necessary for this design module were chosen are all non-toxic, readily available, inexpensive, and require no special safety measures, or equipment. Energy absorbing panels were made out of a matrix of either plaster of Paris or paraffin wax and discrete phase consisting of an assortment of different shapes and sizes of spaghetti. The panel was constructed on plastic cafeteria trays. The only special equipment required was a container and heat source suitable for melting the paraffin wax. Students were randomly split into groups one group was assigned wax and the other plaster of paris as the matrix. Beyond assignment of the matrix students were given complete freedom to develop the best design using a large array of different pasta shapes. Immediate feedback with regard to the design project was testing the panels by dropping a series of steel balls onto suspended panels at increasing heights until the ball completely penetrated the panel. The weight of the ball and the height of the highest drop which did not perforate the panel were used to calculate the amount of the energy adsorbed by the panel. In the competition phase, we provided an award for students which had the most durable composite. We determined this by calculating the energy of impact of the drop prior to breakthrough. To account for composite size, we normalized this energy by total mass of the composite. Students were highly engaged throughout the module, and their willingness to ask questions was quite pleasing. During the course of the wax composite synthesis, I would ask questions in how they would optimize the formation of their composite. For example, I asked “Could they predict how long the composite would take to solidify?” While

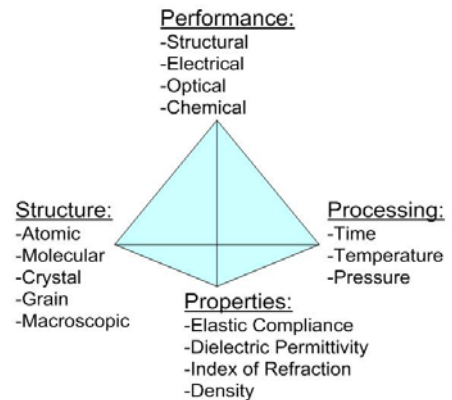


Figure 2. The materials science paradigm

they worked and offered up potential methods, I went to the board and started writing out some principles of heat transfer. By knowing how long it takes to cool the system to drop below the wax melting point, we can know how long it takes to solidify. Many students were interested to see how such a simple, mundane process could have advanced engineering/ principles involved. This was a very rewarding feeling, to know that students felt the excitement that an analytical understanding of their world can bring. It is my belief that it is such moments that will be the biggest draw to science and engineering. UK BEST provided an outstanding medium for these moments to occur.

During the course of the module, several procedural and technical challenges were encountered. While these did not detract from the enjoyment and learning of the participating students, they represent important areas of improvement that will ensure that all planned elements are fully realized. We were faced with the dilemma of rapidly transitioning the students to working with building their composites, but wanted to ensure that they used some planning and design in the process. As such, we attempted to have students draw a composite plan that we would approve. Unfortunately, we did not provide enough explanation nor did we give an example of a design plan. This resulted in student confusion and ended up taking students more time than necessary for the experiment. An improvement over this system would be to give students the composite design question ahead of time (1 day). This will give them freedom and opportunity to create a design with minimal time pressure and open up more time in lab.

While not intended the judging metric we used, in the competition phase energy adsorbed divided by the weight of the panel, actually illustrates one of the most important aspects of engineering design. In many applications (such as the transportation industry) reduction in component weight is key engineering consideration. However an analysis of the type of testing geometry used yields the result that the energy adsorbing ability of the panels should increase with the square of the thickness, while the mass increases only linearly with thickness. This type of analysis by the proper application of engineering principles reveals a thicker panel should more than compensate for its greater weight in its energy adsorbing capacity.

Student Experience

An understanding of the student experience was acquired through the formal assessment as well as an informal daily reflection activity. The formal assessment measure is loosely based on the NSP sponsored Assessing Women in Engineering (AWE) pre-college participation instruments [2]. The assessment tools were modified for male participation; the participants' constructs of career awareness, confidence or self-efficacy, supportive community, and college environment exposure are elements of interest to the program developers. Thus modified versions of the AWE pre-survey, post-survey and six-month post survey were employed.

Pre-survey

The pre-survey included a descriptor section which includes participant profile, career awareness, self-efficacy, supportive community and college environment exposure. The *participant profile* section built a basic profile of the students, which included information on students' expectations of the program, how the participants learned of the program, completed coursework, and anticipated coursework. The *career awareness* section explored participants' anticipated post-graduation choice, their understanding of engineer's functions, participants' interest in engineering and influencing factors. All participants indicated intent to attend college immediately after graduation and an interest in exploring engineering as a possible job choice. The majority of the participants choose the following descriptors to describe engineers: "engineers work with other people to solve problems" and "engineers have lots of choices about what they can do in their jobs". The highest activities and people which respondents indicated most influenced their decision to explore engineering were 1. hands-on activities related to engineering 2. science, engineering, or technology teacher and 3. a parent/guardian.

When asked the open ended question "what do engineering students do?" the majority of the respondents referenced problem solving, mathematics, science and hands-on projects. Trends along gender lines emerged with males tending towards answers involving efficiency and females tending towards answers involving altruistic motives and cooperative work. For example Male 1 responded "Engineering students focus on problems that can be solved using mathematics and sciences. They do their best to solve these problems in the most efficient and effective manner possible." Female 1 responded "Engineering students work with other people to help solve problems for the betterment of mankind."

The *build confidence* section included questions which asked respondents' to list things engineers might develop. The majority of the respondents indicated that engineers design items including "bridges, cars and health equipment." The respondents also indicated that influences in their lives were either supportive or neutral in regards to the respondents' post-secondary and math/science aspirations.

The *supportive community* section gave further evidence of generally supportive environments, albeit environments with limited science, math and engineering exploration opportunities. Finally the college environment exposure section revealed that 85% of the participants had been on a university campus prior to this program, the average response rate of participants likelihood of going to University of Kentucky was 57% (standard deviation of 25, minimum of 5, maximum of 90), and the average response rate participants likelihood of majoring in engineering was 68% (standard deviation of 21, minimum of 40, maximum of 100) in the pre-survey.

Post-survey

The post-survey administered immediately after the program followed a format similar to the pre-survey with students' experience in the program, career awareness, self-efficacy, supportive community and college environment exposure. The students' assessment of the program was overwhelming positive and generally met or exceeded the participants' expectations. The item noted with the highest frequency as being the best component was the "design hands-on activities", the second item was "others". In participants' own words "I like designing and building the different activities", "learning about different types of engineering and getting to know the people", "building things", "I like building things", "the active learning, hands-on activities", "the people", "I liked working with my fellow campers to build things", "being able to be with kids my age with the same interest", "I really enjoyed building the car and the wax structure project" and "the hands on activities and the people." When asked "if you were in charge, how would you change this activity?" six participants noted that they would not change the program, three participants noted that they would include more building activities, three participants noted they would give more time for sleeping, and seven asked for shortened tours. All of the participants noted that they would recommend UK BEST to their friends.

The *career awareness* section revealed that students had expanded their understanding of what engineering education and the engineering career entails. Participants described what engineering students do in the following terms: "they do a lot of calculus", "they take a lot of math and science courses and possibly co-op", "study engineering and a broad range of classes", "study a lot", "learn math and science skills". Respondents indicated that engineers "apply their knowledge of math and science to create new things and solve problems", "they solve problems to make our lives more comfortable", "they work hard to solve problems and to help make life more efficient and better", "work with other people to build/design new things and solve problems", "they create most things and help others meet their needs or solve problems", "design, fix and create a wide range of things and work with people to find solutions to problems", "build, design, make possible every tangible thing", "work to solve problems and create new things".

The *self-efficacy* and *supportive community* sections of the post-survey reflected the high confidence and supportive environment already displayed in the pre-survey. Clearly the participants understanding of engineers' influence was significantly expanded. When asked what engineers might develop that could make a difference participants responded with "everything", "new medicine, new forms of renewable energy", "weapons, medical devices, hybrid vehicles", "fuel efficient transportation, entertainment, safer structures", "medical devices, materials, new technologies", "ceramics, chemicals, lights, bridges, roads", "medical technology, electronics to make life easier, building/bridge safety", "medical machines, robots that make life easier", "everything", "transportation, processed foods, computers, technology", "create new materials, build structures, improve motors", "human clones and everything sprouted from the seed of good intentions".

The *college exposure* section showed an increased interest in engineering and attending the University of Kentucky; both measures increased 12% from the pre-survey. The average response rate of participants interest in attending the University of Kentucky increased to 69% (standard deviation of 19, minimum of 25, maximum of 100), and the average response of majoring in engineering increased to 80% (standard deviation of 18, minimum of 50, maximum of 100) in the immediate post-survey.

Daily Reflection

Separate from the formal assessment instruments were the daily reflections. This assessment was designed to serve as a participant post-processing reflective learning tool. The daily reflection questions are drawn directly from the STEPS program and included the four following questions: 1. What was the best thing about your day today that you will remember for a long time? 2. Was there anything you did today that you would have liked to have done differently? 3. Is there anything that you have done today that you have never done before? What was it? 4. What did you do today that required you to use math or science? By administering the daily reflection with Casemate the program designers were equipped to use the participants' responses as a formative and summative assessment of the students self construction of engineering as these constructs were shaped. The candidness reflected the excitement of discovery: "I liked the tours that we did today because I hadn't seen those type of things up close. The solar car was cool because you got to hear how they actually worked on it, and the lab was something I've seen NASA work on (on tv) but today I actually got to experience it." "I will always remember making the car. It was tough but fun. I like my idea of changing the transmission." "I really enjoyed working on the model cars. It was a challenging and difficult task that took hard work and creative thinking. My partner and I worked well together so that made the whole experience more enjoyable." "I really enjoyed building the wax sheets. It was fun to decide which formation would absorb the most damage."

The participants demonstrated authentic learning as they constructed new math and science concepts from their experimentation: "The gear ratios tie a lot of science and math combined. The math came in the ratios and science was needed to balance forces and find a happy medium between torque and speed." "Most of the day I tried to use the brute method, towards the end of the second session, I learned to plan everything out with math." "All of the activities required me to use some form of math or science." "The best thing about my day that I will remember for a long time would be the basis of polymers and what bonds form to make certain substances and materials." And just maybe the participants learned some important life lessons: "The best thing about my day that I will remember for a long time is never doubt yourself because you don't know if something will work until you try."

IV. IMPLICATIONS AND NEXT STEPS

The enthusiasm generated by the program with the K-12 students who attended is a definite positive out come for the program. This is the expected outcome one shoots for when designing an exposure program. The secondary benefits of University Faculty seeing this type of program as a low-risk arena to develop and fine tune curriculum is very exciting because of the opportunity to engage in undergraduate education reform. To foster the linkage between outreach and post secondary education, efficient mechanisms for creating, sharing and assessing materials in both settings are needed. In April of 1997, the U.S. Department of Education published a research report on 16 school sites that were developing and implementing performance assessments for students. In the report it was stated that "the potential for applying new information and communications technology to performance assessment remains unrealized at all levels of education" [2]. Even though this report is a decade old most universities would find that it still rings true. The development of a platform to serve as a sort of "program coagulant" is currently underway.

In 1998 George Lawton wrote an article entitled, "Paving the information Superhighway's Last Mile". The last mile references the need for increasing the connection speeds from the Internet backbone to the home and office as being critical if users are going to make use of the multimedia capabilities of the Internet. The level of access is improving in schools, but is still an issue that is being actively addressed. While the article is about the "emerging technologies" of cable modems and DSL, it serves as a good metaphor for the use of media and the Internet in instructional settings. With the advent of the Internet the development of materials has exploded. There are multiple academic repositories as well as non-academic sources that instructors can utilize in their instruction. One of the early lessons from using the Internet in instructional settings was that simple turning individuals loose on the web to learn was ineffective at best. This problem gave rise to the development of techniques and processes that teachers could use to structure the use of online materials. The WebQuest format developed by Dr. Bernie Dodge at San Diego State University is probably the most prominent example of a framework approach to building activities that utilize online materials. While instructional frameworks have given educators a roadmap for structuring activities and online repositories have made locating resources easier, there is still the problem of the instructional last mile.

Educators still must go through the process of packaging and publishing materials for students to use. Many educators do not have the skills or access within their districts to efficiently create web pages. Even if they have the ability to create a website, there is the question of its effectiveness from a design perspective. The proposed tool provides an environment where instructional frameworks, online materials and data collection intersect. Another target of the environment is to allow flexibility in instructional approach while encouraging good instructional practices. The tool will provide a content management platform that would allow instructors to create a cohesive instructional module in which they upload their own media they may have developed (such as powerpoints, flash animations or word processing documents) or media from other repositories (such as YouTube). Data collection engine will be developed so that each module can have an assessment component allowing students to keep a journal for the module or take multiple choice or open ended questionnaires. The reporting engine for Casemate will allow the module owner to look at individual responses or aggregated data across instruments. A prototype of the environment called CaseMate has been developed to begin the initial exploration of this idea. CaseMate is being developed with all Open Source software. The CaseMate application provides an authenticated environment for both authoring and participating in cases.

The module layout will have simple navigation scheme that will incorporate solid design principles and encourage the effective use of media. The current framework uses a module development metaphor of categories and elements. Categories are used to organize the module according to an instructional framework. The learning cycle is a well accepted format for designing inquiry based instruction. It breaks up instruction into four stages: engage, explore, explain and elaborate. If an instructor wanted to set up an inquiry activity in CaseMate he or she could use these four stages as the categories. The elements associated with each category would be comprised of various media and assessments. The example shown in Figure 2 is a video clip element from YouTube of the Tacoma Narrows Bridge.

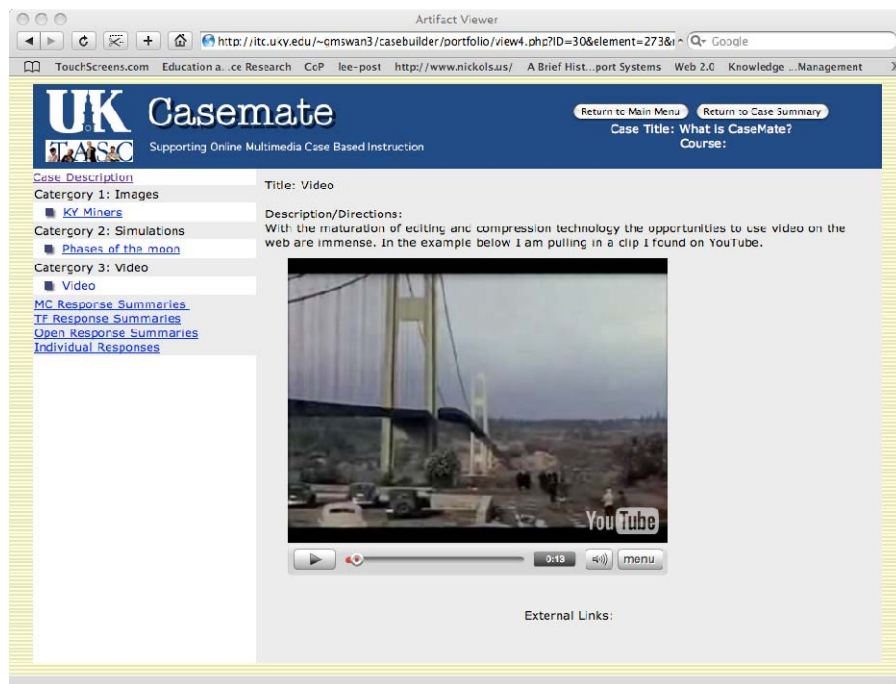


Figure 2: Module Presentation Layout

The ability to embed assessments within the cases is what differentiates the CaseMate environment is what differentiates from a traditional web presence. Figures 3 is a screen shot of one of the data summaries that illustrates the potential assessment benefits of the CaseMate environment. The screen shots are taken from a pilot case that was performed in UK101, an introductory course at the University of Kentucky, where students were given pre-post surveys on issues relating to violence against women. There were over 1000 students who took the module and figure 3 shows a distribution report that allows the module instructor to quickly aggregate the data and make judgments about what areas the follow-up presentation should focus on.

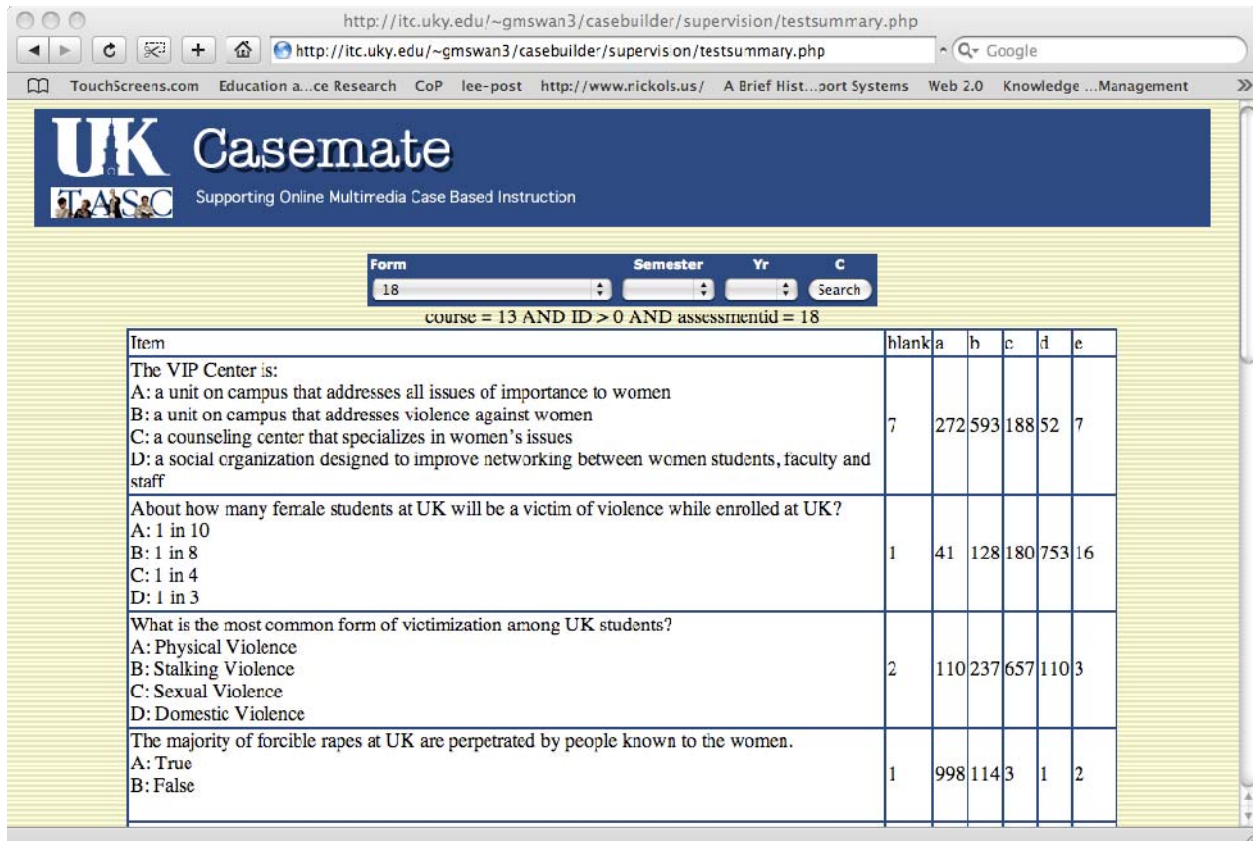


Figure 3: Data Summary for the Pre-Test

In addition to facilitating real time data collection and reporting, as was done with the daily reflections, the CaseMate environment will facilitate longitudinal assessment and enable better programmatic assessment to take place. The UK BEST team envisions being able to reuse modules in K-12 school professional development to provide teachers with the background content knowledge in a specific content (such as linear motion, rotational motion, conservation of energy and forces). As part of the PD teachers will be shown how to create their own modules in the system that they can use with their own classes, which would allow the university to follow its impact back to the K-12 classroom. This step would also create the connection for the K-12 educator learning loop in the UK best community. The ability to have a mechanism to connect the various members of the UK BEST community will be a crucial element that determines how well knowledge is transferred between the various groups.

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