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In this issue:

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Utilization of Robotics in Higher Education

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Abstract

The use of technology in the classroom has evolved from the most primitive to the widespread use of personal computers. One of the trends in technological advancements to enter the classroom is the use of robotics. The relationship between robotics and education spans many years. This paper details Papert's *Constructionism* theory defining learning as being more effective when students are "constructing" or "doing" activities that are personally meaningful. Research includes assessment of experiences of this method of teaching Information Technology through robotics at such institutions as West Point, Reykjavik University and University of South Florida. Based on the experiences reported at the various institutions, authors conclude with recommendations to Bryant College as the college launches an integration of the utilization of robotic components into the Information Technology curriculum to more effectively introduce students to Information Technology concepts.

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1. ROBOTICS IN SOCIETY

There has always been a fascination with how the mind works and with the possibility of creating a machine that could think and act like humans. Although a machine has yet to be produced that can completely achieve that goal, the field of robotics and its associated research has continuously provided society with new methods of assisting and educating humans.

George Devol, founder on Unimation, designed the first programmable robot approximately 50 years ago. The UNIMATE, an industrial robot and product of this design, began work at General Motors in 1961. The 4,000-pound arm was utilized to handle molten metal door handles. Today, the use of industrial robots is common as over 950,000 robots were operating in the industrial world in 2001 (Galaasen, 2002). Typical applications of industrial robots include welding, painting, ironing, assembly, palletizing, product inspection, and testing; but industrial robots are most frequently utilized on automobile assembly lines due to their ability to provide higher precision and a lower cost of labor.

During a six-year period beginning in 1966, the first mobile robot to know and react to its own actions was developed at the Stanford Research Institute. Shakey, named for its erratic and jerky style of movement, had a TV camera, a triangulating range finder, and bump sensors. It was connected to DEC PDP-10 and PDP-15 computers via radio and video links. Shakey used programs for perception, world-modeling, and acting. It could perform simple moves as well as more complex tasks, including making and executing plans to achieve goals given it by a user. The system also generalized and saved these plans for possible future use (SRI, 2004).

In addition to their being perceived as machines that assist in manufatcuring, society's perception of robots has also been developed by television and the movies. From Robbie the Robot appearing in Forbidden Planet in 1956, through the cartoon Jetson's Rosie the Robot in 1962, R2-D2 and C-3PO in Star Wars (1977), to the movie I, Robot; science fiction entertainment portrays the future as a time when humans have become completely dependent upon their robots, but where robots no longer obey Isaac Asimov's Three Laws of Robotics:

- A robot may not injure a human being, or, through inaction, allow a human being to come to harm.
- A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
- A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

The relationship between robotics and education also spans many years. It has evolved from one based solely in research to one that now includes activity-based learning for students of all ages and abilities.

2. EARLY ARTIFICIAL INTELLIGENCE RESEARCH & DEVELOPMENT

Early university involvement in the subjects of artificial intelligence and robotics occurred in the fields of research and engineering. Artificial Intelligence is understood to describe any attempt to utilize computers and associated devices to simulate human actions. Modern day robots, and their uses, have been developed partially as a result of artificial intelligence research. An overview of that progression can be viewed in the below table.

YEAR (Key Persons)	**HIGHLIGHTS**
1956 (Allen Newell and Herbert Simon)	Allen Newell and Herbert Simon invented a program that solved math programs and were thought to have created a thinking machine; one that knew more than its programmers (Haack, 1984).
	Earliest relationships between education & artificial intelligence (AI) formed in 1956 at Dartmouth College. Workshop proceeded "on the basis of the conjecture that every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it" (McCarthy, 1955). John McCarthy, an organizer of the study, is credited with the phrase "artificial intelligence".
1959-1970s (John McCarthy and Marvin Minsky)	McCarthy and fellow Dartmouth researcher, Marvin Minsky, co-founded what later became known as MIT Artificial Intelligence Laboratory. Minsky made significant contributions in intelligence-based mechanical robots, in addition to contributions to AI.
1970s (Marvin Minsky and Seymour Papert)	Minsky promoted a representation of knowledge considered as the early form of object-oriented programming. Minsky presents knowledge as "frames" (experiences and understandings with general characteristics or values attached to them), which have been developed by past frames (Pioneers, 1999).

3. CONSTRUCTIONISM

The theory of *Constructivism*, identified as the V word by Papert, was created by Jean Piaget. It is based on a belief that children create meaning by doing more than just listening. They attempt to derive meaning by thinking about the subject matter, and these efforts create the meaning and the knowledge – an idea of learning by doing. Utilizing their experiences, the children build frameworks called "knowledge structures".

Seymour Papert was a colleague of Piaget's in the late 1950s and early 1960s, (and later was a colleague of Minsky). Papert supported *Constructivism* and believed it could be utilized to create an educational method. He believed that conventional school environments were too dominated by instruction and that learning is more effective when it is activity-based rather than passively received.

In his essay *Situating Constructionism*, Papert expressed his preference for *Constructionism* over *Instructionism* by describing the use of construction kits in teaching mathematics:

> *Children might come to want to learn it (mathematics) because they would use it in building these models. And if they did want to learn it they would, even if teaching were poor or possibly nonexistent. Moreover, since one of the reasons for poor teaching is that teachers do not enjoy teaching reluctant children, it is not implausible that teaching would become better as well as becoming less necessary. So changes in the opportunities for construction could in principle lead to deeper changes in the learning of mathematics than changes in knowledge about instruction.*

The *Constructionism* theory of learning has two facets: that learning takes place as a result of actively constructing (or creating) new knowledge and that learning is most effective when 'constructing' or 'doing' activities that are personally meaningful, like computer programs or robots. Hands-on construction is a significant part of the learning process. However, just as important as construction, in the *Constructionism* strategy for education, is the opportunity for the students to think about and discuss what they have done.

Constructivism vs. Constructionism

Constructivism is considered a cognitive theory identifying mental modes of constructing knowledge structures, whereas *Constructionism* is considered an educational method (founded on the learning theory of *Constructivism*), where constructing something visible and usable to others is the *means* to achieving the building of the knowledge structures.

The theory of *Constructivism* recognizes that knowledge structures can be realized through lectures or transmitted knowledge (as long knowledge structures result); *Constructionism* discounts lectures and other forms of transferred knowledge since constructing is the means to achieving a meaningful method of constructing knowledge structures.

Constructivism does not preclude that individuals can construct same meanings.

Constructionism differs in that the philosophy purports that the student will construct his or her own completely unique meaning for all that is learned. Students therefore control their own learning regardless of the instructor. In consequence, individual evaluations measured against norms are deemed ineffectual.

A Language for Learning

Seymour Papert, alongside others, created the programming language Logo in 1967, partly as a method for applying the constructionist theories and partly as a method for advancing mathematics education. Papert designed the language to be utilized by novices, including young children, but also sophisticated enough for experienced programmers. As a derivative of the programming language LISP as used in research on artificial intelligence, Logo is modular, interactive, and flexible; promoting learning in all areas from mathematics to robotics to music.

In his well-publicized book *Mindstorms, Children, Computers and Powerful Ideas,* Papert advocated Logo as a language of learning for children:

- Logo programming contributes to the acquisition of general thinking and problem-solving skills, that can be transferred to other content domains;
- Logo provides an ideal environment for learning basic mathematical concepts such as angle, polygon, variable, function, recursion, etc.

There was a tremendous rise in Logo usage in the early 1980's created by Papert's *Mindstorm* and a pilot program at the Lamplighter School in Dallas, Texas.

In a small school about three hundred children had access to nearly fifty Logo computers. The number of computers meant that the teachers in the school were unable to keep track of what was happening. So the first grade students were only taught how to use objects to make still pictures while the third graders were taught how to put objects in motion. For the first two weeks the first graders made still pictures with enthusiasm, enjoyment, and educational benefits. Then something much more exciting happened. The effects the third grade students produced, making objects move, greatly impressed everyone including themselves, their parents, and the first grade children. The situation became slightly 'unstable' (as Papert describes it), until the moment when someone in the first grade had acquired enough knowledge to ask someone in the third for an explanation - and to understand the answer just enough to go back and do something powerful enough to impress the others. This first grader understood enough to produce an action, an action interesting enough to start a movement among the first graders. According to Papert, this is how real learning happens. "You understand just enough to get going, to do something and to learn by doing and by discovery" (Papert, 1982).

Products for Learning

In the mid-80s, Mitchel Resnick and Stephen Ocko, working at the MIT Media Lab, created LEGO®/Logo, a computer-based robotics environment. The package allowed the students to approach and personalize design projects from different directions and perspectives, and created a sense of community where groups shared ideas and designs (Ocko and Resnick, 1988).

Consistent with Papert's theory of *Constructionism*, Resnick and Ocko (1988) wrote the following to describe the ideas that formed the development of LEGO®/Logo:

> *In our experience, design activities have the greatest educational value when students are given the freedom to create things that are meaningful to themselves (or others around them). In such situations, students approach their work with a sense of caring and interest that is missing in most school activities. As a result, students are more likely to explore, and to make deep "connections" with, the mathematical and scientific concepts that underlie the activities* (Ocko and Resnick, 1998).

The first Mindstorms™ kit was released in 1998 as a product of LEGO® Dacta. It has not evolved much since its initial release, though software available to program the RCX microcomputer has increased, largely due to users who felt the RCX code was severely limited. Many software options now exist such as NQC (Not Quite C), Visual C++ and Java.

Today, LEGO® markets robotics products for the home as well as for the educational environment. The current Robotic Invention System 2.0 contains the following:

- RCX™ Microcomputer
- CD-ROM Software
- 717 LEGO® elements
- 2 Motors
- 2 Touch Sensors
- 1 Light Sensor
- Infrared Transmitter

The robotic kits have been created to allow for a step-by-step progression from beginner to advanced level, accommodating individual abilities. Although not specifically marketed to college programs, Mindstorms™ kits are being utilized in courses including robotics, computer science, and information technology.

4. APPLICATIONS IN LEARNING

Elementary & Secondary Schools

As anticipated by Papert, the LEGO® Mindstorms™ system has proven to deliver an engaging and stimulating learning experience for elementary and secondary school students with a hands-on practical application of scientific, mathematical, and technological concepts. Teachers also value LEGO® Mindstorms™ as a tool for providing opportunities to develop creative problem solving skills. With products as such, students can program paths for the robots to move from place to place, while avoiding obstacles & delivering items. According to Robotics Online (2004), the Mindstorms™ system, combined with certain software additions such as ActivMedia Robotics Basic Suite (ARBS), can also effectively extend the reach of the classroom by functioning as a roving "web cam" to promulgate interaction with classmates for the student who requires a period of distance learning. Sheffield Hallam University's research entitled, *Educational Impact of LEGO® Dacta Materials* (2001) indicates that the introduction of LEGO® Dacta resources to a pilot elementary school resulted in student achievements exceeding those pupils taught using different media with pupil and teacher motivation levels high. Yet, LEGO® Mindstorms™ is not to be limited to children.

Higher Education

With versatility and scalability, products such as Mindstorms™ have proven to be exceedingly effective in undergraduate and graduate settings, with additional enhanced creativity achieved through competitions within the class settings and often between various universities and colleges. Mindstorms™ is an appealing product for the university-level student and is frequently used in introductory Computer Science and Engineering courses. LEGO® Mindstorms™ is now integrated in curriculum at many esteemed universities nationally and globally such as MIT, Brown University, University of Maryland, Tufts University, University of Aarhus at Danemark, University of Utrecht in the Netherlands, Trinity College Dublin in Ireland, and University of Manchester in the United Kingdom. The Mindstorms™ system can be a cost- and time-effective means of reinforcing behavioral robotics principles to students of different disciplines and with limited programming skills (Gage & Murphy, 2003), and it demonstrates new customized behaviors quickly for students by practically applying learning concepts when introducing students to robot control and programming in an engaging manner. The system can also provide a rich environment that introduces students to critical technologies such as fundamental computer programming concepts, embedded computer systems, computer vision, infrared data transmission, and mechanical principles such as gear ratios and levers (Schumacher, Welch, Raymond, 2001).

Shortcomings have been noted regarding LEGO® Mindstorms™ when used in higher education such as the pervasive limitations presented in working with the standard programming language. It has been described as too simple to perform complex tasks elegantly; or reasonably powerful yet awkward for anything other than simple tasks (Gage & Murphy, 2003). Schumacher, Welch & Raymond (2001) stated that the LEGO® programming environment is ingenious in its design for a younger audience, but the system does not supply adequate flexibility to teach undergraduate students. Nonetheless, universities and colleges continue to find LEGO® Mindstorms™ as a truly valuable and economical option for supplementing a course in behavioural mobile robotics and work to create enhanced programming environments to work around the inherent limitations.

Overall, student reactions & reviews seem to measure positive when working with LEGO® Mindstorms™. For the introductory course work, the system does provide the option to be used virtually straight away, without a requisite of prior programming experience. Students are able to complete fundamental tasks that directly reinforce the material taught in class, thus visualizing the concepts in robotic motion. The group interaction when working with the system promotes teamwork and students are able to collectively apply creativity in further exploring issues introduced in the lectures and readings. LEGO® Mindstorms™ system is used in many inter-collegiate competitions, which not only encourages student inventiveness, but also provides the stimulus for developing and solving complex challenges. Though LEGO® Mindstorms™ has principally been utilized for engineering and computer science disciplines, its value in the IT curriculum can be measured in looking at successes at West Point, University of South Florida, and Reykjavik University.

The Example of University of South Florida & Reykjavik University

Laboratory experiments were conducted during robotics courses at both University of South Florida & Reykjavik University for the evaluation of the educational impact of the application of LEGO® Mindstorms™ with students of different disciplines and with limited programming skills. As part of this course in Robotics, undergraduate and first-year graduate students in computer science, psychology, and engineering worked in small groups to build and program robots to perform a variety of tasks designed to complement select chapters in the textbook *Intro-*

duction to AI Robotics. Exercises were developed to reinforce concepts such as:

·Affordances (perceivable potentialities in the environment for an action):
Students built robots with complete random motion that navigate an area that is constructed of white & black dots. The robots detect the dots using a light sensor point at the ground reinforcing the idea of perceptual affordances and biologically inspired behavior.

To complete this exercise, students working in groups of two or three required two to three hours. Programming the robot was the most time-consuming aspect. Teacher preparation was approximately 15 minutes.

- Schema Theory
  Students built robots that followed a wall using an antenna (touch sensor to detect the wall) and a dark line on the ground (using light sensor) using the same motor schema. This demonstrated that a biologically inspired behaviour composed of perceptual and motor schemas allowed different perceptual schemas to be paired with a single motor to perform the same kind of task with different sensors.

  To complete this exercise, students required approximately two hours. No teacher preparation was required.

- Manipulation
  Students built a robotic gripper that would grasp soda cans, to reinforce the notion of affordances, to introduce sensor fusion, and to practice the design of a stateful reactive implementation as in the gripper detecting the soda can.

  To complete this exercise, students required approximately two hours. No teacher preparation was required.

- Computer Vision
  Students built a motorized pan-tilt unit for the camera, programming it to track targets using vision. This provided an introduction to issues in computer vision.

  To complete this exercise, students required an approximate two hours. No teacher preparation was noted.

- Robot Interaction
  Students applied concepts in robot teams as in programming the robots to cooperatively detect a target and guide one another toward the target with infrared signals.

  Students required a minimum of three to four (or more) hours to complete this exercise. Programming was a time-consuming aspect and challenging. Teacher preparation includes building a spare robot, for an estimated one hour of preparation.

  The student reactions were positive, and the pedagogical objectives were met in the course exercises such as (Gage & Murphy, 2003):

- Active, Hands-on Learning Environment / Motivational
  Through the building and programming of robots, the students enjoyed an informal, fun environment while gaining hands-on experience in basic programming.

- Practical application during subject exploration
  Students explored issues in behavioral robotics through lecture materials and reading assignments, and further reinforced the material by practically and directly applying and enhancing the material as in *Constructionism*-based learning.

- Team building & creative problem solving:
  Students experienced team building with enhanced creativity in solving difficult problems. Objectives in the exercises were often exceeded, with students opting to earn extra credit for more complex alternatives.

With an estimated cost of $200 per Mindstorms™ kit and an additional $50 for the Vision Command kit, the LEGO® products used in these laboratory experiments are described as a cost- and time-effective means of augmenting robotics principles to students who are limited in programming skills and from varying disciplines. The hands-on learning complemented lectures and course texts, with robots constructed to perform tasks that directly illustrated the concepts learned in the lectures and texts. Lab sessions allowed empowered students to creatively solve difficult problems within the groups, while visibly enjoying the learning process in an informal environment. Groups often exceeded exercise requirements (for extra credit), thereby exploring more complex options and variants. Students worked in groups of two or three, though pre- and post-lab worksheets were due from each respective student to ensure individual contribution. Lab manuals were written based on the results and observations in these classes, and each of the lab exercises was designed to be able to be completed within a single four-hour lab session (Gage & Murphy, 2003).

The Example of West Point

West Point is committed to equipping its future leaders of the Army and the Nation to understand and be capable of taking advantage of IT. Since the influence of information technology on the battlefield is defined as increasingly significant, it is a requirement that all undergraduate students take a course on IT and problem solving using computer programming, so as to expose each student to technology and the concepts that will be a component of their daily lives and future careers. Each semester, over 500 students take a course entitled "Introduction to Computing". West Point is continually revising and improving its introductory computer science courses, and therefore the Electrical Engineering and Computer Engineering departments at the United States Military Academy added the use of LEGO® Mindstorms™ in this required course to teach fundamental computer programming concepts and to introduce concepts of autonomous vehicles, embedded computer systems, and computer simulation. The faculty at West Point found that the LEGO® programming environment did not provide enough flexibility to teach undergraduate students and thus was compelled to create a new environment named Jago, which allows for programming in Java while enabling a simulation of the robot that will ultimately be constructed with the LEGO® Mindstorms™ system.

The positive short-term impact on the students taking this course is cited as being substantial, with long-term impact, though unmeasured, showing the potential to be substantial (Schumacher, Welch & Raymond, 2001). Exercises were developed such as:

- <u>Common Scenario</u>
  In this scenario, the cadet is told that the commander has provided a prototype robotic system that can maneuver across terrain with obstacles. The student's task is to evaluate the system, write an algorithm to negotiate two types of obstacles and successfully maneuver through a test track. There is a specified time limit.

- <u>Specific Assignment</u>
  In this assignment, the student competes to develop a robot that would be utilized for urban warfare and potentially weapons delivery through the air ducts of an enemy bunker. Robots must negotiate 12 feet of ductwork within a limited amount of time.

  The defined purpose of this course at West Point is to teach and apply a problem solving methodology using programming primitives and to teach cadets how to learn about new IT and its uses (Schumacher, Welch & Raymond, 2001). Additional pedagogical objectives for integrating LEGO® robots into the course included:

- <u>Active, Hands-on Learning Environments/ Motivational Tool</u>
  The *Constructionism*-based learning of Mindstorms™ aligns well with the heavy emphasis that is placed on an active-learning environment at West Point.

- <u>Practical Application/Visualization for Cadets in various disciplines</u>
  West Point understands that Computer Science and Engineering students may have more aptitude for the abstract structure of an algorithm, whereas students majoring in other disciplines will typically have difficulty visualizing these concepts even with the use of Graphic User Interfaces (GUI). West Point has discovered that students across multiple disciplines can understand algorithms

through the motion of a robot because it is easier to visualize.

- Exposure to Embedded Code & Autonomous Devices
  LEGO® Mindstorms™ provide cadets with an introduction to autonomous vehicles and embedded code. These are crucial IT learning objectives at West Point. For the cadet, real-life use of embedded code is evidenced in the next version of the infantry rifle, which has thousands of lines of code embedded (Schumacher, Welch & Raymond, 2001). Robots also provide the cadets with a hands-on understanding of the difference between a remotely controlled device and a truly autonomous device.

- Exposure to Simulation
  Coupled with the programming language designed by the faculty at West point, the process of developing the robot gives cadets key exposure to simulation, which is a critical military technology. Simulation plays an increasingly vital role in all aspects of the military from system development, through training, and also with decision support. Students can better visualize the algorithmic primitives of sequence, selection, and iteration using HTML and Java (Schumacher, Welch & Raymond, 2001).

Thus, in preparing and educating graduates to defend the interests of the United States of America, the Electrical Engineering and Computer Science Department at the United States Military Academy at West Point has succeeds in utilizing robotics effectively in educating and exposing all undergraduate cadets to technology and concepts such as fundamental computer programming, embedded code, autonomous vehicles, and computer simulation. Purchasing LEGO® products sufficient to serve 500 cadets per semester per course would likely have been deemed a significant expenditure, in addition to a formidable task for the tracking and cataloging of the approximate 750 pieces per kit. Thus, the Electrical Engineering and Computer Science Department creatively reduced the potential logistical burdens by developing the Jago language, which also allowed for an additional learning objective: simulation. Thus, prior to any assembly of robots, the cadets design code, write their Jago programs and test them on the Jago simulator. Once the algorithm design is confirmed, the cadet can then enter the lab ready to verify that the code runs on the robot as well as it does in the simulator. The cadets can gain valuable experience with simulation in reinforcing the IT concepts through Graphics User Interface (GUI), in addition to experiencing the hands-on learning with the LEGO® robots.

5. BRYANT COLLEGE: A COLLEGE TAKING THE FIRST STEPS

From the time it began in 1863 to the present, Bryant has both led and followed the trend of enhancing the educational opportunities for students by investing in technological innovations. "As early as 1878, Thedore Stowell, president of Bryant and Stratton realized that a revolution in office technology was occurring and that his college would have to offer instruction in operating these new machines" (Quinney, 1988).

Technology has impacted the college over the decades. In 1969 Bryant purchased its first computer, an IBM 1130 model. This eventually led to an entire research laboratory with personal computers, and eventually the implementation of a student laptop program in 2001.

Computers were not just being placed on campus, but the use of technology has become a cornerstone to the programs offered at Bryant. Computer Information Systems was one of the largest concentrations on campus through the 1990's. This program provided students a mix of business and technology classes, with a core of liberal arts courses. Keeping with its trend of mixing business and technology, Bryant would introduce a new degree in 2001: Bachelor of Science in Information Technology. This program was in-line with Bryant's strength as a robust business school, but required students to spend even more time concentrating on technology.

Therefore in wanting to continually revise and improve the learning environment at Bryant College, Dr. Janet Prichard and Dr. Chen Zheng, will be integrating the use of LEGO® Mindstorms™ into the Program Design and Logic course, the foundation course for Information Technology.

The Current Experience

Within the IT program at Bryant College, attrition has been an issue, since the entering student grapples with solidly learning programming concepts necessary to the core course curriculum. Thus, the infusion of hands-on, fun learning may prove to be an asset in engaging first-year students who are defining a concentration for the program while laying the necessary foundational concepts.

For the past few years the IT professors at Bryant have struggled to determine how much programming should be taught to the students in the Program Design and Logic course. Dr. Prichard feels it is important that they obtain a sound background in programming after the first course, but that they also must see that programming is only one piece. "Most students have the misconception that all I will do when I work in IT is write programs. In fact most professionals spend less than 25 percent of their time programming. The rest is working with people and problem solving" (Prichard Interview, July 28, 2004).

Therefore, some of the key pedagogical objectives established by Dr. Pritchard for this course are comparable to those that were outlined and successfully achieved by West Point, University of South Florida, and Reykjavik University such as:

- Active, Hands-on Learning Environments/ Motivational Tool
  As an introductory course to the program, it is essential that the students be introduced to programming and the primitives of CIS in a successfully instructive, yet engaging manner.

- Team building & creative problem solving
  This current course at Bryant does not provide the environment within which the students work collectively. Since the Mindstorms™ system is judged to work best for 2-3 person groupings; the students in this course will group in pairs or trios. Projects, grading and course criteria will ensure that all students are equal in involvement, input, & participation during these projects.

- Practical application during subject exploration
  Through robotics, students will be empowered to directly and practically apply and explore the core programming concepts that are learned through lecture materials and reading assignments.

Assessing Programming Drawbacks

In anticipation of the limits often experienced when utilizing the standard programming language for Mindstorms™, Dr. Pritchard has determined that the students in the Program Design and Logic course will utilize Java as the programming language. Dr. Prichard is excited about the opportunity to introduce Java to the students in a more exciting way.

The LEGO® Mindstorms™ will require students to work in groups and learn basic programming, but they will also have to creatively solve problems with the use of this new tool. Dr. Prichard's expects the Mindstorms™ to add an exciting flair to the Program Design and Logic course, but the use of Mindstorms™ will not stop there. She is already constructing ideas of how the product can be used in other upper level IT courses including Algorithms & Design and Data Structures.

6. RECOMMENDATIONS FOR BRYANT

In order to assess the impact of the integration of robotics in Bryant's IT program, it is suggested that the programming limitations of the product be taken into consideration, as well as the logistical challenges in tracking and cataloguing multiple kits with an average of 750 pieces each. Referring the lab experiments done at University of Florida and Reykjavik University, Bryant College should consider the means to measure individual contributions within the team settings. Based on the experiences researched by the authors, a recommendation is made to limit group size to two to three students maximum. Time allotments as referenced should also be considered.

Qualitative measures should be carefully established within the classroom and subsequently weighed such as:

Pedagogical objectives (current, projected, and actual)

Student evaluations per exercise

Documented classroom environmental observations

Comparing student results to past precedence as in grades, involvement levels, team-building, creativity, etc.)

Meaningful integration with courses at Bryant College that currently utilize robotics.

The experienced professors at Bryant, having taught introductory Information Technology concepts, could readily contrast and compare the documented findings of student performance with their past experiences of performance with previous undergraduate students in these courses.

Since Bryant has been concerned with attrition rates in the IT program, the department can quantitatively substantiate the success of engaging entry-level students through products like Mindstorms™ by tracking and comparing the IT department's past attrition rates to consequent figures of enrollment continuance once Robotics is integrated.

Though the IT department at Bryant is on the advent of incorporating robotics, the Department of Science and Technology at Bryant has successfully implemented robotics into its core curriculum under the expertise of Professor Brian Blais. Therefore, a cross-discipline focus group is suggested so as to provide the faculty with an environment within which further considerations and modifications can be carefully planned. This would also provide a forum for strategizing when planning the robotics integration in the advanced IT course curriculum, since that is anticipated for the near future. This would also propagate a robust exchange of information and ideas between faculty members.

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