The Continuing Development of the Robotics Academy

Submitted By
Michael C. Kelly, Jr.

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR AN UNDERGRADUATE THESIS WITH A

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

School of Engineering
Tufts University
Medford, Massachusetts

May 2004

Signature of Author:
Michael C. Kelly, Jr.

Certified By:
Associate Professor Douglas M. Matson
Department of Mechanical Engineering
Tufts University

Committee:
Professor Chris Rogers
Department of Mechanical Engineering
Tufts University

Table of Contents

Acknowledgements

The undertaking of this project has meant a reliance on some key people and I would like to take this opportunity to thank them. Jim Hoffman, thank you for your patience and machining help; Matt Dombach, thank you for your guidance with the day in and day out dealings of the Robotics Academy; Chris Rogers and Doug Matson, thank you both for your thesis observations and always taking the time to listen to concerns with the project. I also want to thank the other members of Team Kinetic, without whom the Kinetic sculpture would not have been completed: Jason Adrian, Kristi Hamada, Jarred Sakakeeny, Sandra Tang and Marc Weintraub.

Michael C. Kelly, Jr.

May 8, 2004
Medford, MA

Introduction

The Robotics Academy at Tufts University was established in the fall of 2002 with nine senior participants and several underclassmen. The goal of the Academy was to bring together students from the disciplines of mechanical engineering, electrical and computer engineering, engineering psychology and child development in order to produce a solution to a problem by employing a robotic design. The first project was constructed over the course of two semesters. The Academy also strived to include teaching, both at the college and elementary school levels, as a significant component of the program.

From the experience of this first project and the theses produced at the end of it, it was evident that the Academy needed some adjustments in order to make it run in a more effective manner. Members cited several concerns over their project and the Academy including (1) the dissolution of their multi-disciplinary team, (2) failure to reach set project goals, (3) failure to meet projected deadlines, (4) failure of the team members to meet effectively and (5) a lack of educational outreach.

In the beginning of its second year, the Academy grew to twelve senior members, two of which had been involved in the Academy as juniors. The twelve participants were split into two teams: four of the members created Team Spot and the other eight began a team which would later become Team Kinetic. By the end of the project, in May of 2004, Team Kinetic had lost two of its members, leaving six. Those members, along with their major, are presented here.

Jason Adrian	Computer Engineering
Kristi Hamada	Engineering Psychology
Michael Kelly	Mechanical Engineering
Jarred Sakakeeny	Mechanical Engineering

Sandra Tang	Child Development
Marc Weintraub	Electrical Engineering

Unlike Team Spot, who started the year with a defined project, Team Kinetic began the year by choosing their own project. The members of the team met to brainstorm potential projects and identify team goals. The team settled on producing an interactive, closed loop, rolling ball kinetic sculpture to be used as a teaching tool. A ball, moving through the sculpture, would stop at certain way points to wait for user interaction or input. Input would come from five stations connected to the sculpture. Once the proper input was entered into the sculpture, the ball would be allowed to continue to move through the sculpture. This way, the user of the sculpture is directly involved in its function and holds the responsibility for getting the ball to move from the beginning to the end of the sculpture.

The concerns from the first year reappeared in the second year project as well. However, those concerns stem from larger issues prevalent in the Academy, issues that this thesis will address.

In the following pages, this thesis outlines a proposal for furthering and bettering the Robotics Academy. Discussions include (1) the strengths of the Academy, (2) the barriers standing in the way of a successful Academy, (3) several recommendations for change within the Academy and (4) various mechanisms for measuring the effectiveness of the implemented changes.

Strengths of the Academy

The Robotics Academy is one of the most unique and beneficial organizations at Tufts University – nay, one of the most unique and beneficial organizations in any university. It has several strengths owing in large part to the vision of the authors of the original grant proposal for the existence of the Academy.

Multidisciplinary Teams

The idea of a team tasked with creating a robotic solution to a problem containing disciplines other than engineering may appear at first somewhat odd. However, multidisciplinary teams are often the most effective problem solvers in industry and academia.

Including Child Development majors in the Robotics Academy ensures two desired outcomes. First, the engineers on the team have the opportunity to communicate their ideas to non-engineers and to respond to questions and concerns that may arise from a lay perspective. This approach is often not taught in engineering curriculums, yet remains a critical component for effective team building. In industry, for example, the people designing and building the product must be able to convey their ideas to the people who are marketing, funding and managing the company that is producing the product. Second, the Child Development majors represent the critical link between the classroom and the members of the Academy. They are the people who can take the information from the engineers and transform it into information that can be communicated in the classroom.

Another reason for the existence of a multidisciplinary team is that no one major could possibly accomplish this type of robotics project alone. These projects require a

combination of engineering knowledge and experience gathered from the mechanical, electrical, computer and human factors engineering disciplines.

Strong Results

The Academy has proven itself as an organization with the potential for greater success based on its initial projects. The first three projects produced have been successful because they perform, if only in rudimentary stages. The projects prove that the Academy concept of multidisciplinary teams working towards a common goal, as seen in industry, can be reproduced in a university environment.

Excellent Opportunity for Teaching

Teaching in the Academy is given a high priority. Through their projects, the members of the Academy in the last two years have taught basic engineering and robotics concepts to elementary school age children. The opportunity also exists for senior members of the Academy to educate younger members about the intricacies of building a robotics project, as well as help the younger members gain the multidiscipline knowledge to complete a robotics projects.

Barriers to Success

In order to be successful, any organization, especially one as young as the Robotics Academy, needs to constantly evaluate itself. Often times, there are obstacles that need to be dealt with in order for the organization to operate more efficiently and to better attain its stated objectives.

The following sections describe the hurdles that need to be overcome if the Academy is to run more effectively.

Leadership Within the Teams

The teams are the heart of the Academy. In their senior year, however, what the team members lack is peer leadership. So far, the teams have been working by consensus. While such an approach may be the best way to reach critical decisions (particularly so as to take full advantage of the desired multidisciplinary approach), there needs to be someone who has the ability to keep the group focused on the tasks at hand.

Vague Project Requirements

Another stumbling block within the Academy is that there are no defined project requirements set by the Academy. The goals of the project are set by the teams. Without targets that need to be met, the teams end up changing their original goals to meet what they have accomplished in their projects, instead of rising to meet the challenges set by the Academy. For example, Team Kinetic set several goals for their project to meet. It had to be lightweight, easily transportable through standard doorways and enclosed so as to be childproof. However, the project did not have to meet any goals set by the Academy. Some of these goals could include creating an instruction manual for the project and producing a list of vendors and components used in the project.

A Set of Academy Guidelines

Along with a lack of Academy supplied project requirements, there are also no written guidelines that pertain to the Academy. It is important to have a written set of guidelines that can be easily referred to by all of those involved in the Academy. It would benefit the younger members, who would be able to get many answers to their questions by referring to the guidelines. Some of the issues that have come up in the past that these guidelines would address are the roles of the members of the Academy as well as issues for receiving credit for completing an Academy project and thesis.

Academy Membership Continuity

One of the largest hurdles within the Academy is the lack of continuity between the members during different years. In the original grant proposal, students were to be enrolled in the Academy before their senior year. This plan had several parts, one of them being that the underclassmen members would garner relevant technical experience from the upperclassmen and the faculty in the Academy. The underclassmen members would also work to further the projects of the past members. Having the underclassmen members begin to plan their own projects was also a desired outcome.

At this point, however, most of the Academy's focus has remained on the senior members. Without the interaction between senior and underclassmen members, the benefits of enrolling in the Academy before senior year are lost.

Departmental Requirements

A large frustration of many members of the Academy this year has been the issue of credits and departmental requirements. Many of the engineering majors involved in the Academy have a senior design project requirement from their department. Some of

these departmental projects take place in the fall, while others are required in the spring. Unfortunately, many of the departments do not recognize the Robotics Academy as a suitable replacement for their senior design project, and therefore the seniors involved in the Academy must do both. This puts a large strain on the senior members as they may be trying to complete both projects simultaneously.

Recommendations for Change

In order to address the issues discussed above, the following recommendations for change are presented to benefit the Academy. While several possible solutions exist to each of the concerns, the following are believed to be the top recommendations.

Implement Team Leaders

Each team within the Academy must have an appointed team leader. This leader would be chosen one semester prior to the start of that team's senior year. However, severe care should be exercised when such a leader is chosen. To begin with, the decision must be made whether to have peers elect the leader or to have the leader chosen by the graduate Academy leader and Academy faculty. A compromise between these two ideas is the ideal solution. The faculty, graduate Academy leader and team members should work together to jointly elect a team leader. A leader chosen with the input of team members is likely to be viewed as having been granted legitimate authority to lead the team. The specifics for how the team leader will be elected will be outlined in the Academy Guidelines.

The responsibilities of the team leader start immediately upon election, essentially granting the team leader a full semester to work with the team before the team starts the construction phase of the project. Once elected, the team leader is responsible for several things specific to the team.

The team leader will be responsible for focusing the team members as part of the consensus process during design meetings. These team meetings will begin the same semester that the team leader is elected. However, the team leader should not be making decisions. A good leader is someone who can listen to the team, take the suggestions of

the team members, and present to the team the solution that the leader has heard. In this way, the team leader is using the consensus of the team to further the work of the team without letting the team members lose their focus.

Define the Team Project and Goals

The first responsibility of the team leader will be to take the content from the preliminary project design meetings and commit them to paper. The leader will outline the scope of the project, any specific design ideas that have been produced by the team so far, as well as the goals of the project. For example, some of the goals that the team leader might specify are that the project weigh no more than 200 pounds, be made entirely out of non-metallic materials and operate on 120VAC. This report should embody the desires of the team. The leader must take care to avoid personal bias in summarizing the selection of the project and the goals of the team.

Create Project Timelines

Once the project is defined, several project timelines must be completed. There will be a timeline for each major (*e.g. mechanical, electrical, etc.*), as well as an overall timeline for the project. The team leader must work with the team to produce these timelines. It will be the responsibility of the team leader to make sure that each major-specific timeline is submitted by the end of semester that precedes the construction phase of the project. The team leader will also be responsible for compiling the timelines in order to produce the overall timeline for the project.

Generate the Project Budget

In the past, Academy teams did not know what their budget was or that they had to keep one. Keeping a budget is a skill that is important to teams producing a product

and it helps the team to plan their purchases. Therefore, in consultation with team members, the team leader will produce a prospective project budget. The budget should track expenditures by major and by supplier.

During the project, the team leader will keep a record of the expenses of the team. At the end of the year, the team leader will produce a budget that outlines all realized expenses. This allows the team to review how the actual expenditures match the proposed budget from the planning phase of the project. Comparing actual versus planned expenditures at year end is a valuable learning process for the team as it imparts real life experience and knowledge.

Develop Leadership Skills

Effective leaders are difficult to find. The best way to learn how to lead is to listen to your team and to have a base of leadership skills and knowledge that can be applied to your team. Therefore, the team leader will work with the graduate Academy leader and the faculty to build leadership skills. As part of that learning, the team leader will be responsible for keeping a journal that outlines the ways leadership skills were applied to the team.

Senior Academy Member Mentors

The gap between the older and younger members of the Academy must be bridged. The younger members must be more effectively involved in the Academy. They should be present during the weekly meetings between the graduate Academy leader and the teams. They have to be aware that progress within the Academy is limited by personal growth and responsibility.

One of the best ways to involve the younger members is to have the older members act as mentors. The older members should invite the younger members to their team meetings. In this way, the younger members can see what challenges the current senior teams are facing, and apply that knowledge to their own project.

Mentoring the younger team members also reinforces the teaching aspect of the Academy. By educating the younger members, the older members are strengthening the Academy. The younger members are going to be able to produce more complicated and meaningful projects because they will have the foresight gained from the knowledge imparted to them from the older members. The mentoring process also supports the continuity of the Academy by strengthening the bonds between the member generations.

Grant the Graduate Academy Leader More Authority

The graduate Academy leader is the single most vital piece in the Academy puzzle. Up to this point in the existence of the Academy, many of the duties of the graduate Academy leader have been those that the new team leaders will assume. Without those duties, the graduate Academy team leader will be able to concentrate on some of the more fundamental issues within the Academy. However, without the proper authority to oversee the Academy, the graduate Academy leader position loses its meaning. To remedy that, the graduate Academy leader will assume the following responsibilities.

Create a Set of Academy Guidelines

The graduate Academy leader for the 2004-2005 academic year will be charged with creating the first set of Academy guidelines. These guidelines will cover, in writing,

all of the issues involved with the Academy. The guidelines should address the following issues:

1) Academy mission statement
2) Role of an underclassmen Academy member
3) Role of a senior Academy member
4) Role of a faculty Academy member
5) Role of a team leader
6) Electing a team leader
7) Role of the graduate Academy Leader
8) Academy project requirements
9) Thesis requirements
10) Credit for Senior Design Projects / Thesis
11) Team budget

Following the 2004-2005 academic year, future graduate Academy leaders are expected to amend and add to the guidelines as appropriate. These guidelines should be available to all prospective and current members of the Academy, the faculty involved with the Academy and the graduate Academy leader in booklet form and via the Academy website.

Resolve the Senior Design Project Differences

A top priority for the graduate Academy leader should be a plan for the Robotics Academy to satisfy the requirements for a senior design project in all of the departments involved in the Academy. It is imperative that students who are members of the Academy be given credit for their work on their project and not feel burdened to do both an Academy project and a senior design project.

Act as a Liaison Between the Faculty and Team Members

The graduate Academy leader should also act as a liaison between the team members and the faculty. The faculty has been largely ignored in the past Academy projects – a mistake. The graduate Academy leader should strive to make the faculty and student members act as a cohesive unit. The graduate Academy leader should organize

sessions to be taught by members of the faculty on basic electronics, basic human factor design, teaching skills, team skills and leadership skills.

Act as a Resource to the Team Leaders

Finally, the graduate Academy leader will act as the manager for the team leaders. The team leader should look to the graduate Academy leader for advice on leadership and management skills, as well as to answer to budget and timeline questions. In this way, the focus of the Academy remains on the student members and their projects. Issues that the members encounter should first be dealt with by the team, with the team leader acting as moderator for the team. If the team can not reach a solution in this manner, then the team leader will bring the problem to the graduate Academy leader. If both the team leader and the graduate Academy leader can not find a solution, the graduate Academy leader will seek a solution from the faculty members of the Academy and bring that solution back to the team leader. The team leader will then bring the solution back to the team for discussion.

Measuring the Effectiveness of Change

The ability to measure how effective the proposed changes will be to the Academy is very important. Following are several indicators that will reflect a positive change in the Academy.

Increased Academy Enrollment

One of the most important indicators of positive change will be an increase in the number of students enrolled in the Academy. As the Academy begins to run more efficiently, the final projects will become more complicated. These projects will attract more attention, from both universities and members of industry. Underclassmen will begin to realize that the Robotics Academy is an important organization to be involved with, and the number of Academy members, both under and upperclassmen, will begin to grow.

Projects Stay within Budget and Time Constraints

The manner in which the projects are completed also serves to measure the effect of change. A more efficient Academy will have members who will have more time to complete their project within their original timeline and within the original specified goals of the project. Projects that are completed within the set deadlines and that perform to the set goals demonstrate that the changes made to the Academy are positive, and that Academy members are able to complete the goals of their team and of the Academy.

With the help of a proposed budget and by keeping track of team expenditures, team members will be able to stay within their allotted budget. Also, the vendor information supplied by the upperclassmen Academy members will help younger

members save money by finding the best prices and vendors. Projects completed within budget also serve as proof to the positive effects of the changes within the Academy.

Academy Members are Better Informed and Focused

Academy members who are better informed about their responsibilities and roles within the Academy will feel more at ease. These members will be able to find the time to focus on their projects instead of dealing with administrative issues. Those issues will have already been dealt with by the graduate Academy leader and by the Academy guidelines.

Précis

The Robotics Academy at Tufts is a young organization. With the third year of the Academy on the horizon, this thesis has identified the weaknesses of the Academy, including (1) a lack of peer leadership, (2) vague Academy requirements, (3) the need for a set of Academy guidelines, (4) a way in which to boost the continuity of the members of the Academy and (5) the need to resolve the departmental credit requirements.

Recommendations to address these weaknesses were then presented, with (1) the implementation of team leaders, (2) senior members acting as mentors for the younger members of the Academy and (3) the altering of the responsibilities of the graduate Academy leader, including the creation of a set of Academy guidelines.

Ways in which to measure the effectiveness of these changes were then introduced. These methods include (1) noticing an increase in the membership of the Academy, (2) confirming that projects stay within budget and are completed within set timelines and (3) ensuring that the members of the Academy feel comfortable with their knowledge of the workings of the Academy and have the opportunity to focus on their project and its goals without having to deal with administrative issues.

With the implementation of the proposed changes, students, faculty and the graduate Academy leader will feel confident in the knowledge that the team members are able to produce robotics projects that are completed on time, within budget and that surpass the goals that have been set for them.