**Session 09-33**

# The Researcher Incubator: Fast-Tracking Undergraduate Engineering Students into Research via Just-in-Time Learning

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## Abstract

An "incubator" in the research context is a place where the formation and development of new skills and ideas is encouraged, while the resulting new discoveries are spun out for further external development. To meet the need for trained researchers in the new Mechanical and Energy Engineering (MEE) Department at the University of North Texas (UNT), the faculty and undergraduates collaborated to develop a "Researcher Incubator" to integrate research experiences into the undergraduate engineering curriculum. This group's missions are 1) to train UNT engineering undergraduates in the essentials of engineering research, 2) offer a pragmatic educational experience reflective of the skills necessary for engineers in the $21^{st}$ century, and 3) fast-track undergraduates into successful research experiences much earlier than would be possible within conventional engineering programs.

To eliminate barriers to entry for undergraduates, the Researcher Incubator uses "just-in-time" learning, a subset of inductive learning, which is modeled after manufacturing processes that deliver products to customers simultaneously with the moment of purchase. The hallmark of just-in-time learning in the context of research is that students are empowered to select and learn the specific elements necessary to solve a problem at the moment that a need for a solution arises. This approach is critical because it frees faculty advisors from being central repositories of knowledge and experience, eliminating a major bottleneck to progress by redistributing this responsibility to undergraduate researchers.

The hypothesis of our just-in-time learning experiment is that if undergraduate students are 1) taught the skills needed to discover technical information and knowledge themselves, 2) enabled to work in collaborative groups that facilitate idea exchange, and 3) vested with responsibility to manage and execute serious research projects, they will spontaneously find or develop the theoretical and practical engineering knowledge required to successfully complete a project. In this paper, we outline the approach used at UNT to formalize, package, and teach just-in-time learning methods to undergraduate students through the Researcher Incubator.

To highlight the validity of our hypothesis, we compared the research performance of undergraduates to that of graduate students over a 14-month period. Two metrics commonly used to gauge faculty success at engineering research universities were applied in this comparison: 1) the number of technical papers presented in a public forum or journal and 2) the dollar value of research

grants authored and won. In the time period studied (September 1, 2007 through November 1, 2008), undergraduates outperformed graduates in both categories in the MEE Department despite many more resources and personnel being devoted to graduate research. In spite of these quantitative and monetary successes, the UNT Researcher Incubator program was deemed dilatory to faculty focus and discontinued in November 2008.

## Introduction

To meet the need for trained researchers in the new Mechanical and Energy Engineering (MEE) Department at the University of North Texas (UNT), faculty and undergraduates worked together to develop a "Researcher Incubator" that integrates research into the undergraduate engineering curriculum.[i] This group was envisioned to become a self-sustaining, self-funded, faculty-led organization with a three-fold mission: 1) to train UNT engineering undergraduates in the essentials of engineering research; 2) to offer a hands-on, interdisciplinary educational experience reflective of the engineering skills necessary for success in the 21st century; and 3) to fast-track students into successful research experiences much earlier than would be possible within conventional engineering programs.

*Research* is defined as the "diligent and systematic inquiry or investigation into a subject in order to discover or revise facts, theories, applications, etc."[ii] The misconception that undergraduates lack the technical depth to perform research[iii] bars faculty from engaging undergraduates in serious research projects. If given early entry into a research project, undergraduates are often assigned non-research tasks, an indenture in support of the more advanced laboratory members. Ironically, graduate students are welcomed to engage in research despite being equally unprepared. Their undergraduate engineering programs most often lack research education and training components. Thus, they are no more skilled than undergraduates in managing and conducting original research.

### *Background Literature*

The Researcher Incubator is the genesis of overwhelming endorsements from the engineering education community for serious organized research integrated into the undergraduate curriculum. According to the National Research Council, undergraduate curricula consisting solely of traditional lectures and laboratories may be inadequate for science, technology, engineering, and mathematics (STEM) education.[iv] The National Research Council identified undergraduate research as "the purest form of teaching" and an essential component for effective learning.[v] The National Academy of Engineering acknowledges that all necessary engineering knowledge cannot be taught through traditional 4-year baccalaureate degrees and endorses research in engineering education as a valued activity for faculty as a means to enhance and personalize the connection to undergraduate students.[vi] According to the Boyer Commission, "there needs to be a symbiotic relationship between all the participants in university learning that will provide a new kind of undergraduate experience available only at research institutions."[vii] The incubator approach encourages active participation of undergraduates by giving them ownership in the research enterprise to enable them as contributing coauthors of published technical works, as recommended by the National Research Council.[viii] Nonetheless, a primary criticism of undergraduate research is the significant investment of faculty time required to train these students. However, according to the National Academy of Engineering, "If domestic engineering students are energized by their undergraduate education experience, it will enhance the possibility that they will be retained and graduate as engineers and aspire to advanced degrees through the academic engineering research enterprise."[ix] In other words, an investment of faculty time early in an undergraduate student's career can yield a well-trained, highly motivated graduate student with 3 or 4 years of research experience who would otherwise have not considered graduate school.

***Hypothesis***

To eliminate barriers to entry for undergraduate researchers, the UNT MEE Department gauged the effectiveness of "just-in-time" learning, a subset of inductive learning,[x] as a tool for engineering research training. Just-in-time learning is modeled after manufacturing processes that deliver completed products to customers simultaneously with the moment of purchase. The hallmark of just-in-time learning in the context of research is that students are empowered to select and learn the specific elements necessary to solve a problem at the moment that a need for a solution arises.[xi]

We tested whether just-in-time learning methods can be formalized, packaged, and taught to undergraduates through the Researcher Incubator to fast-track students into successful engineering research experiences. The hypothesis of UNT's just-in-time learning experiment is that if undergraduate students are 1) taught the skills needed to discover technical information and knowledge themselves, 2) enabled to work in collaborative groups that facilitate idea exchange, and 3) vested with responsibility to manage and execute serous research projects, they will spontaneously find or develop the theoretical and practical engineering knowledge required to successfully complete a project. We demonstrate that given resources and formalized training to find or generate knowledge, undergraduates are as capable as (or more capable than) graduate students in succeeding as researchers.

## Methods

To test the validity of our hypothesis, we compared the performance of undergraduates to that of graduate researchers over a 14-month time period by applying two metrics commonly used to gauge faculty success at engineering research universities: 1) the number of technical papers presented in a public forum or journal and 2) the dollar value of research grants authored and won. However, success for the Researcher Incubator required more than generating research presentations, publications, and grants. To persist in an emerging engineering research university with a predominant attitude that undergraduates cannot be serious researchers, investment of faculty time in this endeavor also had to produce the following outcomes:

1. A pool of undergraduate engineering researchers proficient in managing and executing serious research projects from initial design to public presentation of results.
2. Broadly trained undergraduates skilled in specific research techniques that are valuable to the faculty's main research areas.
3. Students with a developed awareness of how laboratories function and how to be competent, independent engineering researchers.
4. Undergraduates who choose to continue as graduate-level engineering researchers in the same college and department to assure that training efforts are not wasted.

5. An undergraduate experience that addresses program accreditation outcomes difficult to attain through conventional means, such as instilling the desire for lifelong learning among students.

Research activities are rarely well-integrated into the undergraduate curriculum, and most engineering undergraduates are unaware that research is the principal enterprise of a university. Thus, undergraduates will not spontaneously perform research unless they, too, perceive a positive benefit from the exercise. To motivate participation, the student organizers set the following outcomes for the Researcher Incubator.

1. Members learn how to find or develop the theoretical and practical engineering knowledge required to successfully complete a project.
2. Members gain credentials and experience to be competitive in graduate-school applications and industry job searches.
3. Members experience effective teamwork and learn to lead a team.
4. Members acquire the technical competence and self-confidence gained by successfully applying theoretical and practical learning to solve real-world problems.

Founding student members felt that to be of value, the Researcher Incubator had to instill the ability to face unknown problems and find appropriate answers. Moreover, the experience had to enable Incubator members to differentiate themselves from conventional engineering students via their enhanced problem-solving abilities and laboratory skill sets. These student-driven outcomes were seen as being attractive to potential employers and graduate schools. In other words, to engage students, membership in the Researcher Incubator had to provide the promise of a career-boosting outcome.

**Table 1:** The combination of learning through seminars and projects is essential to meet all Researcher Incubator stakeholder outcomes.

| Faculty Outcomes | Seminars | Projects |
|---|---|---|
| Managing and executing research project steps | X | X |
| Acquire research techniques complimenting faculty areas | | X |
| Build awareness of how laboratories function | | X |
| Motivates continuation to graduate-level researcher | X | X |
| Addresses accreditation, especially lifelong learning | X | |
| **Student Outcomes** | **Seminars** | **Projects** |
| Skills to find or develop engineering knowledge | X | |
| Gain credentials and experience sought by employers | | X |
| Experience effective teamwork and learn leadership | | X |
| Acquire technical competence and self-confidence | | X |

The Researcher Incubator program consisted of two parallel components: 1) a seminar-style classroom section focused on teaching concepts, organizational structures, and principles underlying the research enterprise; and 2) a practical experiential component where students managed and executed real engineering research projects. While these components served different purposes, they were complementary and essential for ensuring student success and for meeting all program outcomes important to faculty and identified by students (Table 1).

***Classroom Training***

On successful completion of the probationary period (see "Student Promotion"), students could enroll for credit in a lower-division research experience course, which met once per week in a 1-hour lecture format cast as laboratory meetings. This course added theoretical underpinning to the practical experience already obtained in the lab during probation, and it instilled students with basic skills to carry out the just-in-time learning required to conduct research. The seminar format was critical to the success of the Researcher Incubator because lectures are the most recognizable teaching venue for students. These familiar weekly classroom interactions with faculty provided both a regimented schedule to keep research progress on track and bridged the gap to unfamiliar, independent research activities in the laboratory.

In weekly seminars, incubator students were trained in knowledge and skills critical for successful research, including 1) use of university library facilities to conduct literature searches [see Figure 1]; 2) use of analytical and numerical modeling techniques to solve engineering problems; 3) critical assessment of technical manuscripts; 4) application of professional ethics to resolve dilemmas relevant to the research enterprise; and 5) technical writing and oral communication skills to enable articulation of technical knowledge and research findings to a broad audience of academic and industry professionals. In addition to these research skills, seminars also covered practical aspects of engineering research, including 1) how research is funded through grants and how to apply for grants; 2) how to assess the prestige of target journals and conference venues for research publication and presentation; 3) how to develop a project plan and a Gantt chart to manage and schedule research activities; and 4) how to interpret the academic hierarchy and how politics within academia influence research. To test whether students were learning and could apply the presented material, weekly graded homework was assigned that challenged students to apply seminar teachings to their own research projects.

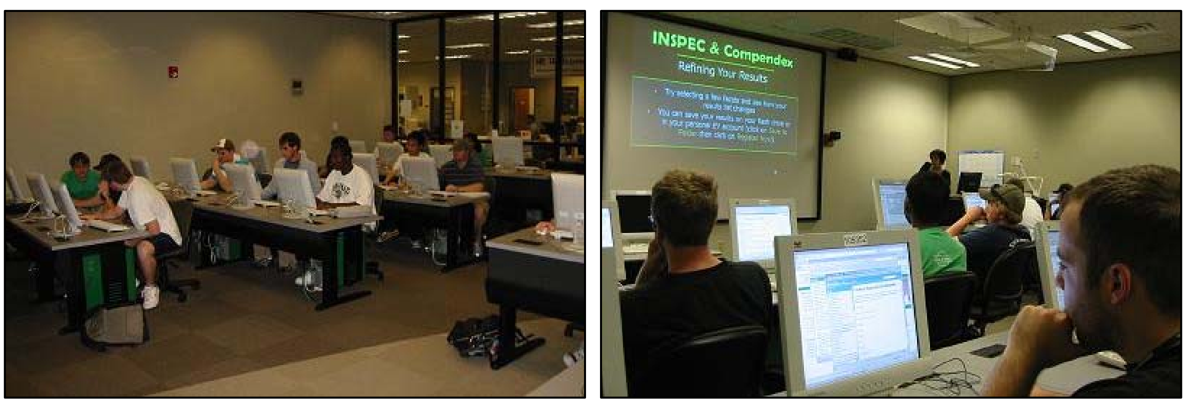


**Figure 1:** Lower-division student researchers learn how to perform literature searches (left) in a library information session given by a UNT engineering librarian (right). Acquisition of literature search skills is essential for students to locate needed technical information under the just-in-time learning paradigm.

For example, a seminar was given by the UNT engineering librarian on how to use technical search utilities, including Scirus, INSPEC, Compendex®, Google Scholar, and Engineering Village to locate technical references. Students then completed a homework assignment to perform a literature search and write a review for their research topic. To connect this assignment to research activities, students' literature reviews were later assimilated by their research team into outgoing technical papers and presentations. Lower-division students also worked in groups with their team leaders to

1) write short blurbs describing their research for Web publication, 2) generate project plans to organize the group's efforts, and 3) review a technical paper. These activities showcase important connections to demonstrate how underlying concepts learned in the seminars map onto the practical research activities. One incentive to complete these assignments is that the lower-division research experience is treated as a graded course, counting toward the student's grade point average (GPA).

Students who completed the lower-division research experience course were allowed to enroll in an upper-division research experience, where autonomy and ownership of a research project becomes much more pronounced. Like their lower-division counterparts, upper-division students also participate in a weekly 1-hour seminar course. To earn credit, these students must 1) pitch their research project to freshmen to recruit new members, 2) assist lower-division students with authoring research blurbs and project plans, 3) generate a list of potential funding sources and write research grants requesting funds, 4) identify target journals and venues to present research, and 5) review a technical paper. The capstone deliverable of the upper-division research course is that students must publish or present their research in a journal or conference. Students who do not complete this ultimate deliverable may not count the research experience toward completion of a B.S. degree technical elective. After completing all the upper-division research course requirements as the culmination of the three-semester promotion process, students experienced all the underlying mechanics faced by a true academic researcher: designing a research project, seeking funding, mentoring students, and presenting research. Through these activities, undergraduate research students obtain a broader and richer experience than most graduate students who are fixated on performing research and rarely see the broader purpose and reach of their actions.

***Laboratory Practical Training***

In addition to seminar participation, the second Research Incubator component was compulsory involvement as a research team member in one of the ongoing engineering projects. This activity complemented the classroom seminars by providing a practical hands-on environment in which skills could be practiced, research intuition developed, and the classroom theory applied and evaluated in the context of real engineering research problems. To maintain organization and continuity, all project teams were led by a veteran upper-division engineering undergraduate researcher. Team leaders had to have previously been active in the Incubator, successfully completed the Incubator training process, and published or presented research.

To house the Researcher Incubator, a laboratory with dedicated bench space, basic engineering instruments, and shop tools was provided. Each team was allotted a start-up budget of $500.00 with the requirement that any additional expenses must be raised externally by the students.

The underlying research project ideas were developed jointly by students and faculty and were all linked to some existing research apparatus or external connection already available to UNT. For example, one team designed a novel solar energy collector because Fresnel lenses and a small parabolic dish were freely available. Five ongoing research projects appeared to be a sustainable number for one faculty member to manage. While additional projects spread faculty time too thin, a self-correcting effect transpired. Without focused faculty support, students lost interest in the weakest projects and moved to more dynamic projects, which invariably led the weakest projects to become dormant. Eventually, the faculty advisor artificially set the cap on active projects at five to avoid lost time and resources incurred by projects that became dormant.

Regular weekly meetings were set between each individual team leader and the faculty advisor. Instead of acting as a manager, the faculty member took on the role of technical advisor. For example, if specific mathematical steps were needed to develop a research model, the professor would work through the problem with the team leader, and the leader would present the solution to the group. Because of his/her research experience, the faculty advisor could also identify more precise, inexpensive, or facile approaches to solve certain problems. In these cases, suggested approaches were shared with team leaders, but a specific path forward was never mandated.

***Student Promotion***

Students engaged in the Researcher Incubator advanced through a three-semester gated promotion process to successfully complete the program. Incubator candidates started out as not-for-credit volunteers working in a research team for a semester as probationary members. Once the probationary period was completed to the satisfaction of the faculty advisor and the team leader, the candidate was cleared to enroll for academic credit in a lower-division research experience course which was counted in the GPA but which could not be used toward satisfaction of a B.S. degree in engineering. Upon successful completion of the lower-division experience, Incubator students could enroll in an upper-division research experience course, which was both counted in the GPA and as a technical elective toward the B.S. in MEE. Successful completion of a the upper-division research experience within the Incubator enabled a student to become a Team Leader, continue as an undergraduate research assistant (for salary or academic credit) on an Incubator project, or apply for placement in a UNT engineering laboratory as an Undergraduate Research Assistant (for salary or academic credit).

Each level of the Incubator promotion process served a critical function. In the initial probationary period, students were assigned to an existing project that was of interest to them. This initial period filtered students who claimed interest in participating but did not make a serious commitment to the program. For example, in the first semester that the Incubator was made available, 22 students volunteered to join, but only 8 advanced to the for-credit stage within the organization. The probationary stage represented a low-risk exploratory period in which students could decide whether research suited them without worrying about earning a poor grade for unsatisfactory performance in a for-credit experience. The probationary period also made the Incubator accessible to freshman-level students who were mentored by experienced upper-division team leaders. In fact, applications to join the Incubator were handed out on the first day of the MEE freshman-level introductory engineering course, allowing students to join and participate at extremely early stages of their careers. These students enjoyed the fulfillment of connecting with other engineering students and making an important contribution to the department without the risks and time commitment required of leadership positions . In some cases, undergraduate research was the only connection some lower-division students had with the MEE department as they completed their math and science prerequisite courses outside the College of Engineering.

## Results

The original charter between faculty and students creating the Researcher Incubator outlined seven metrics to be monitored in support of the organization's mission:

1. Number of technical papers written by Incubator researchers based on their work.
2. Quantity of public research presentations successfully delivered.
3. Value of research dollars won for Incubator research projects.
4. Number of technical elective credit-hours offset by research course credit.
5. Number of research project targets completed.
6. Number of Incubator students placed as research assistants in UNT engineering research labs.
7. Number of Incubator students admitted into advanced engineering degree programs.

Unfortunately, the 14-month period that the Incubator was active was not enough time to measure metrics 5, 6, and 7. To gauge the performance and effectiveness of the organization, results for metrics 1 to 4 were archived. For comparison, Table 2 demonstrates quantitatively how Researcher Incubator (undergraduate) students performed versus MEE graduate students in the same 14-month period. In Table 2, "Students Advised" is the total number of individuals who were enrolled in at least one research experience for credit. Although over 40 undergraduates participated in the Researcher Incubator, only 11 enrolled in a research experience for credit; and only these students were counted. Four MEE graduate students enrolled for thesis credit or project credit. "Research Posters Presented" and "Conference Presentations" refer, respectively, to the number of posters and presentations delivered at conferences. For inclusion on the poster list, two requirements had to be met: 1) a research abstract had to pass conference peer review, and 2) a research poster or plenum presentation had to be given by students in a regular conference session. No extended manuscript was required. Researcher Incubator students gave six poster presentations[xii, xiii, xiv, xv, xvi, xvii] (Figure 2, left). No graduate student posters were given in this time period. For inclusion on the conference list, the requirements given for posters had to be met. In addition, an accompanying research manuscript had to pass conference peer review. Researcher Incubator students gave three conference presentations[xviii, xix, xx] (Figure 2, right). By comparison, MEE graduate students produced only one conference presentation[xxi] in the same time period. The number of accepted peer-reviewed papers is reflected in "Journal Articles." No such articles were produced. The number of grants on which a research student is named as a co-principal investigator is given in "Grants Co-Authored." No distinction is made between internal and external grants. "Value of Co-Authored Grants" refers to the total dollar amount requested in grants co-authored by student researchers, and "Dollars Won by Co-Authored Grants" gives the total value of grants won. Researcher Incubator students co-authored three grants with faculty totaling $41,008 in funds requested, and $3,150 was awarded. Graduate students did not contribute to any grants during the time period studied.

**Table 2:** Research performance summary comparison between undergraduate and graduate students over the 14 months when the Research Incubator was active.

| Research Student Type | Students Advised | Research Posters Presented | Conference Presentations | Journal Articles | Grants Co-Authored | Value of Co-Authored Grants | Dollars Won by Co-Authored Grants |
|---|---|---|---|---|---|---|---|
| **Undergradaute** | 11 | 6 | 3 | 0 | 3 | $41,008.00 | $3,150.00 |
| **Gradaute** | 4 | 0 | 1 | 0 | 0 | 0 | 0 |

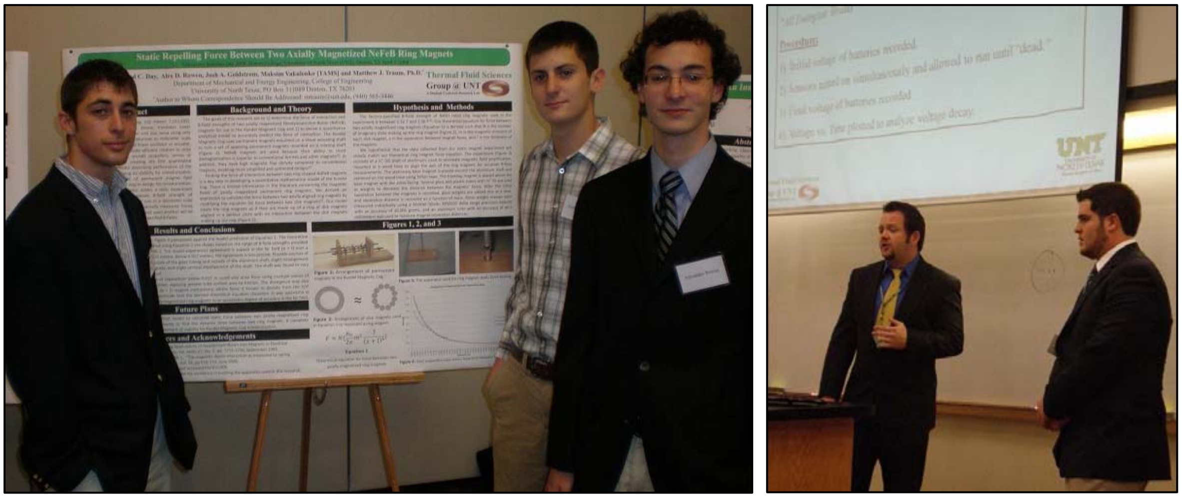


**Figure 2:** Undergraduate researchers presented their results in three different conference venues using a variety of media, including posters (left) and plenum talks (right). A public research presentation is the capstone requirement of the Researcher Incubator training program.

## Discussion

Using just-in-time learning, the Researcher Incubator proved successful in harnessing undergraduate researchers in the MEE Department to generate publically presented research and funding within a very short 14-month time span. The Department's graduate students produced comparatively less. The accomplishments made by the Researcher Incubator are also impressive because they were achieved with limited resources. The undergraduates had one faculty advisor, whereas the graduate students had four faculty advisors. In addition, most undergraduates were taking 15 or more semester credit hours (5 full-time classes), whereas the graduate students were taking 6 hours or fewer (2 full-time classes). In addition, the 14-month time period considered includes a 3-month summer session through which the graduate students worked, whereas no Incubator students were present. Finally, the undergraduate students worked on a for-credit basis and were not paid by the university for their effort (in fact, they paid UNT for the privilege of conducting research), whereas graduate students were university-supported by research and teaching assistantships.

To be fair, comparing undergraduate to graduate student productivity by only counting research presentations and grants generated in a 14-month period may be a misleading evaluation approach. Undergraduate research students in the Incubator tended to think about projects on the time scale of a single semester (15 weeks), whereas master's students have much longer time horizons (18 to 24 months). Thus, the question underlying undergraduate projects was "what can be accomplished in 15 weeks that is worth presenting?" Graduate students perform significantly more preliminary literature research, experiment design, and data interpretation because they are driven by the question of "how can the desired outcome be achieved, measured, and proven?" These differing philosophies yield undergraduate research results that are incremental as compared to graduate results, which are richer and more transformative. In addition, the threshold to entry and successful passage through peer review is probably lower for undergraduates, owing to the special sessions dedicated to undergraduate research at conferences. It is doubtful some of the Incubator work that passed peer review as undergraduate research would have been successful if submitted by a graduate student. Moreover, graduate students are not encouraged to co-author research grants because it is dilatory to their research focus. On the other hand, Incubator students were encouraged to help with grants to enable full participation in all parts of the research process. It is not surprising, therefore, that undergraduates outperformed graduates in the grant writing category.

Importantly, the Researcher Incubator was open to all students who sought participation, not strictly high-achieving honors students. UNT has a separate research training program accessible only to designated honors students. However, most Incubator researchers did not qualify for affiliation with the honors program. Nonetheless, after demonstrating the quality of their work through a peer review process, Incubator students were invited to participate in University Scholar's Day, which showcases undergraduate research performed by UNT honors students.

Why was the Researcher Incubator so successful? Besides the measured research output, no quantitative assessment instruments to explain or measure program success were applied. Thus, only anecdotal observations are available to explain why this organization worked so well. The MEE Department at UNT has two unique attributes that contributed to the Incubator's success. First, the Department started in 2007, making it very new. Second, while the mandate upon faculty to perform research within MEE is extremely strong, the Department does not yet have a Ph.D. program and the M.S. program is under-populated.

The newness of the Department instilled in Incubator students a sense that they were helping grow and shape the program from scratch and pioneer its genesis, which represented a unique opportunity that could not be found elsewhere at UNT. This interpretation was specifically engineered by the faculty mentor to mirror successes of the "Student Partners" program essential for founding Olin College.[xxii] Since students valued opportunities that enhanced their ability to be competitive in future job searches, the unique ability to help faulty build the program was a great motivator. In addition, lack of established student organizations within the new Department limited the availability of engineering co-curricular activities for the students. With no student chapters of ASME, ASHRAE, Pi Tau Sigma, etc. to be the foci of student engagement, the Researcher Incubator became the ad hoc engineering student organization in the MEE Department. Thus, students saw social, professional development, and networking value to joining and participating actively in this organization.

The combination of strong Departmental research mandate with no Ph.D. program and a nascent M.S. program provided strong incentive for the faculty to embrace innovative approaches to conducting research. Had ample graduate students been available at the inception of the MEE Department, there would have been no faculty motivation or need to engage undergraduates in research. However, given the dearth of qualified graduate students, faculty had no choice but to perform the work themselves or train available undergraduates to become researchers. Unlike in established research universities where undergraduate research is seen as an extension of a Department's teaching mission, the MEE Department was almost totally reliant upon undergraduates to perform research, and faculty involved in the Incubator invested ample time, as much as would be invested in graduate students, in their training and success.

In addition to the MEE Department's unique situation, attributes of the cohort of students who self selected for Researcher Incubator membership contributed to success. In conventional engineering undergraduate research opportunities, students rarely have ownership of their projects, and they often work on menial tasks under the close supervision of a graduate student or other senior researcher. Relegation to the margins can instill a sense that students are not responsible for the outcomes they produce and that a senior researcher looking over their shoulder will correct any careless mistakes. By design, the Incubator gave undergraduates complete ownership and mastery of their projects with almost no oversight (Figure 3), which for many students was a welcome responsibility and challenge that had never before been bestowed in an educational environment. Students (especially Team Leaders) adopted a vigorous level of focus and commitment to these projects, often spending long hours in the labs and writing many drafts of research manuscripts. Once given the responsibility to own a research project, undergraduates began behaving like graduate students in these respects.

**Figure 3:** Team-based, hands-on learning was a key aspect of the Researcher Incubator experience as were opportunities to lead teams and receive mentoring from more experienced research students. To learn how thermal-fluid engineering systems work, students conducted a mechanical dissection of an air conditioning unit (left). Students also designed and carried out their own experiments, such as a solar concentrating energy generation study (right).

Finally, public recognition (both actual and virtual) was an important motivator for student success. By delivering presentations in public forums, students interacted with senior members of the technical community (Figure 4) and received praise for their effort. To cement this recognition, Incubator students were invited to present in MEE Departmental seminars in front of their peers (who were not Incubator members) as well as departmental faculty. These presentations allowed undergraduate researchers to demonstrate in front of peers that their experience empowered them to engage in technical discourse with faculty on a sophisticated level. These seminars were purposely scheduled to occur during class time in front of audiences of peers to assure praise from MEE faculty occurred in public, peer-attended forums. Public recognition on the Departmental Web site was an additional motivator. Many in this cohort of students maintain profiles on social networking sites such as Facebook and share their college activities with friends and peers through this medium. To capitalize on this new form of peer communication, students pictures and brief bio's were posted on the faculty advisor's laboratory Web site, and each new student presentation was immediately posted on the lab's publication list. For many students these public postings represented the first time they could Google themselves and get hits associated with efforts beyond social networking sites. This public success and recognition was then easily shared with peers, friends, and family, and provided positive reinforcement to motivate more work.

**Figure 4:** While delivering poster and plenum presentations, undergraduate researchers interacted with senior members of the technical community, to build valuable experience in technical discourse.

The most important question is: can the Researcher Incubator model be reproduced elsewhere? Or did the unique attributes of UNT's MEE Department during start-up lend themselves to a successful venture that cannot be reproduced in an established engineering program. We believe that the Researcher Incubator CAN be reproduced elsewhere using the same missions and underlying Just-In-Time learning techniques presented here. However, a commitment is required on behalf of the Department and the University to disregard misconceptions about undergraduate's inability conduct meaningful research and allow faculty time to mature the program to a successful, sustainable, productive state without criticism or withdrawal of support.

## Conclusions

UNT's Researcher Incubator has successfully pioneered a symbiotic relationship between engineering research and undergraduate education within an emerging research university. The three-fold mission of this organization was to 1) to train undergraduates as engineering researchers, 2) to teach engineering skills for the 21st century, and 3) fast-track undergraduates into successful early research experiences. These missions were achieved while providing value to faculty by 1) providing proficient student project managers, 2) providing researchers trained in faculty research areas, 3) illuminating for students how laboratories function, 4) motivating undergraduates to apply to graduate school, and 5) addressing program accreditation outcomes difficult to attain through conventional means. Simultaneously, value was provided to students by 1) teaching them how to find or develop engineering knowledge, 2) making them competitive for graduate school and industry, 3) providing team leadership experience, and 4) improving their technical competence and self-confidence.

We showed that if undergraduate students are 1) taught how to discover technical information and knowledge, 2) enabled to work in collaborative groups, and 3) vested with responsibility to manage and execute serious research, they can successfully complete open-ended projects. Researcher Incubator success was demonstrated by comparing MEE undergraduate to graduate researcher productivity in the 14-month period of Researcher Incubator activity. Undergraduates gave six poster presentations and three conference presentations, co-authored three grants, and were awarded $3,150 in funding. By contrast, graduate students gave one conference presentations and wrote no grants.

Despite the demonstrated success of the Researcher Incubator at UNT, the program was deemed dilatory to faculty focus and discontinued in November 2008.

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