Rose-Hulman Ventures
Outcomes from an Experiential Learning Program

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Abstract

Rose-Hulman Ventures (RHV) began in 1999 at the Rose-Hulman Institute of Technology as a unique program providing outstanding experiential learning opportunities for math, science, and engineering students. Funded by the Lilly Endowment Inc., the program has been an incubator/ technology center engaging students and technology-based companies in project work that provides students employment with the challenges and excitement of real professional practice. Over 1500 internship positions have been offered to 575 students working on a range of design, prototyping, and testing projects for over 84 client companies.

The challenges of educating the 21st century engineer call for innovative approaches in both curricular and co-curricular programs. The global economy and highly competitive workplace of today are creating needs for a solid technical education combined with professional practice experiences in the undergraduate curriculum. Many programs focusing on industrial partnerships, service learning, or other project based experiences have been documented. These are usually offered as a for-credit course, often as part of the senior design experience.

Rose-Hulman Ventures takes a unique, co-curricular approach. For the student, the program offers paid internships on-campus and is like working at a real job. It offers unique benefits beyond a curriculum based approach to both the client companies and students, including realistic, cross functional views of the innovation process and the very real need for useful deliverables that in many cases have been important inputs to business success or failure. A key feature of the program is the role of project managers who are full time professional staff members that serve in a project management and leadership role for the student teams and assure professional level results.

This paper describes Rose-Hulman Ventures, the mechanics of the project work, and the synergistic benefits for students, the industrial clients, and the Institute as a whole. Particular emphasis is placed on benefits of a co-curricular approach to professional practice experiences and learning outcomes and to client companies. These include the ability to easily assemble

interdisciplinary teams of students, to scale the size of the team to suit the project, to have students think of themselves as contributing professionals and to start and stop projects at any time. In addition, six years of data will be used to summarize key steps in program composition and evolution, history of student involvement, and measured outcomes of the program for students and the Institute. Annual assessment data will be used to demonstrate the high level of student satisfaction with the experiences offered, as well as the important educational benefits.

1. Program History and Background

Rose-Hulman Institute of Technology is a private institution that offers mathematics, science and engineering degrees at the bachelors and masters levels. From its origins in the late 19^{th} century, the school has emphasized the integration of rigorous classroom work with hands-on exposure to applications of what students are learning. For over two decades, Rose-Hulman has been evolving methods to prepare students to meet the increasing demands to be significantly productive in shorter and shorter amounts of time. Traditional, single discipline focused laboratory experiments do not adequately convey current professional requirements. Since the 1980's, the Institute has increasingly used realistic experiences to educate students about the multidimensional challenges of actually implementing innovation. In 1999, building on successes of earlier efforts in new product development first in applied optics and later in a broader range of disciplines, Rose-Hulman launched a unique incubator/new product development center with generous grant funding from the Lilly Endowment.

There were dual purposes for the grant and the subsequent activities it funded – demonstrate effective experiential education and change the Indiana economy. From Rose-Hulman's perspective, the project enabled a dramatic increase in the use of real new product development projects to prepare the best new engineering and science professionals. While a number of industrial relationships supported capstone projects each year and there had been some success at getting students involved in a few products that made it to the marketplace, Rose-Hulman Ventures provided dozens of employment opportunities for students to work directly on new products. The original idea was to offer technical entrepreneurs a chance at seed funding in in-kind R&D and cash forms if they brought appropriate project work to Rose-Hulman Ventures. While established firms were reluctant to let student teams tackle anything but back-burner projects, struggling start-ups had little to lose and investment to be gained. Early projects included some ideas that have gone no where, but there were also successes like a breast biopsy system and compact chemical detection technology that are being marketed and have provided returns on Rose-Hulman's investments.

The Lilly Endowment provided the funding as part of their mission to promote educational initiatives, especially in Indiana. However, they hoped to use higher education projects to accelerate changes in the state's economy. At the end of the 20^{th} century, figures showed that Indiana ranked at the bottom of states for percentage of college graduates in its population and that 63% of the graduates of the states science and engineering programs were pursuing careers elsewhere. Fostering better linkage of higher education and initiation of new business represented a way to reverse such data and provide exciting opportunities for educated young people to stay. On the same day Rose-Hulman's award was announced, there was a comparable grant to Indiana University to launch its major efforts in Informatics.

2. Structure and Evolution of RHV Program

The current mission of the RHV program is to engage technology based businesses to provide outstanding educational opportunities for students. Using the earlier successes with start-up companies, the program is now promoted to technology based companies of all sizes, maturities, and types to identify technical needs they may have and to create structured project work that can be executed in the RHV program as shown in Figure 1. A legal agreement is executed including a general project scope and terms concerning confidentiality, intellectual property, and indemnity. The companies contribute the technical needs and financial support to the arrangement. The RHV program provides dedicated infrastructure, project managers, students and faculty support as needed.

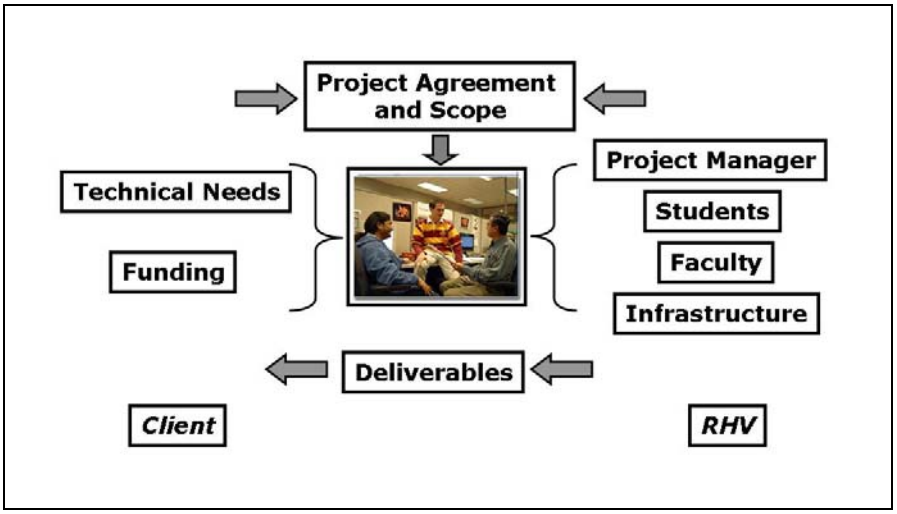

Figure 1 – Project Structure

The program operates on a continuous, year-round basis and at any time, the program has ongoing project work with 14 to 18 companies involving 70 to 85 students and 20 staff/faculty members working on the projects. Projects are pursued and selected to cover a broad range of industry segments and company profiles. The projects typically fall in the 'innovation' stage, as opposed to the invention or research stage, and include the common activities of design, model, prototype, build, and test. Projects with client companies may run anywhere from 6 months where one particular project is completed to 36 months to indefinitely where a program of ongoing projects are identified by the client company and move through the program. A typical sample of projects is shown below:

- Prototype designs for handles for medical devices,
- Software for medical imaging and transcription applications,
- Testing and prototype development for automotive seating technology for improved driver comfort,
- Pressure regulation system for medical mattress application to minimize pressure ulcers,
- Image processing algorithms for formed plastic parts,
- Material handling solutions for transporting printing rollers.

A key element in the success of the program is the nine project managers. The project managers are full-time staff members typically with a masters' degree in engineering and some industrial experience. The project managers develop the project scope agreements, hire and manage the student teams, and provide a consistent point of contact for the client companies. The project managers work in a mentorship role providing direction, guidance, and advice to student teams without performing the work. The project managers also work to push students outside of their 'comfort zones' and encourage them to take on new technical and professional challenges when appropriate.

The program is housed in a 30,000 square foot facility five miles from the main Institute campus. The building was formerly a commercial office building and is divided into approximately 15 flexible/modular work rooms with one or multiple teams assigned to the work rooms. Each room includes defined team areas, modular furniture with a workspace for each student, a printer, a small meeting area with conference table, and usually space for the project manager. Dedicated laboratories have been setup for an electronics shop, machine shop, wet lab, and rapid prototyping equipment. Each student is assigned a desktop computer with necessary software to support their work. Work spaces are 'open' which facilitates communication among the team. Co-locating the project manager with the student team facilitates both formal and informal communication among the team and project manager. Smith and Reinertsen[1] highlight the importance of co-location of team members citing team cohesiveness, cooperation, and communication factors. Additional spaces include a 100 seat meeting room, conference rooms, and lunch room.

The separate facility for the program has advantages and disadvantages. The primary disadvantages are that a perception of mission separateness may be created and it is more difficult to maintain close ties and communication with the campus community. The advantages are that with a separate facility, it is possible to create more of a 'commercial' culture in the program and it provides students the experience of 'going to work' in a building that does not look or feel like their campus classroom.

From the program start to the fall of 2005, the Rose-Hulman Ventures operated as a technology center and incubator. The primary focus for clients was small, start-up companies and the program offered cash and in-kind (engineering services offered for equity) investment as a means to attract appropriate projects and clients. Since mid-2005, the focus of the program has expanded to focus on companies of all sizes and growth stages through fee-based project arrangements as well as continuing an in-kind investment option at lower priority. This expansion to include companies of all sizes has been successful in securing a larger and broader range of projects in all disciplines while maintaining a high level of quality in both the experiences and results.

For students, the experience is an on-campus, paid internship. Students work part time during the school year and full time during the summer. Pay rates are typical internship wages in the \$10 to \$15/hr range and students commonly work two to three quarters in the program although some do work up to six to seven quarters. The student team composition is adjusted as the projects progress to ensure the right mix of technical skills exists on the team. As students rotate in and out of the program, project managers work to ensure their teams include students with a quarter or two experience on the project while bringing in new students with no experience. A student's grade point is not a factor in hiring decisions and students of all class standings work in the program although juniors and seniors are the majority of student workers.

Class Standing	***%***
Senior	44%
Junior	25%
Sophomore	19%
Freshman	6%
Graduate Student	7%

Table 1 – Student Class Standing in RHV Projects

Major	***% Students***
CS/SE	33%
ME	20%
EE	16%
CPE (Computer Engr)	14%
MSEM (MS Engr Mgmt)	1%
BE (Biomedical Engr)	5%
CHE	4%
Other (CE, Math, OE)	7%

Table 2 – Student Majors in RHV Projects

Tables 1 and 2 show a typical snapshot of class standing and major breakdowns for students in the program. In class standing, almost 70% of the students are juniors and seniors, but a full 30% are freshmen, sophomores, and a few graduate students. With majors, a broad range of the 15 majors at Rose-Hulman are included in the program with a high percentage of Computer Science and Software Engineering. While no special effort is made to attract 'software' projects, the nature of the complex systems of today often includes a software component with electro-mechanical systems.

The nature of the project work naturally generates multidisciplinary teams. On average, about 65-75% of projects are multidisciplinary and the additional elements of mixed class standing and prior project experience provide an additional richness to team structure.

A number of formal and informal 'professional practice' activities take place in the program. There is a formal lunch speaker series where managers and executives speak to the students and project teams regularly (daily or weekly) and students communicate through oral and written updates with managers or executives at their client companies. Informally, the program hosts visitors or groups on a daily basis and students routinely provide updates on their projects to visitors to their work areas.

Students cite many benefits of the program including:

- A high quality internship on-campus which can they can participate in without extending the time to graduate,
- Ability to leverage the RHV internship to secure a premium industry internship,
- Ability to apply classroom concepts to a real project,
- Ability to work on important, real, and large projects,
- Ability to relate RHV project experiences to more engaged classroom performance,
- Experience on which to base career decisions – what they like to or don't like to do,
- Internship experience and professional polish essential for job seeking.

For faculty, the program offers professional development opportunities through the applied development projects. Some projects require additional depth of expertise on a particular field and faculty involvement ranges from advice, to short term consulting, to serving as a project manager for a student team. Faculty gain valuable industrial experience and are able to work 'on the same team' with students in an un-graded experience. Faculty are compensated as consultants for short term involvement and in some cases, release time from teaching can be sometimes be arranged for a longer engagement. Despite the benefits, not all faculty find the program to be an appealing professional development activity. The projects in the program may not be a good match to their expertise or professional development plan and with client confidentiality limitations, publication of results and promotion/tenure benefits may be limited. The faculty who do work in the program often cite development of professional skills, project management, client interaction, and connection with industry as their primary benefits above application or development of technical skills.

For the client companies, the benefits of the program include flexible and configurable engineering resources allowing them to accomplish some important yet not top priority technical work. The structure of the program and guidance provided by project managers gives client companies the confidence to choose projects of higher importance and challenge than might be given to a typical classroom project. In addition, some companies view the program as an 'easy' internship program with less overhead than their own programs where they can review the work of several students in project work related to their business and hire any suitable students upon graduation.

The project work is priced at a level comparable to 'internship' wages ($20-25/hr) and the preferred arrangement is a subscription agreement where the company pays a flat fee per month for the student team plus materials and supplies costs. A five student team for twelve months is priced at about $85,000 and on an annual basis, the program now generates over $800,000 in revenue. The revenue generated covers a portion of the operating cost of the program with the remainder covered by grant funding.

Companies often comment on the following factors as differentiators between the RHV program and working with a 'research' university or a capstone design project :

- Confidentiality and intellectual property are a top concern and the terms of the RHV project agreement have been biased in favor of the client company. Companies do not want to haggle for weeks over these terms and if unfavorable, they will not enter into the agreement or will not offer project work with a high level of importance and challenge.
- The full-time project managers offer confidence that the student team will be managed on a day to day basis, results will be of higher quality, and that continuity will be maintained on project know-how as students move on and off the team.
- The co-curricular structure allows projects to start and stop at any time so that companies do not have to wait for the start of the academic term for their project work to begin. This again results in projects being offered with a higher level of importance and challenge.
- The ability to accomplish project work following processes and achieving outcomes defined by the client company is a significant factor in client satisfaction and the fact that many clients have continued project work for two to three years. Clients often feel that

collaborative work with universities sometimes follows unrealistic processes and pursues academic paths unrelated to their primary interests.

From the start of the program, RHV has featured a 'realistic' work environment for students. Students work in teams managed by a project manager and perform the majority of the technical work under the guidance of the project manager. As projects are secured from client companies, the size and technical needs of the student team are identified and positions are advertised at that time. Students apply for the posted positions, submit a resume, interview, and are hired for a defined term. Students sign a nondisclosure agreement, report to work in a separate facility dedicated to the Ventures program, report to a project manager supervisor, and track hours and work results. Students may enter a project at the start of a new project or enter an ongoing project in the middle to continue previous work. The deciding factors in hiring students are usually skills, interests, and prior experience in hands on project or hobby work. While students usually list grade point average, there are no GPA thresholds and it is not a primary factor in hiring decisions.

The program has two main goals of providing outstanding educational experiences to students as well as providing project results and value to the client companies. The realistic work environment as an 'engineering services' organization has emerged from the priority to provide results and value to the client companies. While not a professional services company, modeling the environment and culture in a realistic manner has been successful for both students and clients.

3. Attributes and Analysis of Project Based Experiences

As a project based, educational experience, the RHV program has several unique features compared to the traditional 'for credit' project experience. Many different types of project based experiences have been described including capstone design sequences[2-6], service learning opportunities[7], and industry collaborative projects. In many or most of these cases, even though the projects are related to a company or a client, they are 'for credit' experiences, students are graded on their work. The primary differentiator for the RHV program is that it is an on-campus, 'for pay' experience and a number of significant and subtle differences emerge.

Project based experiences, either a capstone design sequence or a course based project, are often a part of a curriculum plan to satisfy the ABET educational outcomes. The ABET 'a through k' educational outcomes are divided into the technical skills and the professional skills. In Table 3, items a.,b.,c.,e.,k. comprise the technical skills and items d.,f.,g.,h.,i.,j. are the 'soft' or professional skills.

Engineering education has historically focused on the technical skills with adjustments and refinements to curricula to ensure the proper and current technical content of coursework. Recent work as described in Shuman et.al.[8] has provided perspective on the importance of the professional skills and the growing demand for these skills in the industrial workplace. In addition to providing a good environment for technical skills education, the project based activities described above also provide the basis for professional skills education. With the increasing attention to the professional skills, the question arises of what are the best pedagogical methods and environment to provide education in the professional skills.

a	an ability to apply knowledge of mathematics, science, and engineering
b	an ability to design and conduct experiments, as well as to analyze and interpret data
c	an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
d	an ability to function on multi-disciplinary teams
e	an ability to identify, formulate, and solve engineering problems
f	an understanding of professional and ethical responsibility
g	an ability to communicate effectively
h	the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
i	a recognition of the need for, and an ability to engage in life-long learning
j	a knowledge of contemporary issues
k	an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Table 3 – ABET Educational Outcomes 'a through k'

In Shuman et.al.[8], it is suggested that an environment with high 'fidelity and complexity' are the ideal context for team skills education. Experience from the RHV program indicates that the concept of the 'real workplace' provides the fidelity, complexity, and ambiguity ideally suited to a broad range of technical and professional skills experience and application. Attributes of a project environment with capability of describing the degree to which a 'real workplace' environment has been achieved are proposed below in Table 4.

Project Attribute	***Levels***
Location :	On or Off Campus
Reward :	For Grade or For Pay
Problem Definition :	Ambiguous or Well Defined
Solution Process Definition :	Ambiguous or Well Defined
Outcome Definition :	Ambiguous or Well Defined
Technical Challenge :	Low to High
Professional Context :	Low to High
Supervision :	Faculty, Boss, or Mentor
Guidance :	Guided or Unguided
Structure :	Individual, Group, or Team
Disciplines:	Single or Multidisciplinary
Class Standing:	Freshman to Senior
Time Constraints :	Academic Term Constraints or No Constraints
Culture :	Academic or Commercial
Client :	Single, Multiple, None
Client Profile :	Size, markets, etc.

Table 4 – Attributes of Project Experiences

Students are exposed to a variety of project based experiences over their college careers including classroom, capstone, internship, and guided projects like RHV. Each of these experiences take on different project characteristics and each focuses on certain educational objectives under practical constraints. Table 5 summarizes project attribute rankings for a classroom, capstone design course, industry internship, and a guided project like RHV. A industry internship is described as 'variable' in some categories as students report that many experiences are excellent and others are lacking. The RHV experience is described as closely and consistently modeling a realistic workplace setting. While this approach appears promising, further work is needed to develop these concepts further and to relate the attributes to suitability and quality of the educational experience for different desired outcomes.

Project Attribute	***Classroom***	***Capstone Design***	***Industry Internship***	***Guided Project Like RHV***
Location	On Campus	On Campus	Off Campus	On Campus
Reward	Grade	Grade	Pay	Pay
Problem Definition	Defined			Ambiguous
Solution Process Definition	More Definition	Some Definition	Variable	Ambiguous
Outcome Definition	Defined	Defined	Variable	Ambiguous
Technical Challenge	High	High	Variable	High
Professional Context	Low	Moderate	Variable	High
Supervision	Faculty	Faculty	Boss/Mentor	Mentor/Boss
Guidance	Minimal	Minimal	Variable	High
Structure	Individual	Group	Variable	Team/Group
Duration	Academic Term	Academic Terms	Academic Term	No Academic Term Limits
Culture	Academic	Academic	Industry	Industry
Client	No	Yes	Yes	Yes
Company Profile	NA	Variable	Variable	Variable
Company Priority	NA	Low	Low-Medium	Medium

Table 5 –Attribute Comparison for Project Experiences

4. Desired Program Outcomes

It should come as no surprise that the desired outcomes of the student experiences at Rose-Hulman Ventures are closely related to the 'a through k' criteria for ABET accreditation as listed in Table 3. For comparison, Table 6 lists the learning outcomes monitored by the RHV program.

Although the two lists are similar in many ways, there are some important differences in emphasis. The RHV list is more specific, more practice oriented and more customer-oriented. For example, criterion 'f' in the ABET list addresses "understanding" of ethical responsibility, while Rose-Hulman Ventures addresses ethics at the top in '1' and '2'. RHV wants each of the student interns to demonstrate that they know the code of ethics of their field and how it relates to specific practices with that field. While ABET talks about functioning on teams, RHV is specifically interested in sharing duties and building consensus before applying solutions. The ABET list calls for designing within political and environmental constraints and broad education to understand multidimensional impacts of engineering solutions, RHV asks for specifics on the role of social concerns in the problems and the effects on the environment and culture of particular proposed solutions. RHV also asks for interns to think strategically about what they are doing and how it fits in the overall client picture.

Item	***Learning Outcome***
1.	Demonstrate knowledge of a professional code of ethics.
2.	Evaluate the ethical dimensions of professional engineering, mathematics and science practices.
3.	Demonstrate an awareness of how the problem is affected by social concerns and trends.
4.	Demonstrate an awareness of how the proposed solution(s) will affect culture and the environment.
5.	Share responsibilities and duties with other team members.
6.	Analyze ideas objectively to discern feasible solutions and then build consensus.
7.	Develop a strategy for action.
8.	Identify readers/audience, access their previous knowledge & information needs and organize/design information to meet the needs.
9.	Provide content that is factually correct, supported with evidence, explained in sufficient detail, and properly documented.
10.	Test readers/audience response to determine how well ideas have been relayed.
11.	Submit work with a minimum of errors in spelling, punctuation, grammar and usage.

Table 6 – Rose-Hulman Ventures Learning Outcomes

While the outcomes from the Rose-Hulman Ventures intern experience clearly support the outcomes desired by ABET, the method of approach emphasizes learning from the experiences with a particular project. The quote often attributed to Confucius - ‘*I hear and I forget. I see and I remember. I do and I understand.*’ is quite fitting and appropriate. As Table 10 on skills acquisition shows, the expectations go further and ask students about specific areas, including such things as marketing and finance which are not explicitly mentioned by ABET.

5. Impact and Evidence from Assessment

The impact of a program of this type can be expressed in a variety of ways including benefits for students and faculty in the program, the client companies, and the Institute as a whole. Similar broad-based impacts have been noted with other programs.

Since the start of the program, over 1570 internships have been offered to some 575 students. An internship is defined as a student working one academic quarter in the program, so on average, a student works 2.7 quarters in the program. Figure 2 shows the historical pattern of the number of internships offered by the program per quarter. The increase in student participation starting in early 2005 reflects the expansion of the program to include client companies of all sizes through fee-based arrangements.

Another measure of impact is the percentage of a graduating class that has had an experience in the program or in some way has been affected by the activities of the program. It is calculated that 30% of a graduating class of approximately 400 have had an experience as an intern working in the program.

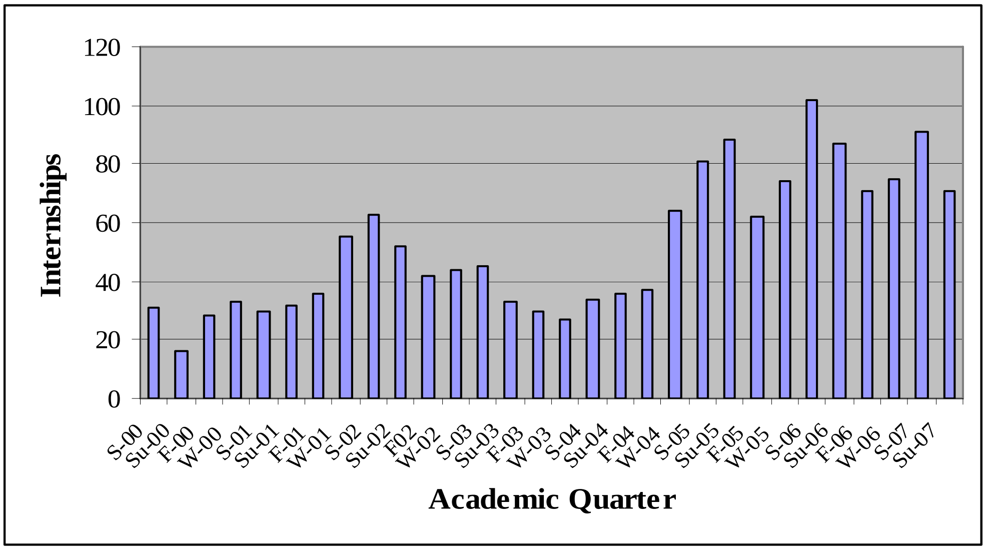

Figure 2 – Student Internships per Academic Quarter

Further connections between the program and academic program are accomplished through the RHV staff members serving in advisory roles on senior design projects. The project managers provide advice, assistance, and guidance to senior design project teams and the program reaches an additional 230 senior students (in Mechanical, Electrical, and Biomedical Engineering) per year in this way. This activity also provides important connections, awareness, and education between the faculty and RHV staff.

Since the start of the program, project work has been done for 84 different companies and organizations. The geographical coverage of the projects ranges from projects for clients within the Institute, to companies in the local community, to statewide and national companies, and to companies with international connections. The company list includes small to large companies and companies in a broad range of industries and technologies including medical devices and software, wireless devices, automotive, transportation, and energy related. All project work typically falls in the 'innovation stage' including activities of design, modeling, prototyping, assembly, and testing. In all projects, a project agreement is executed with the client company including terms related to confidentiality and intellectual property. Due to confidentiality restrictions, a detailed discussion on project activities and outcomes is not possible.

A variety of formal assessment activities have been performed over the years including student outcomes, client outcomes, economic development impact, and performance feedback between project manager and student. Results reported here focus mainly on student surveys and outcomes. A simple, single measure metric tracked since 2002 is the senior survey score for the RHV program. In the spring of their graduating quarter, seniors are surveyed on a broad range of campus classroom, facility, and program activities, one of them being the RHV program. Students are asked to rate the quality of the program on a 1 to 5 scale where 1 indicates poor quality and 5 indicates excellent quality. Table 7 shows the senior survey score for the RHV program.

Year	***2002***	***2003***	***2004***	***2005***	***2006***	***2007***
Senior Survey Score	3.43	3.95	4.06	4.07	4.12	4.29

Table 7 – Senior Survey Score for RHV Program

A consistently increasing trend is seen with a score of 4.29/5.00 in the current year indicating a high overall level of student population awareness and satisfaction with the program.

In selected years, focused assessment activities have been carried out with students in the RHV program. A common question in all these surveys is 'O*verall, how satisfied have you been with your RHV experience*' with five possible choices being very satisfied, satisfied, neither satisfied or dissatisfied, dissatisfied, or very dissatisfied. Table 8 below indicates the percentage of students answering 'very satisfied or satisfied' with their RHV experiences and the trend again indicates a high level of student's satisfaction with the program.

Year	***2001***	***2004***	***2006***
% Very Satisfied or Satisfied	91%	95%	100% (80% very)

Table 8 – Student Satisfaction with RHV Program

The rare dissatisfaction comments related to items such as – not enough work, poor project organization, unresponsive client, and low pay.

In 2006, the assessment survey included a number of issues including comparisons to classroom experiences and learning outcomes. Students in the program were asked the following question - '*Overall, my experience in working with the Rose-Hulman Ventures project team was meaningfully different than my experience with working with a team of students on a class-related project.*' The majority of students (90%) reported their RHV project team experience was meaningfully different from their experience working in teams for class-related projects (60% strongly agree, 30% agree, 10% neither agree nor disagree).

A series of questions on learning outcomes, skills, and roles are completed by students. The first question is related to general learning outcomes for the program, '*For each of the learning outcomes below (Table 9), please indicate how well your Rose-Hulman Ventures project experience contributed to your development of that attribute'* and student responses are summarized in Table 9.

Student responses fall primarily in the 'moderate, well, and very well' categories indicating a broad range of educational impacts on students.

Outcome	*Not at All*	*Barely*	*Moderatel y*	*Well*	*Very Well*
A. Demonstrate knowledge of a professional code of ethics	10%	0	50	30	10
B. Evaluate the ethical dimensions of professional engineering, mathematical, and scientific practices	20	10	40	20	10
C. Demonstrate an awareness of how the problem is affected by social concerns and trends	10	5	35	30	20
D. Demonstrate an awareness of how the proposed solution(s) will affect culture and the environment	0	25	40	25	10
E. Share responsibilities and duties with other team members	5	0	20	30	45
F. Analyze ideas objectively to discern feasible solutions and then build consensus	0	0	10	35	55
G. Develop a strategy for action	0	0	5	55	40
H. Identify readers/audience, access their previous knowledge & information needs, and organize/design information to meet the needs	0	15	40	30	15
I. Provide content that is factually correct, supported with evidence, explained with sufficient detail, and properly documented	0	15	30	20	35
J. Test readers/audience response to determine how well ideas have been relayed	20	10	45	10	15
K. Submit work with a minimum of errors in spelling, punctuation, grammar, and usage	0	20	25	25	30%

Table 9 – Student Development of Educational Outcome Attributes

The next question relates to technical and professional skills learned in the program, '*Please indicate the 5 skills learned at Rose-Hulman Ventures that you feel will be the most useful in the upcoming academic year'* and student responses are summarized in Table 10.

It is interesting to note the top skills cited include technical skills but also include team skills, the impact of market and financial factors on engineering decisions, and life long learning. Several of these are items in the ABET outcome list in Table 3.

Finally, a question about different roles played during project work is asked. In Davis et.al.[12], the concept of an 'engineer profile' is developed describing the skills and behaviors that an engineer needs to exhibit to be successful in the workplace. The roles identified in the engineer profile of leader, designer, collaborator, communicator, and self-grower are included in the question *'For each of the roles below (Table 11), please indicate how frequently you fulfilled each role during your Rose-Hulman Ventures experience.'*

Rank	*Skill*	*%*
1	Ability to design a product or process to satisfy a client's needs subject to constraint	90%
2	Ability to apply problem solving skills necessary for engineering practices	75%
3	Ability to work effectively in teams	65%
4	Understanding of the impact of marketing factors in engineering decisions	45%
5	Understanding of the impact of financial factors in engineering decisions	40%
6	Ability to recognize the need for life-long learning	35%
7	Understanding of the role of intellectual property in engineering decisions	30%
8	Ability to communicate effectively orally	30%
9	Ability to understand the impact of engineering solutions in global societies	20%
10	Ability to design experiments	20%
11	Ability to communicate effectively in technical writing	15%
12	Understanding of discipline specific contemporary issues	10%
13	Ability to conduct experiments	10%
14	Recognition of ethical and professional responsibility	5%
15	Other	5%
16	Ability to analyze data	5%
17	Ability to interpret data	0%

Table 10 – Student Ranking of Skills Learned

	Never	Rarely	Occasionally	Often	Frequently
A. *Leader:* take initiative in guiding the project	0%	15	25	40	20
B. *Designer:* produce work products on time and within Budget	0	0	5	50	45
C. *Collaborator:* contribute constructively to team performance	0	5	5	40	50
D. *Communicator:* communicate effectively with key stakeholders	0	0	30	25	40
E. *Self-Grower:* proactively learning and using resources	0	0	0	35	65%

Table 11 – Roles Fulfilled During RHV Project

Responses to the question indicate students often or frequently are able to experience and practice roles they will need to play in the workplace. One of the lower ranked roles is 'leader' and while seemingly surprising, with team based projects, not all students experience team leader opportunities. Ways to increase and provide leadership opportunities to more students are being considered.

6. Summary and Future Directions

Through the generosity of the Lilly Endowment grants, the RHV program has had the opportunity to develop and explore a unique experiential learning program and structure for engineering, science, and math students. The primary differentiators for the RHV program are that it is an on-campus, 'for pay' experience and from this basis, a number of significant and subtle differences emerge. These include:

- A highly realistic experience for students working as technical professional,
- A highly engaging environment for both student and client company,
- Realistic team structures including a manager/mentor, teams with multiple majors, team members of different class standings and experience levels, and team members entering and exiting a project in the middle,
- Challenging project work with project durations spanning weeks to months,
- An environment that naturally creates 'professional skills' challenges and opportunities,
- A culture which is more commercial in nature but with a mentorship and academic support system.

The vision for the Rose-Hulman Ventures program includes a continued focus on the core student–industry projects while expanding the program to include a number of supporting activities including:

a. Academic program connection support through senior design and other classroom activities,
b. Collaboration activities with partner universities and technology programs and centers,
c. Expanding 'professional' activities for students and faculty through projects with business, marketing, and legal components,
d. Developing new program components to provide students more leadership, management, and creativity opportunities, and
e. Continued discussion and focus on creating a cost-effective and financially sustainable program supporting the educational mission of the Institute.

While the future directions for Rose-Hulman Venture activities are evolving, it is clear that there is also a need for more research on how well experience-based versus alternative approaches are accomplishing their goals. Given the importance of finding more and better ways to effectively educate the technical professionals our world will need, it is crucial that we find ways to measure improvements and setbacks in the process. It is clear that a variety of 'project' experiences are offered to students with different characteristics, attributes, and educational impact. A better understanding of these characteristics of projects is needed to develop and apply the 'right project' for desired outcomes. It is possible that the ideal educational experience for technical and professional skills education will include a mix of curricular and co-curricular activities. This concept runs counter to the traditional concept that student learning occurs in a graded, classroom experience. The results from program outcomes and student responses here indicate progress and differences with the Rose-Hulman Ventures program, however, continued investigation into standardized assessment measurements are needed to facilitate comparisons with other campus programs and with other schools.

Many challenges and questions remain to accomplish education of engineers needed in the 21st century but it is clear that client based, industrial project experiences for students with high quality and challenging project work, realistic team structures, and engaging environment for both student and client can play a key role in this process.

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