Education Case Analysis For Pre-engineering Robotics After School Programs : Assessing The Intangibles

Marcos Chu[1]

Abstract - In today's economic situation, school districts are facing very challenging budget environments. School leaders need to have a sound education case analysis (ECA) strategy to invest in pre-engineering programs that are sustainable in the long run. As part of ECA it is necessary to understand how intangible factors such as current pre-engineering curriculum established within the district, community acceptance of the program and metrics used to calculate after-school program effectiveness can affect the educational case analysis. The purpose of an ECA is to enable school leaders to integrate financial information such as one-time program cost and recurring program support cost with intangible program benefits and costs. The ECA will also enable school leaders in making an informed decision to approve the after school program implementation, identify requirements for additional information or reject the project at time.

The success of an after-school STEM program is dependent mainly in the commitment and engagement of all the stakeholders in the learning community. There needs to be a broad support across the community and not only be a program driven from a sole organization. The goals is not necessarily to engage students so they will pursue a STEM career, but rather the purpose is to engage the whole community that will enable the goal of more students to pursue careers in STEM.

Keywords: education vase analysis, pre-engineering, curriculum development, robotics, systems engineering.

[1] INCOSE MG Spiral 5 Demo Robot Team Leader, marcos.chu@incose.org

Background

K-12 education has changed drastically over the last decade, not only in regards to the curriculum but also how the curriculum is deployed. In some school districts Science, Technology, Engineering, and Mathematics (STEM) education have been successful amid changes that require ever more investment from strapped school districts already financially struggling to provide technology, teacher training and community engagement. Districts have been finding new ways to engage students in STEM education by providing project-based learning [Rapp, 5]. The new project based learning has shifted the importance from student knowledge to individual student experience and skill mastery. The learning process used in higher education and in the business community is been adopted by school districts looking to emulate more closely the environment in which the youth will become the professionals of tomorrow. The United States higher education tradition of free inquiry and peer reviewed research has been emulated in K-12 classrooms across United States and also by countries with highly developed workforce such as China [Duncan, 1]. The education competiveness is no longer an affair between United States college bound students taking standard tests such as ACT or SAT in the United States to get into a good engineering college , but now college bound K-12students are competing for an opportunity to get a good college and job among the global primary and secondary education system students. Score performance is no longer the standard metric to measure student learning success but instead it is student engagement, specially after the last bell has rung. Student engagement is mostly likely to occur at an after-school robotics program that have the support of the local community. This paper takes a closer look how to effectively develop a business case analysis to help school administrator to evaluate the intangibles assets within the community when making a decision to support a after-school robotics club.

Situation

K-12 education is no longer confined to the classroom with the teacher who as the primary facilitator of education for a individual student. Today it takes virtually a “village” of individuals for STEM education that not only includes the education system but the community within the local system from business, service organizations and non-profit after school programs such as robotics competitions [Fan, 6]. In the current economical situation all the stakeholders feel the pressure to meet their goals with scarce financial resources. The implementation of an after-school robotics program needs to be done with careful analysis to ensure a return on investment (ROI), which not only includes financial data but also intangible cost that can be monetized. Schools districts interested in investing and supporting a robotics after-school program should take many factors into consideration related to intangible assets. The main intangible to take into consideration is the current outreach programs already in place at local higher education institutions and how school districts can partner with these institution to grow STEM outreach programs not only in regards to participating schools, but also in the diversity of STEM related programs been supported.

Cost Effective Project Based Learning Platform

Robotics provides a cross-discipline platform in which enables problem solving in a variety of engineering disciplines including mechanical, software, electronics and most importantly systems engineering. It enables students to have hands-on experience that helps the student to translate abstract mathematics and science concepts into concrete real-world-applications [Nugent, 4]. One of the advantages of using robotics as a learning platform is that it enables students to be fully be engaged in a real-life relevant problem solving activity. Robots can be built from every-day material such as wood using a hand power drill that can be bought at a hardware store to carbon-composite materials requiring extremely expensive capital investment. The availability of a wide range of materials and tools used for robotics building allows different learning communities to be engaged in STEM education. An industry robot prototyping team might require an investment of $100,000 to develop and build an unmanned aircraft while a college team can develop an aircraft prototype using off-the-shelf components for $10,000 and K-12 teams can build robots costing less than $1,000 to assemble a modular unmanned aircraft. The higher the cost of material and tools, the more investment will be needed for training to enable the student to have a high self-efficacy since specific knowledge will be in lower supply. While robotics provides an environment that can match the student self-efficacy at their current learning stage it can also provide a framework that enables positive message framing that enables students to decide to be engaged in after-school competition given it is viewed as a risk-free decision option [Lindenmeier, 5].

Assumptions

Non-recurring Program Cost

Most after school programs have recurring costs be the cost of Math team uniforms to providing snack at a science club meeting. It can be argued that most of those costs are optional costs to be incurred and not necessary to have a successful after-school program. This argument will be assumed true for this paper assuming that the student action of not re-enrolling on the program yearly does not relate to the student engagement interest due to perceived experience and will not impact the student future interest in STEM related programs or the choice to pursue a STEM related career. The intangible benefit of student engagement and translating it to an economical value is a task that needs further research.

Capital Investment

A major barrier for any robotics program is the initial capital investment needed. Another point to take in consideration is the distance between the competition venue and the organizations sponsoring the after school program. Given the considerable investment needed, organizations will more likely desire to have their employees to be mentors for the teams and it is necessary that the teams are local and reside within the team school district to ensure that mentor engagement is feasible and appropriate.

Reusable Hardware

The longevity of a robotics after school program will be primarily depend on the affordability of operation and be in line with other after school activities requiring low financial engagement thru fundraising. Fundraising is an activity that requires a lot time and resources that could be used instead on robot engineering activities such as preparing a Powerpoint presentation or holding a design brainstorming activity along with a trade study activity.

Recurring Benefits/Costs

The benefit of a student participating on a robotics after school program will be an intangible benefit that would need to be calculated by complex models to be able to obtain an accurate estimate. For the purposes of calculating an ROI that can be used to make a business decision on what after school program would be give the highest return on investment, it is necessary to make fundamental assumptions. The cost of a student volunteering to participate on the program will vary depending on the student realistic assessment of foregone wage and the benefits on one's social embed ness [Lee, 7].

Other Intangible Benefits/Costs

- Availability of professional organization chapter "seed" money between $500-$1000.
- Re-Usable Material (Engineering) per team is valued at no more than $750.
- Student participating on after-school STEM program would be making $8/hr otherwise on a part time job.
- Minimum Commitment of 3 times a week for 2 hours over a period of 6 weeks.
- Engineering Mentor available in the community : 8 hour commitment per year

The above assumptions is a few of the considerations that should be taken into account when a school district is considering to support a robotics club. Any investment should be carefully considered looking at both the short-run cost of the program and also the long-run cost of the program. Once a formula to calculate ROI is established, it is necessary to ensure that all stakeholders are in agreement of the ground rules and assumptions used to calculate this metric.

CALCULATING THE RETURN ON INVESTMENT

The calculation of return of investment is made assuming intangibles such as the commitment of the learning community stakeholders to be engaged, although it is hard to predict the future, when making a decision to implement a new after-school program, specially one deemed of great importance to the development of the youth that will become the professionals of tomorrow, it is necessary to get an early engagement from all the stakeholders and not only the change agent spearheading the effort. Clear communication is necessary to ensure that all stakeholders are providing accurate information of the program and it's benefits to the community. The ROI is an important metric measured on the Education Case Analysis (ECA).

$$
\begin{aligned}
&ROI \\
&= \frac{\mathrm{Re}\, CurringBenefits}{Non\,\mathrm{Re}\, curringCost} \\
&= \frac{(\mathrm{Re}\, curringEngagement - \mathrm{Re}\, curringCost) * yearsofoperation}{CapitalInvestment} \\
&= \frac{((nTeams \times nStudents \times OpportunityCost \times nContactHours) - yr\,\mathrm{Pr}\, ogramCost) * LearningCommunityCommitmment}{\mathrm{Re}\, suableMaterialCost}
\end{aligned}
$$

If we assume that a group of four rural counties, can each generate a CI of $5,000 each by raising money from the local business and service and professional organization chapters and have the local community college commit to financially sponsor the program for 4 years at a cost of $2,000 a year for 20 teams. We can say the LC CI would be $20,000 and RC would be $8,000 over the same period of program performance. Given the cost assumptions and assume the intangible asset of the cost opportunity of a student engaging at a STEM activity at $8.00 an hr instead of working part-time at a minimum wage job with the profile of 6 weeks program with a 2 hour contact every week. The Opportunity Cost per student is $288 dollars and for 20 teams of 30 students would be $172,800.

$$
\begin{aligned}
&ROI \\
&= \frac{((20 \times 30 \times \$8 \times 36) - \$2{,}000) * 4}{\$20{,}000} \\
&= \frac{(\$170{,}800) * 4}{\$20{,}000} \\
&= \frac{\$683{,}200}{\$20{,}000} = 34.16
\end{aligned}
$$

A ROI greater than one shows that the benefits out weight the cost of the program. A lower ROI would be if each team capital investment hardware cost is $6,000 and the additional material needed to build the robot is $3,000 per team. The ROI for a more expensive "robotic system" would be 3.76 and to achieve the same ROI as a more cheaper robotic system, it would be necessary to either increase the student hourly and frequency commitment to the program and also identify other intangible benefits that can be financially accounted for.

LEARNING COMMUNITY DEMO ROBOT

Robotics competition programs are focused on the students and assume an engaged community that can provide not only the financial support to enable such a program in the local community but also the technical mentoring to the students. The reality is that engineers in the community that can provide the relevant hands on experience may either been in their careers for long time and is no longer be involved in the hands-on activity of fundamental engineering or they are just starting their careers and juggling family and career priorities. The key is to engage the members in the given organizations financially supporting after school robotics competition programs.

KNOWLEDGE MANAGEMENT

Robotics after school programs generate a wealth of information that should be captured for future use, it is an important part to be able to implement a successful strategy, planning and operations of the team core mission and goals. Knowledge management is the management of the organization intellectual capital [Jamali, 3]. Intellectual Capital is intangible assets of an organization that needs to be captured, managed and be able to be used within the organization strategy to enable the organization to be competitive in the marketplace. Physical assets such as the material used to build the robot or the tools such as a drill are commodity in which the value can be measured and evaluated the benefit of a given asset in a straight forward fashion, while knowledge is an asset that add value to the organization where not only its ownership is necessary to ascertain but also how it is used to further the robotics team mission as it matures and the members become more experienced. The implementation of knowledge management can be as simple as an excel sheet that keeps tracks of the name of the students, their tasks they performed and the ranking of the team on the given year at competition.

MEASURING PERFORMANCE

Performance analysis is an important part of setting the robotic student team strategy and ensuring the team is moving forward each week as they build their robot and this metric can be used set strategies that enables a balanced performance of team. The key metrics is the ability to measure how well the team is performing against a set of schedule expectation and how well they are able to engage the community, parents, teachers and administration but also the local media.

SUMMARY

The success of an after-school STEM program is dependent mainly in the commitment and engagement of all the stakeholders in the learning community. There needs to be a broad support across the community and not only be a program driven from a sole organization. The goals is not necessarily to engage students so they will pursue a STEM career, but rather the purpose is to engage the whole community that will enable the goal of more students to pursue careers in STEM.

REFERENCES

[1] Duncan, A.. (2010). Back to School: Enhancing U.S. Education and Competitiveness. Foreign Affairs, 89(6), 65- 0_11. Retrieved November 29, 2010, from ABI/INFORM Global. (Document ID: 2186815551).

[2] Lord, M.. (2010). WHAT'S KEEPING THEM AFTER SCHOOL? ASEE Prism, 19(8), 45-47. Retrieved November 27, 2010, from ProQuest Education Journals. (Document ID: 2026586431).

[3] Jamali, R.. (2010). Measuring and Comparing of Intellectual Capital in the Public and Private Universities in an Iranian Context. Interdisciplinary Journal of Contemporary Research In Business, 1(9), 88-103. Retrieved November 25, 2010

[4] Nugent, G., Barker, B., Grandgenett, N., & Adamchuk, V.. (2010). Impact of Robotics and Geospatial Technology Interventions on Youth STEM Learning and Attitudes. Journal of Research on Technology in Education, 42(4), 391-408. Retrieved November 27, 2010, from ProQuest Education Journals. (Document ID: 2056317171).

[5] Rapp, D.. (2010, March). REDESIGNING STEM. Scholastic Administrator, 9(5), 33-34,36. Retrieved November 27, 2010, from ProQuest Education Journals. (Document ID: 1991035231).

[6] Uei-Jiun Fan, Jawaharlal Mariappan, & Saeed Monemi. (2007). Enhancing Experiential Pedagogy With Interdisciplinary Engineering Service-Learning Activities. International Forum of Teaching and Studies, 3(2), 5-16,61. Retrieved January 24, 2011, from ProQuest Education Journals. (Document ID: 1306357701).

[7] Young-joo Lee, & Jeffrey L. Brudney. (2009). Rational volunteering: a benefit-cost approach. The International Journal of Sociology and Social Policy, 29(9/10), 512-530. Retrieved December 5, 2010, from ABI/INFORM Global. (Document ID: 1963644221).

Marcos Chu

Marcos Chu is an INCOSE Midwest Gateway Chapter Past President and currently serve as K-12 Outreach Ambassador. Chu is also a member of SCEA (Society of Cost Estimating and Analysis), ISPA (International Society of Parametric Analysts) and MSTA (Missouri State Teaching Association) St. Louis Chapter. In the past, he has taught computer programming and web development classes at colleges in Texas, Idaho and Arizona. Chu holds a bachelors degree in Electrical Engineering from Purdue University, an MBA from the University of Phoenix, and a Contracts Management Certificate from St. Louis University. He is currently pursuing a Ph.D in Accounting at Capella University . Chu currently works at the Boeing Company and is also proposal capture leader for a volunteer based Spiral Demo Robot team, working on a proposal for Spiral Demo Robot 6.