Robotic competitions: short term pain for long term gain

Henry Williams, Will N. Browne, and Dale A. Carnegie
Victoria University of Wellington, New Zealand
Henry.Williams@ecs.vuw.ac.nz

Abstract

In the last two decades many extracurricular robotics competitions have been established for university students, but there has been little academic research on whether they are beneficial or detrimental to their target audience. By focusing in-depth on one such competition, National Instruments Autonomous Robotics Competition (NIARC), this paper examines the student experience, academic performance changes and identifies other outcomes, that are influenced by robotic competitions. Although the results cannot be generalised to all students in all such competitions, the paper identifies important factors that need to be considered when deciding to promote these competitions to students. The student narrative shows that the competition has positively contributed to their studies, with a GPA analysis of Victoria University of Wellington (VUW) students suggesting improvements for team members in the long term.

1 Introduction

In the past two decades robotics competitions have been established by various organizations as a way to find innovative solutions to identify tasks (e.g. DARPA robotics challenge), encourage academic endeavour (e.g. RoboCup), promote products (platform uptake and publicity, e.g. NIARC), promote Science, Technology, Engineering, and Mathematics (STEM) (e.g. First Lego), and as a business model (e.g. VEX Robotics). Each competition evolves many of these objectives, including the philanthropic goal of encouraging student academic performance. These competitions have consequently been utilised for teaching by universities to complement course materials, and to generate interest in the field of robotics. The involvement of students in a extra circular robotics competition offers the additional educational benefit of a focused, open-ended, interdisciplinary project that promotes self-directed learning, and research. By designing, building, and programming autonomous robots students learn key engineering subjects and develop problem-solving, decision processes, and team work skills. Studies have shown the benefits of using a robotics competition to generate interest and motivation in studying engineering for high school students and the general public [Manseur, 2000], [Chew *et al.*, 2009]. The aim of this paper is to investigate whether these robotics competitions are having a positive or negative affect on an undergraduate student's learning and associated outcomes.

Studies at VUW have shown that undergraduates students, first year students in particular, were previously disengaged with their courses citing a lack of hands-on experience, and a disjoint between theory and practical engineering projects [Watterson *et al.*, 2013]. As part of the remedial actions under taken at Victoria University of Wellington (VUW) school of Engineering and Computer Science was interested in forming an undergraduate engineering team to compete in a robotics competition as an extra-curricular activity, outside the students' course work. The expectation was to use the challenge to motivate and engage the students in studying engineering, computer science, and robotics. Robotics competitions provide students with a hands-on project that requires applying the relevant theories to construct a mechatronic platform.

As part of the Washington Accord[1] a key requirement for a graduate is the ability to function effectively in diverse teams and in multidisciplinary settings. An extra circular robotics competition allows the flexibility of bringing various year levels together outside of course structures. An important question addressed here was whether through competing in a competition student teams can create a sense of an engineering cohort, where the team can consist of undergraduate students from multiple disciplines and years levels working together to

[1] http://www.ieagreements.org/washington-accord/

complete a common goal.

With the goal of improving student learning VUW has entered the National Instruments Autonomous Robotics Competition (NIARC) [2] from 2012 until new (2014), with New Zealand not being eligible for entry in the first competition held 2011. NIARC was considered to be a good choice as it was seen as an academically challenging competition with its focus on fully autonomous robots, complementing course work done at VUW.

NIARC challenges the Engineering faculties of universities across Australia and New Zealand in a head-to-head competition to create an autonomous robot to complete a given themed challenge. These themes have included search and rescue, mining, and agriculture. The challenge runs within a calendar year, with defined progressive milestones that lead up to fulfilling the final task that teams must accomplish. Student teams have the freedom to develop a complete robotic platform during this time, with the only limitations being placed on using a provided NI controller powered by Labview, see section 2.3.

To complete this challenge, a student team must have knowledge in control, electronics, programming, and design to develop a functioning autonomous robot. These required skills are in line with disciplines taught at VUW, allowing NIARC to complement course work.

This paper is an investigation into the benefits of NIARC for all the 2012 until 2014 student team members. This includes academic studies and interest in engineering for all teams in the competition. Student engagement and motivation will be informed by an anonymous survey provided to teams participating in NIARC between 2012 and 2014 with the objective of finding the students' own narrative on how NIARC has influenced them. The hypothesis to be tested is that the project helped improve participating students' interest in engineering and related courses, with a benefit in grades and general understanding of their studies. It is also hypothesised that mixed year level teams have allowed students to form a beneficial mentoring system of the older students with the younger students, producing a sense of cohort between members, allowing younger students to learn where their studies are headed from the older students, and giving them an appreciation for their current level of study. Simultaneously allowing the older students to learn through teaching the younger students. Furthermore, the wide range of disciplines involved in the project has helped students learn about the relationships between each discipline by interacting with their peer group.

Participating VUW student Grade Point Averages (GPA) will be analysed to determine if there is any measurable influence, positive or negative, on participating team members grades in comparison to how team members felt the project influenced their studies. Although a small sample size, it will provide an insight into the academic performance of students entering the competitions and how their grades are effected if at all. It is hypothesized that some students may suffer a drop in grades while participating in NIARC by being distracted from regular course work, but have improved grades in the long term due to the experience. Finally, the overall benefit for students will be considered based on the student survey responses and the VUW students GPA analysis.

[2]http://nz.ni.com/ni-arc

2 Background

This section reviews previous studies into the benefits of robotics competitions in education, highlighting results on their effectiveness and use within schools. The key educational elements of robotics competitions is presented indicating the knowledge robotics competitions can complement or offer students. The challenge of NIARC is then presented, putting into perspective the key areas of engineering that the competition requires and the experience necessary for a team to compete using VUW courses as a point of comparison.

2.1 Robotics Competitions in Education

A wide range of robotics competitions are used to help complement education in class rooms around the world, with popular competitions including Robot Soccer [Plestina *et al.*, 2007]. The main stated aim of schools entering these competitions are to encourage and stimulate interest in engineering from their students, with numerous studies showing that these competitions do generate a more interest from students competing, [Ruiz-del Solar, 2010], [Friesel, 2007]. These studies suggest that the nature of competing extrinsically motivates students in their studies, and generates interest in further applying themselves in order to win [Manseur, 2000]. Further studies show students learn complex skills through solving smaller understandable concepts in the robotics applications, such as driving the robot to a point or making an arm move [Petre and Price, 2004].

Robotics competitions are often based on the premise to promote intelligent robotics research by providing a standard problem where a wide range of solutions can be investigated, allowing different schools to complement designs based on their educational focus. Studies on popular robotics competitions describe how the robotics competition complements a student's studies [Friesel, 2007] [Wang, 2001], with challenges requiring key engineering skills students can put into practice on a real world project. Schools can choose to tailor a course to incorporate a robotics competition [Friesel, 2007], or

tailor the design approach to complement existing course materials. One study suggests that teams that work within a controlled course structure consistently outperform teams that work within an extra circular activity [Wankat, 2005]. However the same study acknowledges that extra-curricular teams with an actively involved supervisor do perform well with the extra guidance and teaching.

One key aspect of robotic competitions is the multidisciplinary requirement of the team working on the robots. The ability for a team to work together across varying disciplines is considered a key element in whether a team will succeed or not at an engineering competition [Davis and Masten, 1996]. A critical obstacle to this goal, however, is the lack of familiarity that students in each discipline have for the other fields of study, making a thorough understanding of overall robotics design principles quite difficult. Robotics competitions provide a means of teaching students to co-operate outside their disciplines [Miller and Olds, 1994], with the goal of giving the experience to the students before entering the real world where multidisciplinary teams are common [Davis and Masten, 1996].

Overall robotics and engineering competitions have been found to be beneficial for engaging students in their courses. This paper's focus is on what educational benefits robotics competitions are having on students, with a focus on improvements in key engineering subjects, understanding relationships between courses, and interdisciplinary team work, shown in section 4.

2.2 Engineering topics in robotic competitions

Robot competitions allow students to integrate and demonstrate knowledge in several courses in the overall engineering curriculum. In particular for digital and analog electronics, embedded systems, physics, math, programming, and design. Robot designs require a team to incorporate at least these aspects in order to develop a functioning robot:

Power Systems Especially in the form of battery powered circuits and power regulation. Students must handle issues in power consumption, power noise, and multiple devices with individual power requirements, incorporating analog and digital design to power a functioning robot.

Actuation The majority of robots require at a type of motor, e.g AC, DC, or Stepper motors, in order to allow motion within an environment. Motor driver circuits and control systems will need to be designed in order to navigate the robot effectively, requiring analog and digital electronics. The configuration of the motors will also need to be considered for motion kinematics, in particular for designs with omnidirectional wheels, requiring students to utilise physics and vectors.

Embedded Control Robots rely on some form embedded processor or FPGA for their control logic. Students must utilise these embedded devices to interface sensors and actuators to allow for intelligent operation of the robot.

Sensors Robots require external and internal sensors in order to make decisions autonomously. Many robot sensor systems usually require and include position encoders, optical sensors, infrared or acoustic proximity sensors, collision switches, magnetic sensors, and others. Each sensor requires an electronic conditioning and interface circuit which may include amplifiers, filters, comparators, as well as Analog to Digital converters. Students will need to be familiar with these systems in order to select the right sensor for each task.

Mechanical Design Students must design the physical robotic platform, through CAD design or otherwise, so that can accomplish the desired task. Students will need to design, select, and create; motors, gears, frames, and other mechanical components in order to construct a functional robot.

Programming Programming the robotic platform is required for sensor/motor control, learning, and goal setting. Students will be required to develop algorithms to effectively navigate the robotic platform to completing its given task. This will require students to incorporate real world sensors and actuators to generate path planning, localisation, decision making, actuation, and control to effectively solve the task.

The level of required knowledge to develop each part of a robotic system can and has been tailored for different robotics competitions. VEX robotics for example is aimed at both high school and university students, with the mechanical design of the robot being simplified to work around the VEX kit sets and micro processing being limited to a friendly programming language. University level challenges vary between restricting the hardware teams can use, and/or restricting the software teams can program in. More advanced challenges give teams the freedom to design and construct their robotic platforms as they desire, such as the DARPA robotics challenge.

VUW offers a four year, accredited Bachelor of Engineering in Electronics and Computer Systems Engineering (ECEN), Software Engineering (SWEN), and Network Engineering (NWEN) specialisations. Along with a Computer Science degree with optional one year honours. First year students at VUW are required to

design and build a simple autonomous robot, around an Arduino, to follow a line through a maze as part of ENGR101. Students get experience in using simple range sensors and line detectors, as well simple navigation and decision programming. A team with this level of experience would not the knowledge to construct a robot for the NIARC challenge, with limited experience of sensors, programming, and mechanical design. Note it is desired that top level first year students are able to work in conjunction with more experienced, second/third/fourth year, students to actively participate in the competition with the mechanical design or programming of the robot.

VUW second year students have the base experience required to develop a simple reactive based robot solution to NIARC. Second year students have introductory experience, through their courses, in analog and digital electronics (ECEN201/202), programming (COMP102/103, SWEN221), and mechatronic design (ENGR101/ENGR110). From these course second year hardware students have experience with batteries, sensors, and actuators required to construct a simple robot with basic sensing and actuation. Second year computer science students have the experience to implement rudimentary path planning (wall following) and reactive obstacle detection/avoidance.

Third year students at VUW have the experience required to develop an autonomous system for NIARC. Third year students learn control theory (ECEN315), project management (ENGR301/302), embedded systems (ECEN302, advanced digital and analog electronics (ECEN303/301), and introduction to Artificial Intelligence (COMP307). From these courses hardware students have experience in PCB/CAD design, control systems, motor controls, filter design, team management skills, and embedded programming. Third year students can construct more of the mechanical aspect of the robot, creating their own electronics and chassis through CAD design. Through control systems students can develop embedded control programs for actuators and sensors to utilise more complex hardware solutions, such as kinematics for arms or legs and PID control loops. Third year software students have experience with tree structures and programming decision logic through COMP307 allowing for path planning methods such as A star, incorporating the sensors to create maps of obstacles. This will require hardware and software students to co-operate to effectively incorporate the appropriate sensors for the desired software techniques.

Fourth (final) year students at VUW have the experience required to develop autonomous vehicles with more complex behaviours. Final year hardware students learn mechatronics (ECEN425/430) and autonomous robotic design. These courses teach the skills required to design for and utilise sensors for autonomy through methods such Simultaneous Localization and Mapping (SLAM) [Durrant-Whyte and Bailey, 2006] and intelligent behaviours. The basic SLAM techniques require a grounding in sensors, matrices, statistics, Kalman filters, and control theory, which software students are not exposed to in normal course work. Through working cooperatively with software students the hardware students can develop the algorithms to run on the robotic platform and allow a robot to effectively navigate its environment in a more intelligent and effective manner.

2.3 NIARC

Each year NIARC challenges team to design, build, and program a robotic platform to complete a given task. NIARC 2012 was themed search and rescue, with teams developing a robot to navigate a grid based maze environment. The objective was for the robot to navigate an unknown maze to the “victims” area and differentiate between the victim cubes, red and green, and the rubble cubes, grey. NIARC 2013 was themed based on the mining industry, the objective was for the robot to navigate to the mining area through the unknown entrances where it must differentiate between the desired gold cubes and undesirable grey rubble cubes. NIARC 2014 is ongoing at the time of writing, being themed based on the agriculture industry, with the objective for the robot to navigate accurately to known but unmarked seeding areas to plant seeds. Each environment is shown in figure 1.

NIARC provides teams with a National Instruments Reconfigurable I/O (RIO)[3] board to develop their robotic platforms around. The RIO devices provide a real time control board with an integrated FPGA, designed to handle multiple sensors and actuators. The teams are only able to implement functionality and processing with this device, with no other computational device allowed unless integrated with sensors or actuators. The rest of the robotic platform is developed by the teams entering. Teams must work with the budget that their respective universities provide to develop a system capable of completing the given task. Working with this device gives students experience working with embedded control systems. At VUW embedded systems are taught within third year courses ECEN301 and ECEN302, however microprocessors are introduced in first year ENGR101 with the application of Arduinos.

NIARC requires teams to program the RIO utilising National Instruments Labview. Labview is a visual based graphical programming language designed for automation control and data acquisition. Its graphical representation, similar to a process flow diagram, was created to provide an intuitive programming environment for scientists and engineers [Elliott *et al.*, 2007]. Labview

[3]http://www.ni.com/compactrio/about.htm

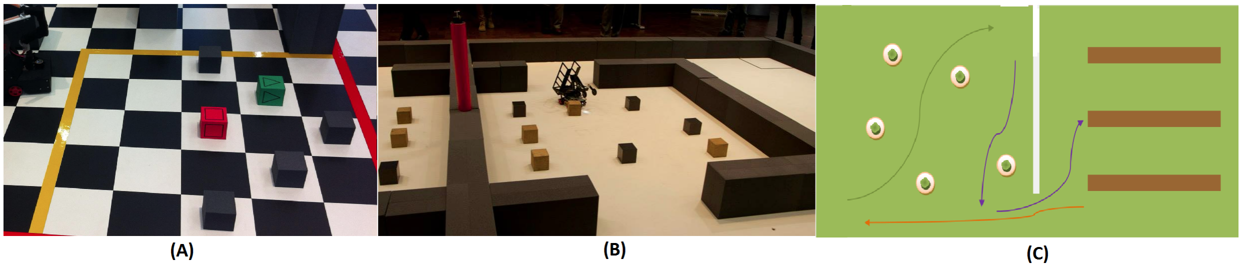

Figure 1: NIARC environments; (A) 2012 search and rescue (B) 2013 Mining Industry (C) 2014 Agriculture

is an industry standard programming language and is the required programming language for NIARC, with teams utilising Labview for automating their robotic platform. NIARC provides an opportunity for a student to learn Labview on a real world robotics application, where they make full use of the data acquisition and control that Labview offers. A subset of the universities teach Labview in their courses even at a first year level, NIARC presents an option to complement those courses through a challenging real world application. At VUW Labview is used in conjunction with a NI DAQ in a optional third year control course ECEN315, but is not otherwise taught within any courses. This does cause a disjoint for students who are not able to apply their Labview skills within their course work, but Labview may be considered a valuable skill for a student to learn for industry.

The mechanical design of the robot is left to the decision of the teams competing, with limited restrictions on what teams can construct. This allows teams with little experience to produce simple but effective robots, while more experienced teams can extend themselves to develop more advanced solutions. The primary challenge for NIARC is the fully autonomous requirement for the robots. Each robot must have no interaction with the team when attempting the challenge. This requires teams to design their robot to intelligently make decisions on its own, utilising only the sensors and actuators the team has selected for it. Given the relatively small size of the challenges each year different levels of autonomy can be utilised by teams to accomplish the given tasks depending on their year level. Second to third year students can develop robots utilising internal sensors to gauge movement, e.g. encoders, inertial measurement units, or mouse sensors, to compete in NIARC. Final year students can further develop SLAM techniques and more advanced path planning methods.

3 Method

3.1 Anonymous survey

An anonymous survey, with ethical approval (0000021230), was used to measure competing student's feedback on how NIARC has influenced their studies from 2012 until 2014. The survey is seeking to determine whether students agree that NIARC has influenced their grades, either positively or negatively, or not at all. The survey is eight questions long, with three to four sub questions, utilising the Likert scale: strongly disagree (1), disagree (2), neither agree nor disagree (3), agree (4), strongly agree (5). The survey asks students whether or not NIARC has helped them improve in key engineering subjects, understand relationships between courses, and learn from interdisciplinary team work.

The first question is to determine why the students want to compete in NIARC, with previous studies indicating students compete for fun and interest. However, we are more interested in if students are also considering competing to extend their learning, and how much of a factor extending their learning is for competing.

Secondly we are interested in which subjects students feel they were simulated in studying within the key areas of engineering; mathematics, physics, electronics, and computer science. Knowing which subjects the project stimulates or not can help focus the application of the project to improve the connection between subjects and application with students.

Third we are interested in how students felt about their studies while competing in NIARC. We are interested in whether or not students felt they were actively participating in the project or not. Preferably all students feel as if they are actively participating, maximizing the involvement in the project and potentially getting the most out of the learning experience. If students are not feeling actively involved in the project then the application of the project will need to be addressed. Extra-curricular teams for example with no active supervisor may find themselves unorganized with some students feeling left out. Next we are interested in if students considered that NIARC was distracting them from their degree course work. It is hypothesised that some students put too much time into the project at a detriment to their other course work during the project. Finally, we esquire if students are more confident in their ability to study and if they feel that NIARC has helped improve their grades.

Fourth, we want to know whether students are learning from their team mates. In particular if students feel as if they are effectively learning from their peers, both through mentoring and being mentored. It is desirable that students are working together as a team, learning not only through teaching/being taught, but also learning about each discipline by cooperatively solving problems.

Fifth, we are interested if teams are communicating with and learning from other teams in the competition. The competition is an opportunity for students to learn how their studies relate to their peers from other universities, both nationally and internationally, by discussing shared problems and ideas.

Sixth, after students have competed in NIARC we are interested in which key engineering subject's students feel more confident in studying. Robotics competitions may stimulate interest in studying courses, but have students learned things from the competition to make them more confident in their studies.

Seventh, one of the key parts of understanding and communicating within multidisciplinary teams is understanding the relationship between subjects. This question is asking if students consider that they have a better understanding of how the key subjects relate to one another through their experiences in the competition.

Eighth, finally we want to know if students feel they are now more focused on their course work and whether or not that they believe their grades have improved after competing in NIARC. We are also curious to know if teams are keeping in contact after the competition, and forming cohorts between universities.

3.2 GPA analysis

The GPA results of team members at VUW were averaged for each year 2011 until 2014, students at different year levels were considered equally. In order to determine if there is any measurable short or long term influences on team members academic performance the average GPA of members in years prior to them competing, and their GPA in the following years after competing are given. To determine if any change in GPA is a general trend or influenced by NIARC, the average GPA of each year's team is compared to the average GPA of the whole engineering cohort from 2011 until 2014. Comparing each year's team average to the cohort also provides an indication of the average academic performance of the team compared to the cohort, giving a limited insight to the types of students who work in these competitions. The GPA for each year's team, and the engineering cohort are based on all the engineering courses (ECEN, SWEN, NWEN, ENGR, COMP) at each respective year from 2011 until 2014 at VUW.

In 2012 the team only consisted of two undergraduate students (mixed between 100-200 level), however the team worked closely with a masters student Brett Ryan. The 2013 team consisted of six undergraduate students of mixed year levels between (100 - 200 level), with one member returning from 2012. The 2014 team has seven undergraduate members (mixed between 100 - 300 level), with two returning members from 2013 with one student competing in 2012. All teams were actively supervised by PhD student Henry Williams. The size of teams each year is too small to provide statistical significance, but does offer some insights into the effects of students studies from competing in robotics competitions compared to their cohort.

4 Results

4.1 Anonymous survey

The results of the anonymous survey completed by 30 undergraduate NIARC team members, from five different competing universities, from 2012 until 2014 is shown in table 1. The results show that students competing in NIARC agree that the challenge of NIARC is why they are involved. However, students strongly agree they are interested in extending their knowledge through the competition. This is a positive result showing students are involved in these project to actively improve their learning. As expected from previous studies, section 2, students strongly agree that they are competing because of the interest in the given project.

Similar to previous studies into robotics competitions students do report being stimulated in studying electronics and computer science while competing in NIARC, however on average students are not stimulated in studying mathematics or physics. This may suggest that students are not connecting their physics and mathematics studies to the practical application of building the robot.

Students do report strongly that they are actively involved in the project. Considering just the VUW results the response is similarly in agreement regarding participation, indicating that the extra circular approach is not negatively effecting them. Interestingly, on average students are almost split on whether or not they agree they were distracted from their course work by NIARC, with the average just below neither agree nor disagree. Student responses are not distinguished between extra circular teams or course teams, which could be the cause for the divide. Taking just the VUW student replies, the average rises to 3.81 with a standard deviation of 0.61. This suggests that the extra-curricular teams tend to be distracted from their course work, potentially causing problems with their regular studies during the competition. Teams within a course structure are inherently focused on their studies when working within NIARC, although whether that subject adversely effects other courses would require more investigation. Students

weakly agree that they felt more confident in their studies while competing in NIARC, however on average the students are unsure if the competition improved their grades or not.

Students are reporting that they are learning from the senior (third/fourth year) students in the team. This demonstrates that teams are actively sharing knowledge with less experienced members, allowing newer students to learn more about their studies. Conversely students are also reporting, but to a lesser extent, about learning from mentoring other students in the team, helping reinforce engineering material for the senior students. Overall students agree that they have learned from working with their peers at different year levels and disciplines, a strong skill needed for students to learn in preparation for working in industry.

Students generally do not report strong interaction with the other teams in the competition, with only limited reports on interacting with the other teams. This could be due to not all team members going to the live finals, where teams interact in person, and from teams not reaching out to competing teams during the build up to the competition. Anecdotally from VUW this was true in 2012, and 2013 with no attempts to contact other teams, however in 2014 the team was in active contact with the University Technology of Sydney team through Facebook after meeting with them at the live final in 2013.

Students do report feeling that NIARC has not made them more confident in studying mathematics and physics, in line with the lack of stimulation. Applying NIARC to stimulate interest in these areas within education needs to be investigated. However, students do agree NIARC has made them more confident in studying electronics and computer science, again in line with them agreeing they are more stimulated in these areas. This is consistent as electronics and programming are the two main components to the application of constructing a robot and thus easier to connect with for students.

Interestingly although not reporting being stimulated in physics or mathematics, students report weak agreement about understanding the relationship between math/physics and electronics better. Students agree with understanding the relationship between math and computer science better, indicating the students programming may be more involved with mathematics throughout the competition. Students do agree with better understanding the relationship between electronics and computer science, which is a positive result indicating cooperation between each disciplines during the project.

Finally, students do report being more focused in their course work after NIARC. On average students are unsure on whether they feel their grades have improved since completing NIARC. Students do not report highly on keeping contacts with their peers in other teams after the competition, this is expected given the feedback on teams limited interaction outside of their own team.

	2011	2012	2013	2014
Team 2012	5.00	4.84	5.50	6.17
Team 2013	3.57	5.36	5.45	5.35
Team 2014	N/A	6.56	4.43	6.18

Table 2: Average GPA for the student teams competing from 2012 until 2014, with the teams average GPA for prior and following years displayed. Note 2014is only trimester one and a new grading scheme was introduced, which obfuscates direct comparison with previous years.

4.2 GPA analysis

The analysis of the GPA results for the VUW undergraduate student team members is provided in table 2 with engineering cohort GPA shown in table 3. Teams competing each year have 100 level students, skewing team GPA average for years prior to competing as they were not at university and thus do not have a GPA score. 100 level students with no prior GPA's are still considered as there may still be an influence on their, and the teams, grades in the following years through mentoring during the competition.

The team competing in 2012 was the first team to compete in NIARC from VUW. The 2012 teams' average GPA of 5.00 in 2011 is similar to the average for their engineering cohort for 2011 of 4.79. In the year of competing team 2012 shows a drop in GPA performance compared to 2011, in opposition to the cohorts' increase in average GPA from 2011 to 2012. Years following the competition however show the 2012 team members average GPA has improved in 2013 and then again in 2014, with their average GPA above their cohort.

Team 2013 does not indicate any influence on their GPA from competing in NIARC. The average GPA of the team is in line with their cohorts for each year of study, although marginally higher in 2014, with no discernible positive or negative influences from competing in 2013.

Team 2014 average GPA in 2014 is above the average GPA for their cohort, indicating a higher level of academic ability. However, the teams' average GPA drops almost two grade levels in 2013, the year before competing, below that of their cohort. In opposition the cohorts GPA increased from 2012 to 2013. In the year of competing team 2014's average GPA improves over 2013 and returns in line with students' GPA from 2012 and above that of their cohorts GPA. This indicates that NIARC may have provided stimulation to students in their studies, leading to an improvement in their overall GPA.

Year level	2011	2012	2013	2014	Mean
100	3.93	4.92	5.09	4.88	4.71
200	4.75	4.63	5.23	4.65	4.82
300	4.90	5.38	5.30	5.00	5.15
400	5.57	5.56	6.18	5.60	5.73
Mean	4.79	5.12	5.45	5.03	

Table 3: Average GPA of VUW students in engineering courses at each year of study between 2012 and 2013.

5 Discussion

A positive result is shown with students stimulated in electronics and computer science. However, students are not reporting stimulation in physics and mathematics, two key areas of engineering. This is also reflected when students report being more confident in electronics and computer science, but do not feel more confident in physics and maths. This is plausible as electronics and computer science are the most explicit subjects teams consider in the construction of the robot, through the mechanical design and programming of the robot. While mathematics and physics are utilised as part of electronics and computer science, they are not explicitly considered on their own. A potential solution to this is by making the connection more explicit by encouraging the students to learn the physics for the generalised problem of the system. Anecdotal evidence from an anonymous team member at VUW does suggest the application of theory from physics during the competition was helpful to some team members "I was becoming apathetic about my learning being focused solely on all the background physics and analysis. Seeing that applied in building something, and watching what goes wrong when you don't know some of this stuff, was a great experience" [Anonymous, 2014]. However, this does not appear to be a common trend from the survey results.

The results do show that teams are forming cohorts and learning from each other and the other disciplines. The 100-200 level students learning from 300-400 level students gives them the opportunity to learn skills required for later years, and improves their understanding of where their courses are headed. Anecdotal feedback from one member of the VUW team states "NIARC helped me understand how to use Solidworks to do virtual prototyping that will be useful in the future of my degree" [Panchal, 2014], demonstrating that students are valuing the skills they are learning from the project and seeing the long term benefits of participating in the competition. Feedback from students on their understanding of subject relationships also indicates that teams are learning from solving interdisciplinary problems, in particular problems relating to the electronics and software aspects of the robot. Using VUW as an example, the students involved in the hardware had to provide the programmers the required physical functionality while providing adequate time for testing of software. Allowing each side of the disciplines to appreciate the need to communicate and plan ahead for each other's respective needs. A team member of VUW states "seeing the challenges faced by the software team and how I can design the hardware to help has been instrumental in my understanding of the relationship between these two aspects" [Lopez, 2014], demonstrating that students are communicating and solving problems cooperatively between disciplines.

One disappointing result is the reported lack of teams interacting with their fellow peer groups. NI generously pays for two members per team to attend the live finals of NIARC and some universities pay to have more team members attend. However for some universities it is too expensive to send team members to the live finals of NIARC, especially teams traveling long distances, such as "crossing the ditch" from New Zealand to Australia. This limits the number of team members that can meet their fellow peer group in person, which is considered a contributing factor to the low response.

From VUW's perspective team members who wish to attend the final pay for themselves, leading to four members attending the 2013 live finals. The benefit of more team members attending the live final is that returning VUW team members from 2013 were in active communications, primarily through Facebook, with attending team members from University Technology of Sydney (UTS) throughout the 2014 competition. Students discussed problems and solutions they were working on, with different viewpoints helping both teams. One member from UTS stating that competition helped fuel their teams efforts "Getting an insight into another teams workings is good and I think that it fueled the competition, pushing everyone to work harder to make sure they put up a competitive robot" [Alvarez, 2014]. This is consistent with previous studies showing that competition drives students to work harder and push their limits, and emphasises the need to have teams communicate with their peers more. Seeing the perspective of another teams process allows members to get a better understanding of their studies compared to other universities, although anecdotal the response shows good signs towards this from VUW and UTS.

The GPA analysis indicates that team 2012 members GPA have been positively influenced by NIARC, with the average GPA improving in the following years. However, in the competing year the team did suffer a drop in GPA performance. This year was the first year VUW competed and interest in the project was low, with two undergraduate's students working on the project. With the lack of experience in the team, but a great amount of

enthusiasm the competition became a large distraction to the undergraduate students who focused on NIARC over their studies. This is reflected in the drop in GPA in the competing year. It is acknowledged that the sample size is too small to draw statistically meaningful results, but it is reflective of anecdotal evidence gained throughout participating years and across university teams.

Team 2013 does not show any improvement in their GPA, however they also do not show large negative influences on their GPA either. Although there is no visible improvement in GPA, the team went on to claim first place at the live finals in Melbourne, in only the second year competing in NIARC becoming the first team in New Zealand to win. Part of the reason for this was the one returning team member from 2012, whose experiences in 2012 helped keep the team more organised and focused based on lessons learned from failure the previous year. Further to this, the supervisor was more active in keeping the team from being distracted from their studies.

6 Conclusions

The survey feedback from students competing in NIARC from 2012 until 2014 indicates that NIARC has been a positive influence on their studies, making them more confident in key aspects of engineering and helping form a sense of cohort among their peer group. A GPA analysis of VUW students supports anecdotal evidence that some competing students suffer drops in GPA in the short term, but in the long term their GPA improves over years prior to competing and to their peers not involved in the competition. This indicates that although robotics competitions, such as NIARC, may distract students in the short term, the long term benefits of the project are beneficial for students.

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#	Question	Responses	Min	Max	Mean	Standard Deviation
1: I participated in NIARC						
A	For the challenge	30	3	5	4.27	0.88
B	To extend my knowledge of Engineering	30	4	5	4.53	0.52
C	Because it seemed interesting	30	3	5	4.67	0.62
2: Participating in NIARC stimulated my interest in studying						
A	Mathematics	30	2	5	3.60	0.83
B	Physics	30	2	5	3.40	0.74
C	Electronics	30	3	5	4.33	0.72
D	Computer Science	30	3	5	4.40	0.74
3: While participating in NIARC						
A	I was actively participating in the project	30	2	5	4.07	0.96
B	The project distracted me from doing my course work	30	1	5	2.87	1.19
C	I was more confident about doing my course work	30	1	5	3.53	1.19
D	My grades improved	30	2	5	3.27	1.16
4: From interacting with my NIARC team						
A	I learned from senior students	30	2	5	4.13	0.92
B	I learned from mentoring other team members	30	2	5	3.73	1.16
C	I have a better understanding of my studies from working with different year levels and disciplines	30	2	5	4.10	0.69
5: Interaction with other universities NIARC teams						
A	I communicated with other NIARC teams	30	1	5	3.00	1.41
B	I learned from watching or talking to other teams	30	1	5	3.27	1.44
C	I shared what I had learned with other teams	30	2	5	3.00	1.31
D	I have a better understanding of how my study compares with my peers	30	2	5	3.21	1.31
6: Since doing NIARC I find myself more confident in studying						
A	Mathematics	30	2	5	3.21	0.89
B	Physics	30	2	5	3.13	0.83
C	Electronics	30	2	5	3.89	1.06
D	Computer Science	30	2	5	3.87	1.06
7: Since doing NIARC I now better understand how subjects relate						
A	Mathematics to electronics	30	2	5	3.53	0.99
B	Physics to electronics	30	2	5	3.67	1.05
C	Maths to computer science	30	2	5	3.80	0.94
D	Computer Science to electronics	30	3	5	4.20	0.44
8: Since doing NIARC						
A	I am more focused on my course work	30	2	5	3.73	1.03
B	My grades have improved	30	2	5	3.33	1.05
C	I maintain contact with my peers in other teams	30	1	5	3.33	1.29

Table 1: Anonymous survey question results of teams competing in NIARC between 2012 and 2014.