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EXPLORING THE CURRICULUM BENEFITS OF ADVANCED MICROPROCESSOR PROGRAMMING AND ROBOTICS IN PRIMARY SCHOOLS

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Abstract

This paper provides a summary of research undertaken of a project which aimed to build professional knowledge and understanding of classroom teachers to support learning by students in upper primary classes in the area of microprocessors and robotics through the provision of PikBlok resources; to communicate and share learnings of project teachers; and, to generate data to inform Curriculum Branch to ensure that Queensland is well placed to respond to emerging opportunities in microprocessors and robotics. The project, implemented by Education Queensland, Australia, involved nominated teachers and students from 17 schools located in 3 Education regions. Key findings are reported, as well as recommendations to inform more widespread introduction of microprocessor programming and robotics in schools.

Introduction

This paper provides a summary of research of a project to explore the curriculum benefits of microprocessor programming and robotics. The following sections present information about the background and the significance of the project, and clarification of the terms - microprocessor programming, mechatronics, and robotics. Subsequent to the presentation of a brief overview of the design of the study, a summary of the findings of the study, and some of the key recommendations are provided.

The general aims of the project were to:

- Build professional knowledge and understanding of classroom teachers to support learning in the area of Robotics and Microprocessors through the provision of some leading edge resources (PicBlok);
- Communicate and share the learnings of project teachers and students through a series of events with other teachers within Greater Brisbane, South Coast and Moreton regions; and
- Generate data to inform Curriculum Branch ensuring Queensland is well placed to respond to emerging educational opportunities in Robotics and Microprocessors.

The specific aims of the project were to provide insights into the:

- Impacts on learning, curriculum and student behaviour;
- Impacts on general learning skills;
- The 'support structures' needed for wider introduction; and
- Impacts on students, and teachers.

The Project

Background of the Project

The proposal for this project indicated that, due largely to observations of the microprocessor programming and robotics activities being undertaken in schools in Hong Kong and Singapore, there was the need to introduce programming of microelectronics and microprocessor technologies at an elementary school level to achieve the best educational results and for Australia to remain competitive in this area on a world stage. Funding was sought and provided to undertake research into the curriculum benefits of microprocessor programming and robotics activities in the upper primary school in a research partnership between Education Queensland and Griffith University. Picblok Corporation would also partner with Education Queensland to provide materials and professional development activities for the schools, teachers and students who participated in the project.

The project was planned as a one year study to commence during Semester 2, 2006 with nominating schools and conclude in Semester 2, 2007. The research team from Griffith University was requested to provide a report at a Forum involving the participating schools in August 2007, and a final report being provided after the conclusion of the project. This paper provides a summary of some of the key findings of provided in the final report.

Schools were provided with details about the project so that they could determine whether or not they wished to nominate to become participating schools. For example, schools were informed that they would be expected to meet their own TRS costs and to contribute to the subsidised purchase and training cost of obtaining a range of robotics equipment (approximate cost \$3500 per school). That would supply the school with enough equipment to undertake a range of activities. They were also informed that much of the associated training would be done in class or after school to minimise TRS costs. The project was planned to have a direct link to the implementation of the *Years 1-10 Technology Syllabus* and the *Years 8-10 Information Communication and Technology Education Syllabus* as well as providing timely advice and support to schools regarding the new generation of technologies that are emerging to support and enhance student learning. Furthermore, this project would be seen to align with the *Advance Design and Technology Electronics Centres (ADTECs)* project proposal for Secondary schools.

Significance of the Project

The significance of this research project is the need for Queensland students to be globally competitive in terms of technological innovation, as indicated in *Queensland Education-2010* (Education Queensland, 2002). Innovation in technology has been identified as a major factor in economic growth (Fee & Seemann, 2003), and it is well understood that countries and regions that possess and encourage technological innovation translates to economic benefits for those countries and regions. This is apparent in economies characterised by strong commercial technology economies driven by 'smart' industries.

Future advancements in technology innovations and the sustainability of smart industries are reliant on individuals who are innovative, knowledgeable and motivated to follow a career path within technology areas. It is estimated that Australia will need

8000 systems-electronics graduates to support our ‘smart’ industries and for current and future students, careers in this area will need to be viewed as exciting and attractive (Thomas, 2002). However, as enrolments in science and technology courses in Australian tertiary institutions have tended to decrease, there is a need to familiarise and motivate students to engage with technology and ‘work technologically’, earlier in their educational life. Secondary schools have previously been the intended entry point to provide students with these opportunities, but due to the earlier maturation of students and the complexities of gender, for example, fewer girls tend to enrol in such technology courses (Mammes, 2004), it has been recommended that students are immersed in technology learning experiences at a younger age. It has also been identified that earlier exposure to technology education leads to higher interest and adaptability in both boys and girls, influencing their subsequent interest and later, their choice of career (Kekelis, Ancheta, & Heber, 2005).

Microprocessor Programming, Mechatronics, and Robotics

A microprocessor is defined as a programmable digital electronic component that incorporates the functions of a central processing unit (CPU) on a single integrated circuit. Continuing developments in microprocessor technologies have resulted in microprocessors being used in many devices and applications, from aviation, security systems, household appliances, to mobile phone technologies. Within this project, the microprocessor is a PIC microcontroller, a programmable device that is able to store sets of instructions and carry them out when the program is run. This process is called microprocessor programming. Bolton’s definition of a mechatronic system is adopted here by being seen not as a marriage of electrical and mechanical systems and is seen as being more than just a control system, but is defined as a complete integration of electronic, mechanical, computer and control systems (Bolton, 1999), as displayed in Figure 1.

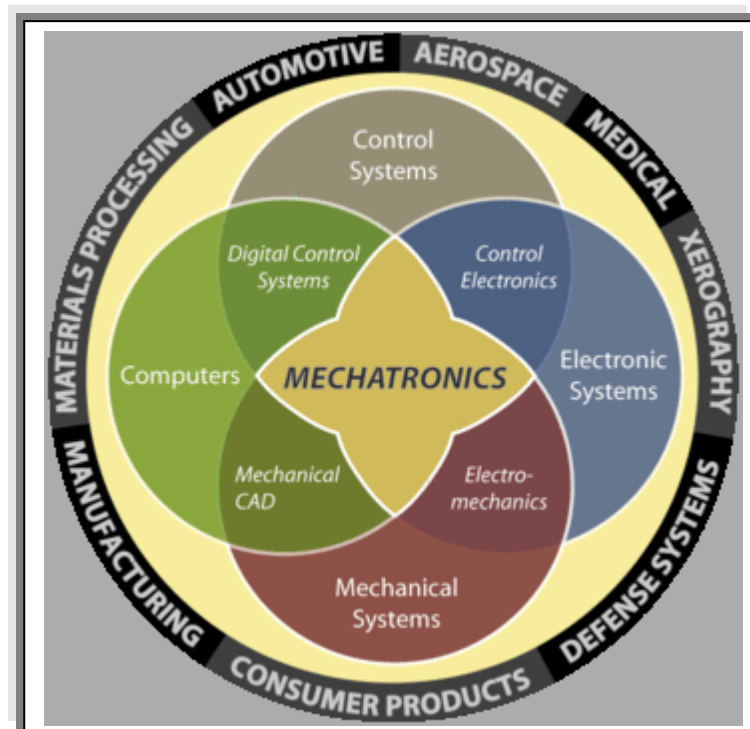


Figure 1: Conceptualisation of Mechatronics as the Integration of Control, Electronic, Mechanical, and Computer Systems (Source: Craig, K.C., 2008)

From this conceptualisation, robotics can provide examples of mechatronics, through applications in a range of specialist areas, such as mechanical engineering, computer science, control systems and electrical engineering integrated to create a device under some kind of autonomous control. As Earnshaw (2005) indicates, robots all have three elements in common; namely, 1. Body – a physical body of some type; 2. Control – a program to control the robot; and 3. Behavior – they exhibit some type of behaviour.

Research has reported that students simply find robots exciting (Miglino, Lund, & Cardaci, 1999; Sklar, Johnson, & Lund 2000; Sklar, Eguchi, & Johnson, 2002). Moreover, motivation for students and interest are also important drivers for inclusion within the curriculum, and this has been supported by some researchers who have identified unprecedented perseverance from students whilst engaged in robotics activities that is not demonstrated in other learning areas (see, for example, Thomas, 2002). Developments in microprocessor programming, mechatronics, robotics and electronics have been identified as growth markets and the most important factor identified as necessary to ensure a strong growth in those areas is the man-power to support the demand. In Singapore, this has directly resulted in providing educational opportunities for students to engage with smart technologies earlier to be internationally competitive. The Singaporean Curriculum document *Design and Technology Syllabus-Lower Secondary Normal (Technical)* (Ministry of Education Singapore, 2006) has been implemented in 2007 and aims to help students to “develop an awareness of design in the made-world” and to “think and intervene creatively to become autonomous decision makers”. There is an obvious link between the Singaporean Curriculum and developing smart industries in that region. Similarly, in the United States of America the need for nation-wide comprehensive technology studies have been identified as a major economic factor (ITEA, 2006). Korea and Japan have made critical changes to curriculum in recent years to address the need to develop smart industries and learners with the interest and capacity to fulfil manpower requirements. Similarly, in Queensland, the ‘Smart State’ strategy sees education as a way of increasing human capital as a foundation of the knowledge economy. These perspectives are evident in the *Years 1-10 Technology Syllabus* (QSA, 2003) which was introduced as a core curriculum Key learning Area to be implemented in 2007. As a new syllabus, it might be expected that teachers might struggle to implement Technology Education, needing to develop new understandings. The introduction of a program of microprocessor programming and robotics can extend this implementation.

PicBlok

There are many commercial options available for robotics in education. This project focused on PicBlok robotics which is only one of the commercial options available. The PicBlok kit comprises a central microprocessor, sensors such as sound, bump/switch, infrared, reflect and object detection. The soft ware is ‘drag and drop’ style flowchart software. It is claimed that problem solving can be supported and enhanced when flowchart techniques are used by the teacher to scaffold student learning by the solving of programming problems. The flowchart software also enables children to get started in a short period of time and to logically detect and solve programming errors. The micro-controller is encased within moulded plastic. The robot does not have a building capacity therefore the focus of the system is in the programming. PicBlok kits have been used in this project with PikBlok also providing teacher training, follow-up support visits to each school, robotics kits and school

licenses for microprocessor programming. Images of the PikBlok materials are displayed in Figure 2.



Figure 2: Images of PikBlok Materials

Design of the Study

The participants of this study included the teachers and the students in classes from the 17 schools which nominated to participate in this Education Queensland supported trial of microprocessor programming and robotics technologies. Griffith University researchers had been chosen by Education Queensland to conduct this accompanying research of this project. In seeking ethics approval, it was clearly indicated that the data collected from this research would be used to generate a report for Education Queensland, and the sharing of findings to participating schools at a Forum organised by Education Queensland. The data collection required teachers and students from selected schools to be involved in the data collection phase of the research, including surveys and interviews with a sample of teachers, and surveys with students in a sample of schools, video recordings, digital photographs and observations.

Teacher surveys were administered during the professional development days at the commencement of the project (*Initial Teacher Survey*) and during the project (*Interim Teacher Survey*). The surveys asked teachers their opinion on aspects of the project's implementation. Due to some staff changes during that period, not all surveys were completed by the same teachers for both surveys. Twenty-seven teachers provided responses to the Initial Survey, and 17 teachers provided responses provided responses to the Interim Survey. Student surveys were administered (*Student Survey*). Those surveys sought background information and student perceptions about aspects of their involvement in the project. 77 Student Surveys were completed by students from Years 5, 6 and 7. Digital photographs and videotapes were made of implementation sessions and were shown at the presentation Forum.

Summary of the Findings

This section summarises the key findings of this research, namely, why teachers were involved in the project

Why Teachers were involved in the Project

In the Initial Teacher Survey, teachers, in response to being questioned about why they were involved in the project, highlighted five main reasons:

1. Progress the Implementation of the Technology Syllabus

“we were looking for something different that would cover the technology outcomes”

“Developing and implementing in response to the Technology syllabus. Expand the practical use of ICTs in the classrooms”

2. Understanding Robotics

“To help me understand what is involved in teaching robotics/Technology in the classroom”

“Interested in extending my knowledge on Robotics to use in classrooms”

3. Future Technologies

“It is the future”

“See students enjoying this in the future”

4. Integrated Curriculum

“Integrate KLAS”

“Interest in this to tie in with integrated studies ‘Energy’ unit”

5. Problem Solving

“To help students develop their thinking and problem solving skills”

When asked again in the Interim Teacher Survey during their involvement in the project, most responses focused on students in terms of engagement, and futures, and some indicated that they saw that their involvement was building their teacher knowledge:

1. Engagement, Motivation, Enjoyment

“Students enjoy the program”

“Students are enthusiastic about the subject”

2. Future Technologies

“Way of the future”

“Opportunity for children to be involved in technology with a future’s perspective”

3. Teacher Knowledge

“So that I can teach my own students – So far another teacher has taught robotics to my students”

“Professional development”

Key Learning Areas

In investigating the curriculum benefits of microprocessing and robotics, teachers were asked at the commencement of the Project to indicate the extent to which they predicted that they planned to use these activities in Key Learning Areas, and were subsequently asked later in the Project to indicate the extent to which they had used these activities in Key Learning Areas. Overall, as displayed in Table 1, teachers tended to predict that the Project activities would be used for Technology (92.5% of teachers), Science (48%), Mathematics (39.3%), and Studies of Society and the Environment (SOSE (33.3%). Caution is needed in comparing the data in the two

Tables as the number of teachers surveyed changed due to availability and staff changes. However, as displayed in Table 2, the reported use of microprocessor programming and robotics activities by teachers during the project did not match their early predictions. Activities were not strongly integrated with Science (reported mean=1.78: predicted mean=2.71) and Mathematics (reported mean=1.77: predicted mean=2.41), and only 11.8% of teachers reported that they used the Project activities to a great or very great extent for Mathematics. The data in Tables 1 and 2 are complemented by suggestions made by teachers in the interviews where suggestions were made for the development of Unit and Lesson Plans which explicitly link to Key Learning Area Syllabus documents. Some teachers suggested that the kit could be enhanced by the provision of those curriculum support materials, and indicated that this could enhance the PikBlok kits when implemented in other schools. Those curriculum materials might more explicitly indicate ideas for teachers to plan for using robotics in other curriculum areas.

Table 1: Predicted Use of Microprocessor Programming and Robotics in Key Learning Areas (N=27)

KLA	Mean* - Predicted (% of Teachers – Great Extent + Very Great Extent)
1. Technology	3.41 (92.5%)
2. Science	2.71 (48%)
3. Mathematics	2.41 (39.3%)
4. SOSE	2.12 (33.3%)
5. English	1.75 (7.4%)
6. The Arts	1.68 (14.3%)
7. Other	1.5 (7.1%)
8. HPE	0.68 (0%)
9. LOTE	0.32 (3.6%)

*Scale: Not at all = 0; Little Extent = 1; Some Extent = 2; Great Extent = 3; Very Great Extent = 4

Table 2: Reported Use of Microprocessor Programming and Robotics in Key Learning Areas (N=17)

KLA	Mean* - Implemented (% of Teachers – Great Extent + Very Great Extent)
1. Technology	3.38 (58.8%)
2. SOSE	2.93 (11.76%)
3. Science	1.78 (34.28%)
4. Mathematics	1.77 (11.8%)
5. Other	1.5 (7.1%)
6. English	1.38 (5.9%)
7. The Arts	0.85 (5.9%)
8. HPE	0.23 (5.9%)
9. LOTE	0.08 (0%)

*Scale: Not at all = 0; Little Extent = 1; Some Extent = 2; Great Extent = 3; Very Great Extent = 4

While not as strong as teachers predicted at the commencement of the project, the most reported use of the Project activities related to Technology with 58.8% of teachers indicating that they used the activities in this Key Learning Area. This is somewhat puzzling as 92.5% predicted they would use the activities in Technology, and most teachers believed that their involvement in the Project would enhance the implementation of this Key Learning Area. It might be that curriculum support materials which more explicitly provide teachers with ideas for the use of microprocessor programming and robotics in Technology is needed as well as ideas for integration with other Key Learning Areas.

Impact of the Project

Teachers were asked to indicate the extent to which they believed that the project had impacted positively on their teaching practice, student learning, teacher learning, student literacy, student numeracy, student interest, student motivation, student behaviour, collaborative learning, teamwork, and problem solving. As shown in Figure 3, almost all dimensions were above the neutral mid-point of 2, student literacy was lower (mean=1.93). Student motivation (mean=3.69) and student interest (3.69) were very strongly seen to be aspects upon which the Project impacted positively, as well as student behaviour (mean=3.06). The microprocessor programming and robotics activities also impacted positively upon problem solving, collaborative learning, and teamwork

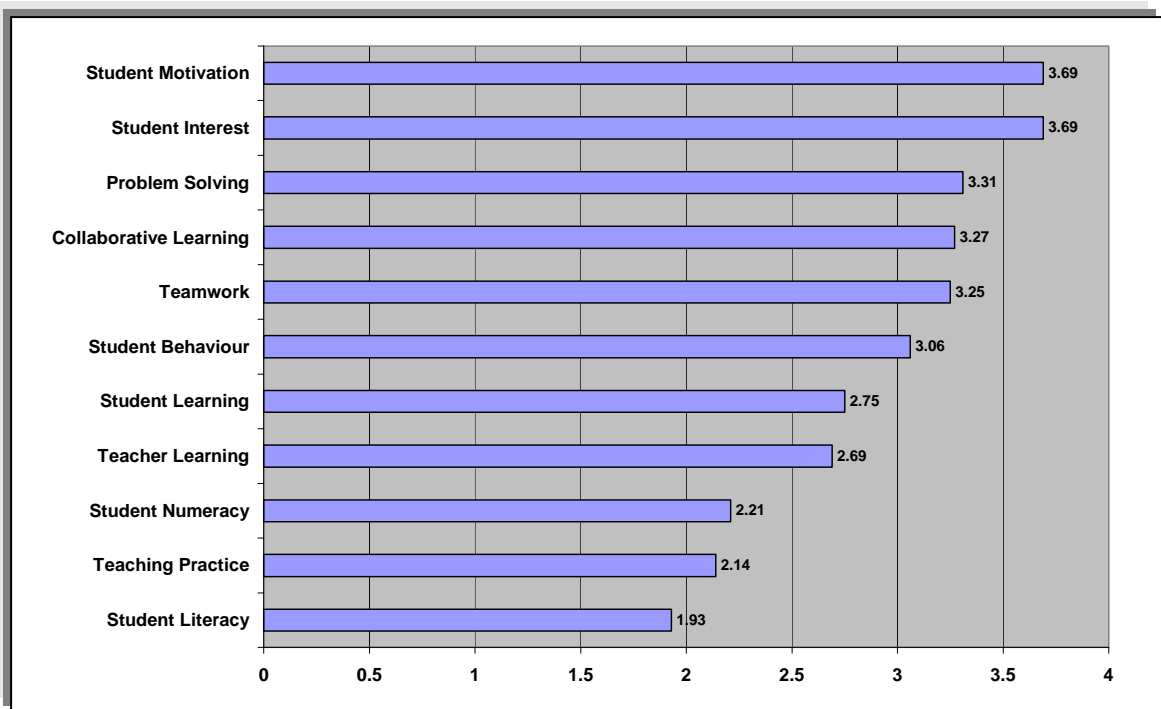


Figure 3: Impact of the Project – Teacher Perceptions (N=17)

(Scale: Not at all = 0; Little Extent = 1; Some Extent = 2; Great Extent = 3; Very Great Extent = 4)

Support Structures

In attempting to inform the wider implementation of similar microprocessor programming and robotics in schools, teachers were asked at the commencement of the Project what support structures they believed were necessary. At the commencement of the Project, teachers reported the following as being needed:

- 1. Professional Development Days**

“I don’t feel confident in helping the students when they have problems”

2. Time to Learn

“I need to get and have a go at some of the things the students have done today”

3. Materials

“We also were told we need to purchase the small spanner which is something that seemed an essential part of the kit”

“There doesn’t seem to be enough instructions/details in the instructions for a non computer person to follow. I am not sure what some of the attachments are/what they do. Do you have more detailed instructions/diagrams?”

4. Support

“Support from Instructors”

“Expert support – ‘How to’ – programming (training)”

“Tech support”

During the Project, teachers were asked to list the support structures which they believed had supported them to successfully implement this project with their students. The most frequently referred to support strategies were training and professional development, materials, school based support, and the role played by students.

1. Training and Professional Development

“Hands on training and experience. Professional development days”

“2 days training was very beneficial to the success of the program”

2. Materials

“Manuals/ lessons/ cards for students”

“provision of materials”

3. Support

“School based encouragement (Principal)”

“24 hour access to Picblok assistance. Ongoing updates regarding Picblok, other schools and Ed QLD initiatives”

“Our school has been in full support (Principal and Deputies)”

4. Students

“training of students to act as peer tutors”

Problems and limitations with the kits were identified by some teachers at the start of the project. For example, one teacher stated that:

“Idealy[sic] it would be preferable for one robot for every two students therefore requiring 14 in the classroom. I am concerned about making sure all students are involved when often if you have 3 students on any one activity there always seems to be two working & one not.

It also appears that the school will always be required to keep purchasing additional items in order to cater for everyone. E.g. The kit only contains 1 motion sensor.

We also were told we need to purchase the small spanner which is something that seemed an essential part of the kit.”

Some teachers also reported that they believed that the instructions could be made more teacher friendly:

“...there does not appear to be enough instructions/details in the instructions for a non computer person to follow.

I am not sure what some of the attachment are/what they do. Do you have more detailed instructions/diagrams?”

Student Perceptions

A sample of students (N=77) completed a student survey which sought their perceptions about various aspects of the project. These were administered in 2 school settings. As displayed in Figure 4 below, more than 80% of students indicated that they thought that microprocessor programming and robotics activities were good or very good.

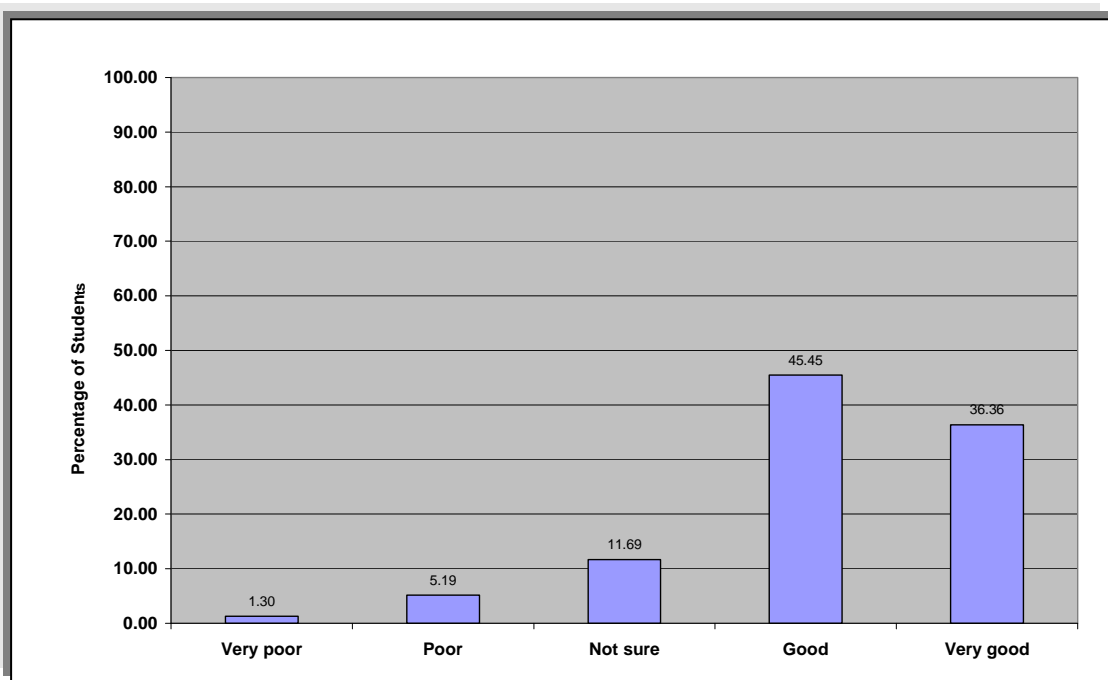


Figure 4: Students - Overall Perceptions of Microprocessor Programming and Robotics (N=77)

The research sought further insights about student interest, student motivation, student behaviour, desire to learn more, problem solving, and collaboration. To obtain student responses to statements about these aspects, the students were provided with a 5-point scale, ranging from ‘strongly disagree’ to ‘strongly agree’. As displayed in Figure 5, all the means are clearly above the neutral mid-point of 2.5. The strongest results were that students reported that, in relation to microprocessor programming and robotics, they were well behaved when they were doing the microprocessor programming activities (mean=4.18), that they would like to learn more (mean=3.97), that they are very interested (mean=3.87), and they were motivated when doing the microprocessor programming (3.78). Collectively, these portray a very positive story that the project had on student behaviour, interest, and motivation. There was a positive response overall to the challenge of having to solve problems (mean=3.83) which might suggest that the challenge provided could contribute to enhancing student engagement. The student data supports the perceptions reported by teachers in relation to the positive impacts of the Project on student motivation, interest and behaviour.

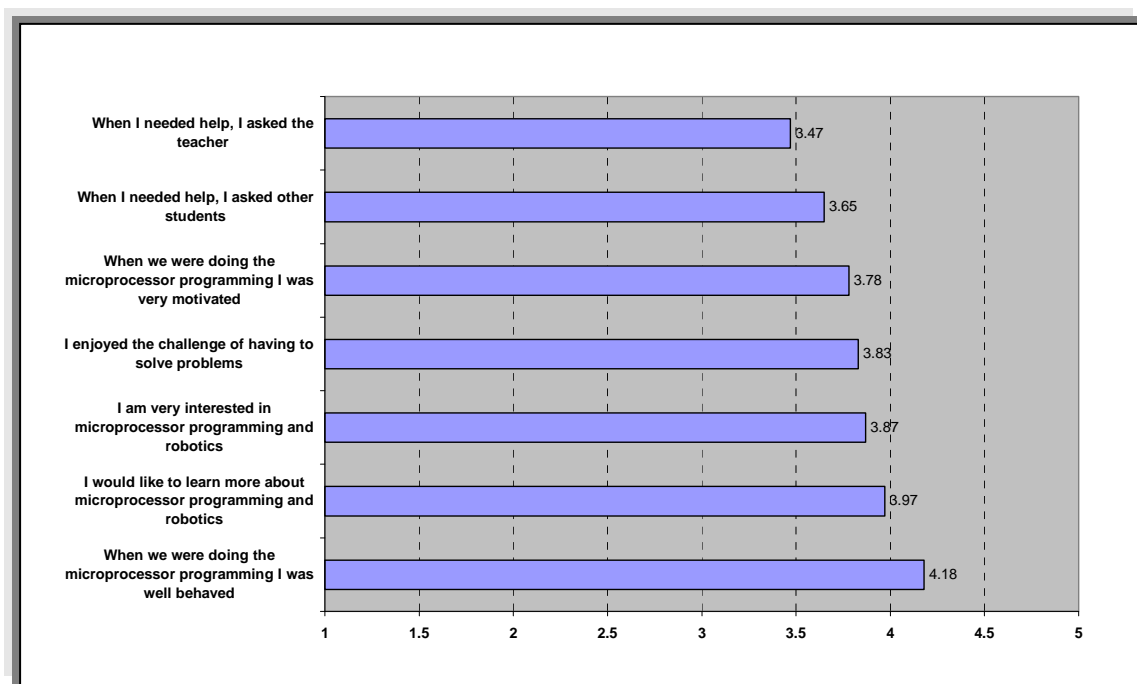


Figure 5: Students' Level of Agreement with Statements about Microprocessor Programming and Robotics (N=77)
 (Scale 1 to 5, where 1 =Strongly disagree and 5=Strongly agree)

Teacher Interviews

In depth interviews were conducted with a sample of teachers from various school sites. Each teacher was asked three questions:

1. What are the key messages you'd like to convey from your experiences in this Project?
2. If this project was to be extended to be implemented in other schools, what suggestions would you make for enhancing its success?
3. Is there anything that you'd like to comment on that you feel is important to convey?

From the teacher interview responses, the following key messages were synthesised:

Having the 'stuff' doesn't mean that it is going to happen.

Explanation: For the project to be successful, it depends upon having enthusiastic people, people who can help you out, and positive relationships between the teacher and learners, and between learners.

The Project was extremely worthwhile.

Explanation: Teachers indicated that that student engagement was enhanced, and saw this as important in developing students' higher order thinking and problem solving.

We didn't see many of the children get as far as we think they can go.

Explanation: Teachers tended to suggest that students had gradually learned how to do the programming and complete tasks, but had not advanced to the design of innovative solutions to real world problems. Some teachers stated that there is a need for students to become the creators of technology and they hadn't seen substantial evidence of this among their students and the activities so far.

We'd like to go further.

Explanation: Now that the project has finished, we'd like to continue to develop and share what we have learned. Some schools have planned to expand microprocessor programming and robotics to other classes in their schools.

We'd like Unit Plan ideas for Microprocessor Programming, and we could help share what we've done and write some for other teachers.

Explanation: There could be a project to develop a set of sample units which teachers in this Project designed and implemented, and further units developed. A key activity needed is for teachers to work with the robotics 'experts' to collaboratively develop curriculum support materials for use by other teachers.

Conclusion and Recommendations

In concluding this paper, the following system recommendations, drawn from the findings of this study, are made. It is recommended that:

Further microprocessor programming and robotics activities should be introduced in Queensland State Schools with students in the middle years of schooling through a well managed, coordinated strategic approach.

Researcher narrative: The current situation is characterised by ad hoc approaches, relying upon the interests and expertise of individual teachers, and is not of a comparable standard to that being achieved in competing countries. A more coherent system-wide practice model is required to enable students to be globally competitive in terms of microprocessor programming and robotics.

Additional projects are developed to explore a variety of robotics devices and systems.

Researcher narrative: Through research, the advantages and limitations of various systems and devices, in addition to those used in this study, can be analysed and summarised in terms of their strengths, limitations, and costs, to provide schools with a set of choices for selection.

Curriculum support materials are developed which explicitly provide teachers and students with links to curriculum documents.

Researcher narrative: Rather than be seen as an additional or discrete curriculum area, microprocessor programming and robotics needs to be more explicitly apparent and linked to Key Learning Areas. Teachers require more explicit curriculum support materials which identify the place and role of microprocessor programming and robotics in existing curriculum syllabuses and frameworks.

In addition to system recommendations, evidence was gained from this research to enable recommendation for implementation of microprocessor programming and robotics. It is recommended that:

In getting started, adequate strategies are provided to support the successful introduction of microprocessor programming and robotics activities.

Researcher narrative: These should include the provision of professional development days which incorporate training and ongoing mentoring of the teachers, training of students, allocation of time for the teachers to learn, teacher and student friendly instructions and details on getting started, kits which include everything that is needed to get started, expert programming and technical support; and ideas for planning and creating educational experiences which explicitly link to curriculum documents.

Effective ongoing strategies are provided to support the successful implementation of microprocessor programming and robotics activities.

Researcher narrative: These should include the provision of professional development days for exploring new, advanced ideas, ongoing support as required, activities which promote a community of practice/networks through sharing of challenges, solutions, ideas, resources and successes, school-based encouragement through peer and leadership support, enhanced, teacher and student online resources, curriculum materials such as unit and lesson plans, extension, and assessment ideas, and peer tutoring by students.

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