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Educating Australian High School Students in Relation to the Digital Future of Agriculture

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Educating Australian High School Students in Relation to the Digital Future of Agriculture

Abstract

The use of technology in Australian agriculture is rapidly advancing, with precision agriculture becoming a major focus of research and practical application. This move requires an appropriately qualified workforce in all aspects of agriculture and presents substantial social and educational challenges. This paper describes the steps being taken at a regional university to address two related needs in the Australian rural context: the lack of tertiary qualified graduates in the Australian agriculture industry and the deficit of qualified science and mathematics teachers in rural locations. In an attempt to address these challenges, a number of engagement strategies targeting high school teachers and students have been developed centered on the university SMART (sustainable, management, and accessible rural technologies) Farm that highlight the role of mathematics, science and technology to improve productivity. The initiatives include student outreach programs in science and agriculture and the development of an interactive digital classroom to engage junior secondary mathematics and science students. These initiatives are often the first time students come into contact with the term 'precision agriculture' and the underlying mathematics, science and information technology involved. The success of the program is evidenced by an increase in enrolments in agriculture based courses at the university of 10-15 per cent per year in the three years since the initiative was commenced.

Introduction

A number of substantial challenges are currently facing the rural and agricultural sector in Australia in relation to the availability of an appropriately qualified workforce. Regional universities have a role to play in addressing these challenges through the provision of appropriately qualified science, technology, engineering and mathematics (STEM) graduates. This paper will summarise one regional university's work in this area and will present the findings of research examining the capacity of practicing teachers to engage with an online curriculum resource intended to introduce students to Australian-based science and mathematics contexts. The benefit of addressing teacher attitudes towards ICT as an integral component of funded national projects that address curriculum resource development will be described.

Background

The Australian agriculture sector includes 7 per cent of workers who are tertiary qualified, compared with 25 per cent for the national workforce. This situation is exacerbated due to tertiary institutions providing 800 graduates each year to meet an estimated demand of 2000 (Pratley, 2008). The Australian National Farmers Federation (2014) estimates that Australian agriculture requires approximately 100,000 additional workers and that for every agricultural graduate, there are 2.5 positions available. They further argue that the average age of Australian farmers at 52 poses problems for the immediate future as the relative age of the workforce nears retiring age. With the increasing challenges of a steadily growing population and extreme climatic conditions, the best use must be made of the agricultural resources available through the use of digitally based precision agriculture by people appropriately qualified in the STEM fields of study (e.g. Gebbers and Adamchuk, 2010; Seelan, Laguette, Casady and Seielstad, 2003; Tilman, Cassman, Matson, Naylor and Polasky, 2002).

The shortage of skilled workers has "profound impacts on regional economies and place great pressure on the social fabric of these regional communities" (Cameron, 2011, p. 10). The lack of appropriately skilled workers in regional Australia is evidenced by government sponsored programs, such as the Regional Sponsored Migration Scheme and State Specific Regional Migration scheme.

These government programs are intended to support the migration of skilled workers into regional and rural areas, but their capacity to address shortages in agriculture related industries is questionable, with the focus being on larger regional cities and resource related industries (Taylor, Bell and Gerritsen, 2014). The 2014 NSW Skilled Occupation List (NSW Government, 2014) acknowledges the shortages in agriculture related industries through the inclusion of a number of agriculture-based occupations e.g. agricultural engineer, agricultural consultant, agricultural scientist.

The number of students studying science and mathematics has been declining in Australia at both the secondary and tertiary levels of education. Figure 1 shows the decline in students studying science and advanced mathematics over the period from 1976 to 2007.
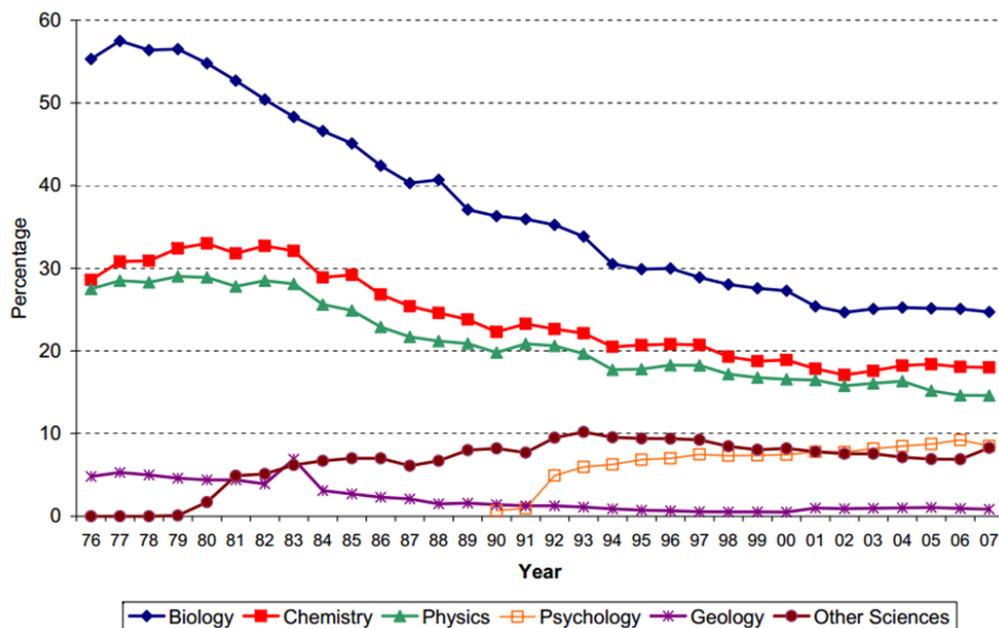

Figure 1: Year 12 science participation as a percentage of the Year 12 cohort in Australian schools: 1976 to 2007 (From Ainley, Kos, & Nicholas, 2008)

Figure 2 shows the reduction in the study of advanced mathematics for the period from 1995 to 2010 (Chubb, Findlay, Du, Burmester, & Kusa, 2012).
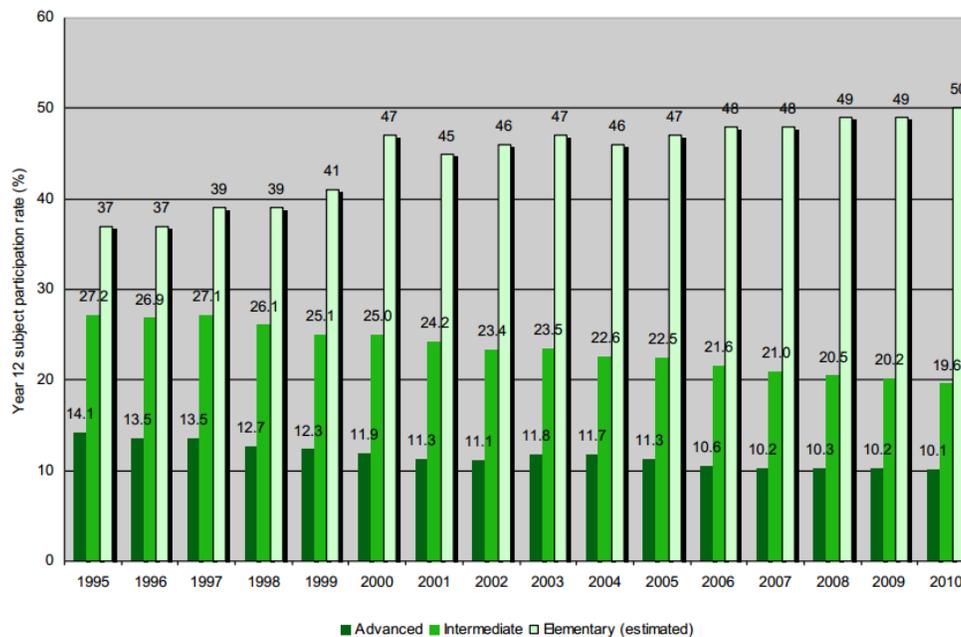
Figure 2: Student participation in mathematics, 1995-2010

It is apparent that the reduction of student numbers in the sciences is being most strongly demonstrated in Biology, a science that provides an important background for individuals who may potentially enter the agricultural workforce. A significantly lower level of interest and satisfaction has been identified for rural and remote students in the study of science when compared with students in large towns and cities, with this being particularly demonstrated in small rural and remote towns with a population lesson than 10 000 (Lyons and Quinn, 2012). Lower levels of mathematical and scientific literacy have also been identified in rural and remote students in Australian schools (Thomson, De Bortoli, Nicholas, K., and Buckley, 2011). The relevance of science education curricula to the everyday experience for rural Australian secondary students has also been questioned (Lyons and Quinn, 2012, 2014 In Press).

A second contributing factor to the state of STEM education in rural and remote areas is that many secondary schools are unable to obtain staff who are adequately qualified to teach these subjects (Harris, Baldwin, and Jensz, 2005; Lyons, Cooksey, Panizzon, Parnell, and Pegg, 2006; Marginson, Tytler, Freeman, and Roberts, 2013). International studies highlight the significance of this issue as

impacting on teacher well-being (Ingersoll, 1998; Steyn and du Plessis, 2007) and the quality of educational outcomes; for example, studies have shown that students taught by out-of-field mathematics teachers perform below students taught by qualified teachers (Attard, 2013; Thomson, Hillman, and Wernet, 2012). The issue of unqualified teachers in science is also greater in the lower years of secondary school, where heads of science departments in Australian schools report a much lower satisfaction with the science qualifications of staff in this area. The lowest satisfaction level (66.2%) was demonstrated at junior school science level, where over 40 per cent of teachers of have one year or less of tertiary study in Biology and Chemistry (Harris et al., 2005).

Research has demonstrated that it is the early secondary school experience of science that is associated with the decision to study science at higher levels (Harris et al., 2005; Lyons and Quinn, 2012; Tytler, 2007). The National Centre of Science, Information and Communication Technology, and Mathematics Education for Rural and Regional Australia (SiMERR) national survey of science, mathematics and ICT education (Lyons et al., 2006) established that teachers in non-metropolitan primary and secondary schools reported "a significantly higher unmet need for their students to have access to a broad range of learning experiences including opportunities to visit education sites, than did their metropolitan colleagues" (p. vii). However, once students from rural and remote schools enrol in STEM related undergraduate courses, they are no more likely to drop out than students from more populous centres (Wilson, Lyons, and Quinn, 2013).

The literature clearly demonstrates the challenges facing higher education institutions to attract and retain students appropriately trained in the STEM fields that will meet the workforce requirements in rural and remote Australia in coming years. In considering the literature, the problem appears to be largely manifested in the lower secondary years of education, where the disconnection from the study of STEM related subjects and the decisions relating to higher education is occurring. This encourages rural universities, in particular, to play a role a more direct role in addressing these challenges. Robinson (2012) proposes that Australian rural university campuses "must act not only as brokers between rural populations and higher education institutions, but as educators of public opinion

and shapers of local educational aspirations" (p. 79). This paper will now present one rural university's attempts to address these challenges.

The university initiatives

In an attempt to address these challenges, the University of New England (UNE) has developed a number of engagement strategies targeting high school students centred on the SMART (Sustainable, Management, and Accessible Rural Technologies) Farm that highlights the use of the latest technology to improve productivity. The initiatives include student outreach programs in science and agriculture and the development of an interactive digital classroom to engage junior secondary mathematics and science students.

A selective student conference Generation2050: Project Feed the World was held at UNE in December 2013. One hundred and one students from all Australian States and the Australian Capital Territory were chosen to attend from over 180 applications based on a short written essay and the subjects they were studying at school. Over the four-day event students were exposed to numerous agriculturally based activities in science laboratories as well as in the field. The precision agriculture sessions were nominated by students as a highlight.

The University also conducted on-campus multi-day workshops for secondary science and agriculture teachers from rural NSW. Two such workshops were conducted during 2014. These workshops are presented by the scientists involved in conducting research at the SMART Farm and who also presented the content from the digital classroom. The purpose of the workshops was to assist teachers to develop a vision of the future of farming in Australia and for exposing the underlying and essential role that mathematics, science and information technology play in that future. In this way, they were able to more effectively promote and teach mathematics, science and agriculture within digital, future oriented contexts relevant to the Australian rural context.

The success of previous school outreach activities at UNE has been further enhanced by a multi-institution project to develop a digital online classroom funded by Australia's Office of Learning and Teaching, titled RUN Maths and Science Digital classroom. Funding for the project, provided under the Australian Maths and Science Partnerships Program (AMSPP), was in excess of $1M. The

component of the digital classroom developed by UNE, due for completion in late-2014, will be available to rural and regional schools to assist engagement of students with some aspects of the science, mathematics and agricultural theory that underpins the functioning of the UNE SMART Farm. This approach will allow students to engage with an interactive online environment presenting real-life contexts related to their personal experience in rural Australia. Expert scientists from UNE present the content to facilitate the students' engagement with science, mathematics, ICT and agriculture and to promote UNE as the students' university of first choice after completing secondary school.

The research context

The most recent teacher professional development program was conducted at the UNE campus for 195 teachers from throughout Australia from 25 to 28 June 2014. A range of sessions were available with the focus being on current research in relation to issues affecting the Australian and global rural sector and which would be useful in secondary school science and agriculture contexts[1]. The program included three 1.5 hour workshops, entitled The RUN Digital Classroom, conducted with different groups of attending teachers on the last day of the program[2]. The workshop introduced attendees to an online digital resource containing contexts based on the UNE SMART Farm that could be used in middle year's mathematics and science, and year 11 and 12 agriculture. The topics in the resource included guided activities that investigated the reasons for SMART farming, the mathematics involved in the remote tracking of livestock and the use of satellite technology in determining the condition of pastures.

The workshops were conducted in a computer laboratory with each participant having individual access to a workstation. Participants were able to work through the full content of the resource. While only UNE developed content was available at the time of the workshop, the resources developed by all institutions involved in the project were to be made available in late 2014. Contexts available at that time included:
- Visualising the human body

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[1] See   http://www.une.edu.au/about-une/academic-schools/school-of-environmental-and-rural-science/ers-news-and-events/teacher-development-conference/conference-sessions)

[2] See http://usq.mrooms.net/login/index.php

- Investigating Australia's past, present and future climate
- Astronomy – Spaceship Earth
- The chemistry of cheese making
- The chemistry of climate change

A total of 60 teachers self-selected to attend the workshops, comprising an equal number of males and females, 44 from public schools and the large majority from NSW (35) and Qld (13). A total of 11 teachers came from Victoria, Tasmania, South Australia and Western Australia.

The research project was introduced to the attendees at the commencement of the workshop. All participants were invited to complete a questionnaire at the conclusion of the workshop. The questionnaire included an initial section where teaching experience, type of school and gender were provided. A second section provided three 5 point Likert-scale items that encouraged teachers to indicate their overall computer ability, their ability to use online resources and the level of access their school had to online resources. The third section of the questionnaire included items comprising the System Usability Scale (SUS) (Brooke, 1996) and the Computer Attitude Scale (CAS) (Selwyn, 1997). The SUS and CAS both utilised five option Likert-scale items ranging from Strongly Disagree to Strongly Agree.

The SUS comprises ten items and is used to measure the perception of the usability of a computer system. The SUS scale is extensively cited in the academic literature when assessing computer system usability and has been identified as being the most reliable for this purpose, even for small sample sizes (Bangor, Kortum, and Miller, 2008; Tullis and Stetson, 2004). The items were re-worded to allow the attendees to identify their perceptions of the usability of the online resource for their students, and are shown in the list below. Lewis and Sauro (2009) report that such changes in the SUS do not lead to detectable differences in the factor structure or reliability of the instrument..

1. I think that students would like to use the digital classroom frequently.
2. I think that students would find the digital classroom unnecessarily complex.
3. I think the digital classroom would be easy for students to use

4. I think that students would need my support to be able to use the digital classroom.
5. I think that students would find the various functions in the digital classroom were well integrated.
6. I think that students will find too much inconsistency in the digital classroom.
7. I would imagine that most students would learn to use the digital classroom very quickly.
8. I think that students will find the digital classroom very cumbersome to use.
9. I think that students will have the confidence to use the digital classroom.
10. I think that students will need a lot of instruction before they could get going with the digital classroom.

The CAS provides four sub-scales: 'Affect', composed of six items and measures feelings towards computers; 'Perceived Usefulness' composed of five items that measure the individual's beliefs about the usefulness of computers in their job; 'Perceived Control', composed of six items that measure the perceived comfort level or difficulty of using computers; 'Behavioural Intention', composed of four items that measure behavioural intentions and actions with respect to computers. Selwyn (1997) reported a high internal reliability (α = 0.90) and test-retest reliability (0.93) for the CAS, a finding supported by Sexton, King, Aldridge and Goodstadt-Killoran (1999). The version of the CAS utilised in this study was that used by Teo (2008), with the generic reference in the items to 'computer' changed to 'digital classroom'.

Table 1 shows the items comprising the Computer Attitude Scale.

Table 1: Computer Attitude Scale (CAS) subscale items

Subscale	Item	Item Text
Affective subscale (AFF)	AFF1*	If given the opportunity to use the online digital classroom, I am afraid that I might damage it in some way
	AFF2*	I would hesitate to use the digital classroom for fear of making mistakes I can't correct
	AFF3	I don't feel apprehensive about using the digital classroom
	AFF4*	Using the digital classroom makes me feel uncomfortable
	AFF5	The idea of using the digital classroom does not scare me at all
	AFF6*	I would hesitate to use the digital classroom in case I look stupid
Perceived usefulness subscale (PU)	PU1	The digital classroom would help me improve my teaching of science
	PU2	The digital classroom would make it possible to work more productively
	PU3	The digital classroom can allow me to do more interesting and imaginative work
	PU4*	Most things that the digital classroom can be used for I can do just as well myself
	PU5	The digital classroom can enhance the presentation of my work to students to a degree which justifies the extra effort
Perceived control subscale (PC)	PC1	I could probably teach myself most of the things I need to know about using the digital classroom in my teaching
	PC2	I can make the digital classroom do what I want it to
	PC3	If I have problems using the digital classroom, I will be able to solve them one way or the other
	PC4*	I do not think I would be in complete control when I use the digital classroom
	PC5*	I would need an experienced person nearby when I use the digital classroom
	PC6	I would not need someone to tell me the best way to use the digital classroom
Behavioural intention subscale (BI)	BI1*	I would avoid using the digital classroom because I know it involves working with computers
	BI2*	I avoid coming into contact with computers in school
	BI3*	I only use digital resources like the digital classroom at school when l am told to
	BI4	I will use the digital classroom regularly in my science teaching

* Item for which scoring was reversed

The opportunity was also offered to make general comments with a single item at the end of the questionnaire.

Results

Table 2 shows the responses to the prompts in section 1 relating to the respondent's perception of his/her computer ability and school access to online resources.

Table 2: Respondents perception of computer ability and access to online resources (*n* = 60)

Prompt	Very Good	Good	Average	Poor	Very Poor
How would you rate your overall computer ability?	19	23	16	2	0
How would you rate your ability to use online resources?	19	25	16	0	0
What access to online resources do students have in your school?	15	26	17	2	0

While about 70 per cent of respondents considered that their overall ability to use a computer and online resources to be good or very good, this still represents a substantial number of the respondents whose computer ability may be considered limited to engage well with the digital classroom.

The descriptive statistics for the questionnaire are summarised in Table 3. Outliers, identified by examination of the boxplot for each scale, were removed from the analysis.

Table 3: Descriptive statistics and reliability coefficient for each subscale (*n* = 60)

Subscale	Number of Items	Range	Cases	Mean	Standard Deviation	Cronbach's alpha
SUS	10	0-100	60	60.3	14.7	0.84
Affective	6	6-30	59	26.8	3.7	0.86
Perceived usefulness	5	5-25	59	20.1	3.7	0.73
Perceived control	6	6-30	60	21.6	4.0	0.72
Behavioural intention	4	4-20	59	20.0	4.0	0.71

All scales demonstrated a satisfactory level internal consistency (Schmitt, 1996).

Independent samples *t*-tests were conducted to identify statistical difference due to gender or type of school. Prior to conducting the tests, the box plots of the data distributions were examined and outliers were removed from the analysis, which resulted in a maximum of two cases being removed for each variable. The results

of the tests are shown in Table 4, with effect sizes for substantial differences shown using Cohen's *d*.

Table 4: Scale independent sample *t*-tests using gender as the grouping variable

Scale	Males		Females		*df*	*t*	*p*	*d*
	Mean	SD	Mean	SD				
SUS	56.8	14.9	63.8	14.0	58	1.860	0.069	0.479
Affective	25.4	4.8	27.9	2.6	58	2.502	0.015	0.646
Perceived usefulness	19.9	3.6	20.8	3.2	56	1.029	0.308	
Perceived control	19.8	3.5	23.4	3.7	58	3.873	0.000	1.000
Behavioural intention	16.6	2.6	17.9	1.8	57	2.263	0.027	0.588

Mann-Whitney *U*-tests were conducted for the responses on items 1 to 3 and are shown in Table 5.

Table 5: Mann-Whitney *U*-tests for computer ability and access to online resources using gender as the grouping variable

Item	Males		Females		*U*	*Z*	*p*
	Mean Rank	*N*	Mean Rank	*N*			
How would you rate your overall computer ability?	25.2	30	35.8	30	291	2.487	0.013
How would you rate your ability to use online resources?	25.9	30	35.1	30	313	2.163	0.031
What access to online resources do students have in your school?	30.5	30	30.5	30	449.5	0.008	0.994

The data in Tables 4 and 5 indicates that a substantial difference exists between males and females in their general computer and online capacities and their attitudes and intentions in relation to the use of the digital classroom, with males demonstrating significantly lower levels than females. A correlation analysis was conducted to assess the association between the number of years of teaching experience with overall computer ability and all subscales for each gender. None of the associations were significant indicating that teaching experience was not a factor in the gender differences identified.

The Spearman correlations between each of the subscales, the respondent's ability to use online resources and school access to online resources is shown in Table 6. The Spearman correlation was used to allow the inclusion of items 1 and 2 in the analysis.

Table 6: Scale Spearman's correlation coefficient matrix

Scale	1	2	3	4	5	6	7
1. Ability to use online resources	1						
2. School access to online resources	.454**	1					
3. SUS	.276*	.320*	1				
4. Affective	.536**	.191	.415**	1			
5. Perceived usefulness	.197	.222	.557**	.367**	1		
6. Perceived control	.449**	.142	.390**	.493**	.106	1	
7. Behavioural intention	.437**	.270*	.412**	.566**	.477**	.550**	1

$* p \leq 0.05$, $** p \leq 0.01$

The correlation between items 1 and 2 in Table 6 ($\rho = .454$, $p < .01$) is of particular interest and suggests a moderate association between the respondent's ability to use online resources and their perception of access to those same resources within his/her school. It should also be noted that relatively high correlations are demonstrated between Affective and Behavioural intention ($\rho = .566, p < .01$), Affective and Ability to use online resources ($\rho = .536, p < .01$) and Perceived control and Behavioural intention ($\rho = .550, p < .01$). These correlations suggest that the affective attitudes towards and the perceived control over the utilisation of the digital classroom will be associated its uptake following the workshop.

A multiple regression analysis was conducted using BI as the dependent variable and SUS, AFF, PU and PC as the independent variables. A residual analysis was conducted for each independent variable against the dependent variable and cases with extreme residuals were removed from the analysis. The final analysis included 52 cases. The results of the regression analysis indicated the included predictor variables explained 53.7 per cent of the variance ($adjusted\ R^2 = 0.498, F(4,47) = 13.647, p < .01$). It was identified that both AFF ($\beta = 0.476, p < .01$), PC ($\beta = 0.262, p = 0.06$) and PU ($\beta = 0.254, p = 0.034$) significantly predicted BI. A Shapiro Wilk test ($p = 0.293$) for normality,

Durbin-Watson test (2.39) for serial correlation among the residuals and an analysis of residual plots indicated that the dataset was appropriate for multiple regression.

An examination of the qualitative comments identified 25 of the 60 participants who made very positive comments relating to the digital classroom with three examples shown.

Great innovation that will help to extend students and develop a managerial overview of farming and agriculture decision making
Fantastic resource!
Well thought out and user friendly program.

There were a number of negative comments made, with the principal focus being the challenge of gaining access to computers in small rural schools and the challenges that students with lower literacy and numeracy skills may have engaging with the online content. Three examples of these comments are shown.

I think it is great and will use it. My biggest challenge is getting access to computers as we are a smaller rural school; which has limited resources.
There are some quite high order operations which many of my students may have trouble with, however I will try using parts of the digital class room.
Some students with literacy problems and students with special needs will find it difficult and would need extra support. A program that is simplified or 1/2 program would be a good alternative.

Discussion

The RUN – Maths and Science Digital Classroom was developed with the view that the presentation of contexts that were meaningful to students would facilitate increased engagement in STEM related subjects and increase the number of students who would opt to study in these fields at the tertiary level. The approach taken to facilitate initial teacher engagement was for the classroom to be presented at the end of the PD program at UNE so that the context of the resource would be better understood. The mean results on the scales for Affective, Perceived usefulness, Perceived control and Behavioural intention were all high

and indicate that teachers recognised value in the resource and possessed the intention to use it in their teaching. The relatively low mean values for the SUS scale indicated that teachers held reservations in relation to the complexity level of the resource. Teacher comments relating to the difficulty that students with low levels of literacy and numeracy would have when using the resource support this stance. Overall, these results indicate that teachers who are provided with access and initial training in an online teaching resource that contains relevant, real-life science, mathematics and agricultural contexts are prepared to engage with that resource.

However, there are a number of factors relevant to the affective dimension that need to be considered before the funds allocated to resources such as the digital classroom will achieve optimal results. The relevant findings in this study supporting this stance were the significant, moderate correlation between the teachers' ability to use online resources and their perception of the availability of online resources in their school and the relatively high correlations that the affective dimension had with the ability to use online resources, the perceived control of the digital classroom and the behavioural intention to use the digital classroom in the future. The multiple regression analysis also identified the affective dimension and perceived control as being the strongest significant predictors of the behavioural intention to use the digital classroom.

This issue is complicated by significant differences based on gender, where males reported significantly lower levels in overall computer ability, the ability to use online resources and all of the summative scales, with the exception of the perceived usefulness of the digital classroom. The largest difference were identified in the perceived control possible over the digital classroom, where males were one standard deviation lower than females, and in the affective attitude towards the digital classroom.

The RUN – Maths and Science Digital Classroom was targeted at the development of a contextually appropriate online STEM resource. However, the findings from this study indicate that the usefulness of the resource ranks below the affective attitude and perceived control over that resource in terms of the intention to incorporate the resource in teaching. This raises the issue of the

appropriateness of developing such a resource without a dedicated targeting of the affective dimension.

Conclusion

There is clear evidence (e.g. Ainley et al., 2008; Chubb et al., 2012; Lyons et al., 2006) that a substantial improvement is required in the education of regional and rural students in relation to the STEM disciplines and that a failure for our education system to provide skilled workers has substantial negative impacts on regional communities (Cameron, 2011). The RUN – Maths and Science Digital Classroom is UNE's latest initiative to address this issue. The success of university based outreach programs is clearly demonstrated by the large number of teachers from around Australia who attended the professional development program at UNE. The school engagement activities conducted at UNE were often the first time that students had an opportunity to explore concepts such as 'precision agriculture' and the contextual use of mathematics, science and information technology in a rural environment. The success of the outreach program is supported by an increase in enrolments in agriculture based courses at the university of 10-15 per cent per year in the three years since the initiative was commenced, although no independent research is available to establish a direct causal relationship between these factors.

The success of these initiatives, however, cannot be based upon the UNE campus. UNE serves a relatively small rural community and its capacity to engage with and support teachers and students in schools outside this community is very limited without the use of advanced online teaching and learning approaches. This study supports the view that any initiative involving online resources developed for use in schools should include a focus on the affective dimension of teacher attitudes towards ICT, and the related issue of teacher computer ability. Such a focus would support teachers in engaging with online resources and would maximise their effectiveness.

In mid-June 2014 $16.4 million of further grants were provided to Australian universities under the AMSPP (see http://www.education.gov.au/successful-projects). The RUN – Maths and Science Digital Classroom project did not receive further funding in this round of grants. The current funding for

maintaining the digital classroom will finish at the end of 2015. From that time the digital classroom will cease to function without further financial support. Considering that the project has not focused on the affective dimension or computer ability of the teachers, but has targeted the development of a curriculum resource, the impact of the project can only be measured in limited terms. However, the targeting of the affective dimension does provide an opportunity for future research that would potentially influence both teachers and students beyond the life-time of any teaching resource.

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