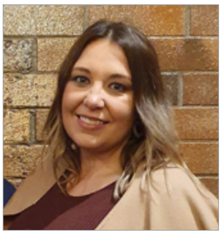
The future agricultural workforce – is the next generation aware of the abundance of opportunities?



Australian school-aged students represent both the future agricultural workforce and next-generation consumer. To ensure students are best placed for future career and purchasing decisions, adequate knowledge of agriculture is essential. The current research explores the agricultural knowledge of primary and secondary school students, including a discussion of how factors such as gender, year level, location, and farm exposure may impact student understanding. As expected, agricultural knowledge increased with year level. Farm exposure also had a significant impact on student knowledge with students that have never visited a farm found to have lower agricultural knowledge than all other exposure groups. School location was also found to impact agricultural knowledge, though it was students from inner regional areas that displayed the greatest knowledge. This research has highlighted the importance of developing adequate formal and informal education programs for Australian school students. Recommendations from this work include regular and consistent exposure to agriculture or agricultural-related activities across multiple year levels. Further development of modern agriculture learning programs is also recommended, particularly those focused on emerging agricultural technology to ensure students are aware of the current state and how technology is revolutionising the industry and subsequent agricultural workforce.

Amy Cosby,[ab] Jaime K Manning,[a] Kristen Lovric[a] and Eloise S Fogarty[a]

a Institute for Future Farming Systems, School of Health, Medical and Applied Sciences, CQUniversity

b Centre for Research in Equity and Advancement of Teaching and Education (CREATE), School of Education and the Arts, CQUniversity

Agriculture in the Australian context

The agricultural industry plays a critical role in the Australian economy, contributing 1.9% of value to the gross domestic product (GDP) and accounting for 12% of goods and service exports in 2020–21 (ABARES, 2022). According to the 2016 census, agriculture accounted for 3% of the total workforce (ABS, 2016b). However, between 2011 and 2016, 59% of low-skilled and 45% of high-skilled employees left the sector (ABS, 2016b), and the total number of workers declined by 7% from 2006 to 2016 (ABS, 2006, 2016b). As of 2021, the proportion of the Australian workforce in agriculture has dropped to 2.5% (ABARES, 2022). Reasons for the decline include an ageing workforce and increasing urbanisation as people move from regional to metropolitan areas (Wu et al., 2019). An increase in the time spent in higher education and subsequent later entry in the workforce has also contributed to this decline (Wu et al., 2019), though higher secondary school is still the most common level of education reported by agricultural workers (ABS, 2016b). While these labour market statistics paint a picture of the agricultural workforce as one in decline, it may be more accurate to describe this as an on-farm workforce in decline. Bassett et al. (2022) has argued that agricultural production is becoming increasingly professionalised in response to the complexity of the context under which farmers operate. Furthermore, the professional agricultural services sector captured through the Australian and New Zealand Standard Classification of Occupations codes categories (ANZSCO, 2021) vastly under-represents the breadth and diversity of professions that work in the agricultural industry. Many of these "missing" agricultural professionals are younger than those employed in on-farm jobs and reside in urban areas. Despite the clear importance of agriculture in Australia, and an increasingly diverse range of professionals who work in the sector, knowledge of agriculture and farming processes appear to be on the decline (PIEFA, 2020; Worsley et al., 2015), particularly as the gap between metropolitan and rural communities continues to expand.

Agricultural literacy

Being agriculturally literate refers to more than just having a basic knowledge or awareness of the industry. Instead, agricultural literacy requires "knowledge and understanding of agriculturally related scientific and technologically-based concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" (Meischen & Trexler, 2003). This reflects the multidisciplinary nature of agriculture, requiring scientific, technological, engineering and mathematical (STEM) concept knowledge (Meischen & Trexler, 2003), as well as an understanding of the broader environmental and social significance (Brandt et al., 2017).

In a systematic review of agricultural literacy in school students, Cosby et al. (2022) found that peer-reviewed research in this field is limited, with only 11 studies published between 2000 and 2020; eight from the USA and one each from India, Nepal, and Korea (see Cosby et al. (2022) for details). In general, most studies reported low levels of agricultural literacy for both primary and secondary school students. Other key findings were a positive association between agricultural literacy and previous experience with agriculture-based activities (e.g., learning about plants; Jeong & Hmelo-Silver, 2010) and that student knowledge generally increased with age (Brandt et al., 2017) or rural location (Gartaula et al., 2020; Pense et al., 2006). Although no peer-reviewed literature involving Australian student agricultural literacy is available to date, industry reports such as PIEFA (2020) and Hillman and Buckley (2011) show similar trends for Australian students, including a knowledge divide between urban and rural students and that the stereotypical notion of agricultural work as simply 'being a farmer' is firmly entrenched in student's minds (PIEFA, 2020). This suggests a failing by the agricultural industry and the education system to provide sufficient learning opportunities, potentially due to a shortage of trained teachers (PIEFA, 2020), or due to the inadequate representation of the industry in formal curricula.

Agriculture's place in the Australian curriculum

Australian school students are generally introduced to agriculture, or 'food and fibre', throughout both their primary and secondary education. Established by the Australian Curriculum, Assessment and Reporting Authority (ACARA), the national curriculum predominantly teaches food and fibre concepts to primary-aged students in Design and Technologies and Humanities and Social Sciences/Geography (ACARA, 2021). For secondary students, food and fibre is similarly taught in Design and Technologies and Geography, with linkages to Science, History, Economics, and Mathematics encouraged. Despite the inclusion of these outcomes in the national curriculum, implementation is still the responsibility of each State and Territory, and the addition of agriculture as a subject across most Australian schools is not mandated. The exception to this are secondary schools in New South Wales where agriculture is part of the compulsory curriculum in Year 7 and 8 (NESA, 2017). Research has found that exposure to specific learning areas such as agriculture or science increases the likelihood of deciding to study these subjects at a higher level (Terry & Frances, 2012; Whannell & Tobias, 2015). Thus, adequate learning experiences across a student's schooling career is imperative to ensuring a thriving future agricultural workforce.

Further to the lack of mandated learning, the Australian education system lacks a formal framework for assessment of students' agricultural literacy, and what is anticipated knowledge at the end of each year of schooling. For example, in the United States, Spielmaker and Leising (2013) developed the National Agricultural Literacy Outcomes (NALOs), a framework that allows for national benchmarking of student knowledge. The prescriptive NALOs outline the expected development of knowledge as students' progress through each grade and can be used to develop uniform assessment tools to examine student agricultural literacy (Brandt et al., 2017). The NALOs were also fundamental in the development of the National Agricultural Literacy Curriculum Matrix, a searchable online database containing lesson plans and supporting documents to address the requisite agricultural literacy outcomes (National Center for Agricultural Literacy at Utah State University, 2020). A similar system exists for the Australian tertiary sector (Learning and Teaching Academic Standards Statement for Agriculture; Botwright Acuna et al., 2014) though the level of uptake across the sector is unknown. Moreover, the absence of an agricultural literacy framework for Australian primary and secondary schools represents a significant deficit and limits the capacity for comprehensive examination of the current level of agricultural education taking place.

To ensure the Australian agricultural industry can continue to prosper, attraction and retention of a modern workforce is essential. One way to achieve this is by increasing the knowledge and awareness of young people to aspire to one of the many career pathways available in agriculture. Young people are also the next-generation of consumers, and their future purchasing decisions will help to shape the future of the industry. Improved knowledge and awareness are therefore imperative to ensure good future purchasing decisions and an understanding of these choices in terms of animal welfare, environmental sustainability, and healthy eating practices (GHD & AgThentic, 2018).

The current research explores the agricultural knowledge of primary and secondary school students, including a discussion of how factors such as gender, grade/year level, location, and farm exposure may impact student understanding. Without an existing assessment framework, a formal benchmarking of agricultural literacy against expected outcomes is not possible. Instead, this research focuses on general agricultural knowledge of primary and secondary students in Australia, with the aim of providing a baseline dataset for use in the future development of both formal and informal agricultural education programs by the agricultural industry and schools.

Data collection

Australian school students ranging from Years 4 to 10 (ages 9 – 16) were surveyed to determine their level of agriculture knowledge.

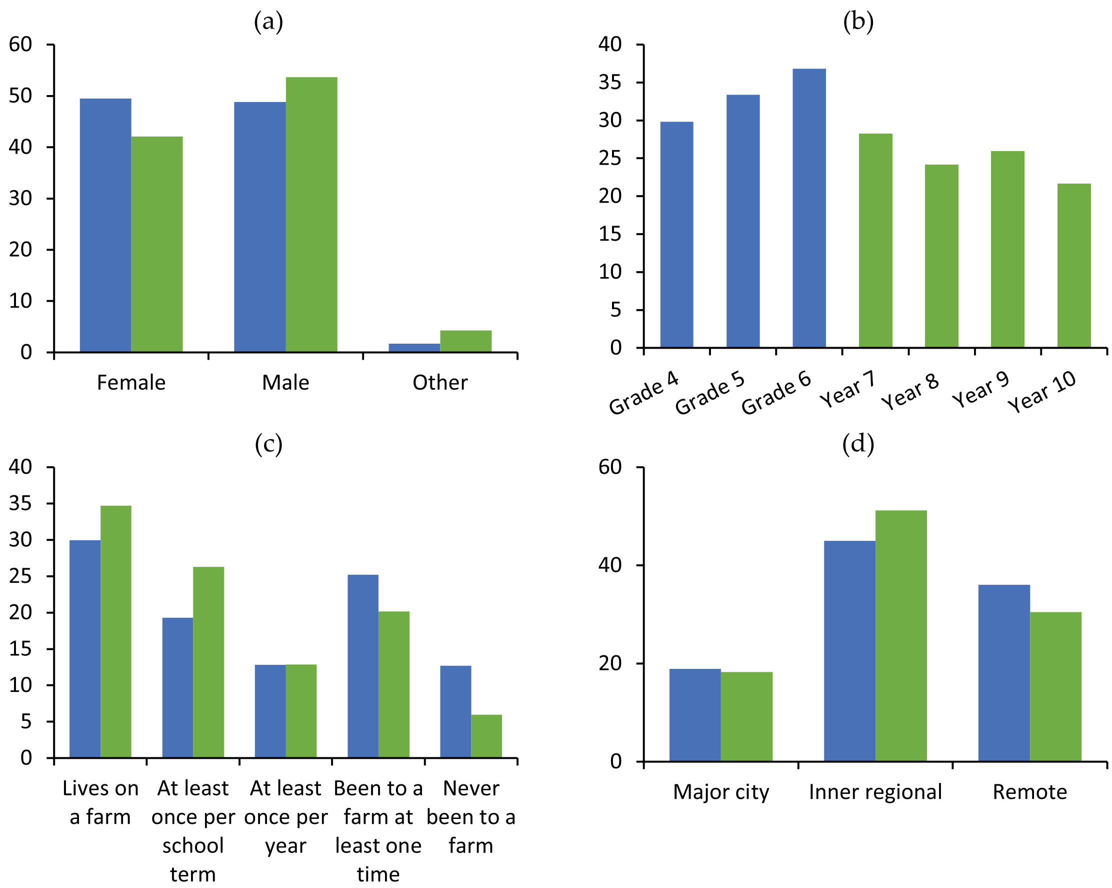


Figure 1: Demographic data of primary (blue) and secondary (green) participants including (a) gender, (b) grade or year level, (c) level of farm exposure and (d) location of school based on ABS (2016a). Values represent percentage of respondents for primary (N = 2392) or secondary (N = 2603) school students.

Students were selected by their principal and/or teacher to participate in the research and completed the survey in either written or electronic format. This research was approved by the CQUniversity Australia Human Research Ethics Committee (approval number 21738). Additionally, approval was granted from each state or territory's Department of Education, relevant Catholic Diocese, or independent school, with the exception of Western Australia.

The primary survey (Grades 4 – 6) and secondary survey (Years 7 – 10) were two separate surveys containing questions of differing difficulty. Each comprised of one open-response and 16 closed-response questions, the latter of which were mostly knowledge-based (N = 13). The remaining closed-response questions were used to collect demographic data including gender, grade/year level and extent of farm exposure (N = 3). The open-response question is not presented in this paper. Though most questions were different between the primary and secondary surveys, six were consistent, including questions regarding techniques used in commercial dairy farming, technology use on farms and agricultural jobs.

The overall sample presented in this paper consisted of 2392 primary students and 2603 secondary students. Basic demographic data is presented in Figure 1. Location (i.e., major city, inner regional or remote) was based on school location and defined by the Australian Statistical Geography Standard Remoteness

Table 1: Distribution of primary and secondary student participants by state. No participants were recruited from Western Australia (not shown). An additional 33 secondary students did not include their school on their survey and therefore their state is unknown.

	Primary		Secondary	
State	Total schools	Total students	Total schools	Total students
Australian Capital Territory	1	20	1	99
New South Wales	3	196	12	978
Northern Territory	2	183	-	-
Queensland	58	1752	24	1093
South Australia	-	-	3	121
Tasmania	3	95	4	136
Victoria	8	146	3	138
Unknown	-	-	-	33
Total	75	2392	47	2603

Structure (ABS, 2016a). The structure defines five areas of relative remoteness across Australia: major city, inner regional, outer regional, remote, and very remote. In this study, outer regional, remote, very remote were amalgamated into a single 'remote' group. The distribution of participants across the country is shown in Table 1.

Analytic strategy

Responses to all closed-ended questions were numerically coded using Microsoft Excel in preparation for statistical analysis. For 'select all that apply' items, correct responses were weighted based on the total number of selections needed for a fully correct answer. For example, for a question with four correct responses, students were given a score of 0 for no correct response, 0.25 for one correct response, 0.5 for two correct responses and so forth. A standardised agricultural knowledge score was then calculated for each student, representing the sum of correct responses out of the total number of knowledge-based questions (N = 13). Scores below 1.96 were filtered out of analysis as these were the result of missing responses.

All statistical analysis was performed in R (R Core Team, 2018). Shapiro-Wilk normality tests and Levene's tests of homogeneity were used to test the assumptions of normality and equality of variance, respectively. The data did not meet the assumption of normality. Therefore, the non-parametric Kruskal-Wallis test was used for analysis of gender, grade, farm exposure and location, with post-hoc testing of pairwise comparisons using a Dunn's test with Bonferroni adjustment. The significance value for all tests was set at $P \leq 0.05$. Group-wise medians, were also calculated, including 95% confidence intervals using the percentile method.

As both cohorts received different surveys, direct comparisons between the overall results were not possible. Nevertheless, for those questions that were consistent, the number of correctly identified question items (represented as a count) were compared using a Chi-Square test of independence.

Primary and secondary student agricultural knowledge

The mean agricultural knowledge score for primary students was 8.7 (SD = 2.1) out of a maximum of 13 (range 0.5 – 13.0). The median score was 9.0. Knowledge varied between year levels $P \leq 0.001$), increasing significantly from Grade 4 to 5 ($P < 0.001$), and then again from Grade 5 to 6 ($P < 0.001$).

For secondary students, the mean agricultural knowledge score was 8.6 (SD = 2.5) out of a maximum of 13 (range 0.6 – 13.0). The median score was 8.8. Similar to primary students, agricultural knowledge varied

Table 2: Group-wise median scores including 95% CI for each grade or year group. Knowledge scores were calculated out of a maximum of 13. 95% CI was calculated using the percentile method.

	Grade/Year Level	Median	95% CI
Primary	4	8.3	[8.2, 8.5]
	5	8.8	[8.7, 9.0]
	6	9.5	[9.3, 9.7]
Secondary	7	8.2	[8.0, 8.4]
	8	8.4	[8.2, 8.7]
	9	9.5	[9.3, 9.8]
	10	9.7	[9.4, 9.9]

with year level ($P < 0.001$), with students in Years 7 and 8 having significantly lower levels of knowledge compared to Years 9 and 10 ($P < 0.001$). However, knowledge was not significantly different within those year pairs, i.e., within Years 7 and 8 ($P = 0.5$) or within Years 9 and 10 ($P = 0.3$).

A summary of the group-wise median scores for each year group are presented in Table 2. Overall, there appears to be a trend for increasing agricultural knowledge with increasing year level, although this cannot be confirmed by formal comparison.

Within each survey however, there was some overlap in specific questions between the primary and secondary survey versions. For example, students were asked to select from a list of answers all the methods that Australian farmers used to collect milk on commercial dairy farms. Possible responses were "with milking machine"; "in a robotic dairy" or "by hand into a bucket", with students expected to identify the first two options as correct. Secondary students were more likely to identify the two correct options compared to primary students (X^2 (2, N = 4995) = 379.7, $P < 0.001$). Furthermore, almost 4 in 5 primary students and 3 in 5 secondary students thought that commercial milking occurs by hand, including 14% of primary and 4% of secondary students that believed this was the only method used on commercial farms. This suggests that students do not fully understand large scale production systems, even as year level increases. This may also provide more of an understanding as to why previous studies have reported a stereotypical view of farming as hard manual labour (Peltzer, 2019; Turner & Spence, 2014), which, although true of more traditional systems, does not accurately reflect the more tech-savvy businesses seen today.

In a question regarding the types of jobs available in agriculture, secondary students were more likely to identify more agricultural job options compared to primary students (X^2 (6, N = 4995) = 133.1, $P < 0.001$). For both cohorts, the vast majority of students were able to identify being a farmer as an agricultural job (86.7% primary; 89.8% secondary). Following this however, other jobs such as a veterinarian (44.0% primary; 62.9% secondary), scientist (33.2% primary; 43.7% secondary), journalist (16.1% primary; 14.9% secondary) or banker (7.9% primary; 7.6% secondary) were identified to a lesser extent, while non-agricultural jobs such as a doctor (13.3% primary; 7.2% secondary) or childcare worker (10.0 primary; 5.0% secondary) were identified in similar proportions. This is comparable to PIEFA (2020) which similarly noted jobs such as mechanic, data analyst or drone operator as having less association to agriculture (39 – 45%) compared to a scientist, machinery operator or labourer (59 – 64%). This suggests that while students are aware of more traditional roles in agriculture, they do not have a solid understanding of the breadth of career opportunities available.

Finally, students were asked to identify from a given list new technologies that may be used on-farm. The selection of possible technologies differed between the surveys (iPads and drones for primary students; drones, electronic identification tags, water tank sensors and autosteer tractors for secondary students). Thus, a formal comparison is not possible. Nevertheless, the descriptive results still warrant discussion. While most primary students were able to identify drones (63.3%) and iPads (54.6%) as new technologies, a considerable proportion also identified cattle yards (48.0%) and taps and hoses (32.5%). Similarly, most secondary students were able to identify electronic ear tags (73.1%), drones

(67.7%), water tank sensors (67.2%) and auto-steer tractors (54.7%), but again a large proportion identified cattle yards (58.7%) and taps and hoses (34.9 %). Akin to the dairy production question above, these results suggests that the 'modernising' of agriculture is not being adequately portrayed to Australian school students, including the rise of the fourth agricultural revolution (Rose et al., 2021) and associated innovations (Deloitte Access Economics, 2016).

The adoption of new technologies has seen a reduction in the need for manual labour in agriculture, and a resulting workforce shift from low-paying manual jobs to more high-paying technical roles (Azarias et al., 2020). If students are not being shown an accurate vision of modern agriculture, including the use of different technologies and the need for skilled workers to manage them, this may create barriers for entry as they are unlikely to recognise that agricultural jobs can be highly skilled, highly paid and possibly located outside of rural areas (Graham, 2021). This has been identified in numerous industry reports (ADIC, 2020; Azarias et al., 2020; Dairy Australia, 2021b; Poole et al., 2018; Wu et al., 2019). It was also identified in research by Pratley (2008), stating that the "image of agriculture, compounded by the ignorance about the industry by the general public, needs to be made positive and exciting".

Student demographics and agricultural knowledge

Farm exposure

Primary students that live on a farm reported a significantly higher group-wise median score (9.5 [9.3 – 9.7]) compared to all other groups (all P < 0.01), except for "I visit a farm at least once per school term" which was not significantly different (P = 0.7; Figure 2). Conversely, students that have never been to a farm reported the lowest group-wise median score (8.1 [7.7 – 8.5]) compared to all other groups (all P < 0.01). There was no significant difference in scores between students that visit a farm once per term or once per year ($P = 0.7$), and those that visit once per year or have visited a farm at least one time before ($P = 1.0$).

The impact of farm exposure was similar for secondary students (Figure 3). Again, students that live on a farm reported a significantly higher group-wise median score (9.9 [9.8 - 10.1]) compared to all other groups (all $P < 0.01$). Similarly, students that have never been to a farm reported the lowest group-wise median score (6.8 [6.1 – 7.1]) compared to all other groups (all $P < 0.01$). The only pairwise comparison which was not significantly different was students that visit a farm at least once per year, and those that have been to a farm at least one time before ($P = 0.5$).

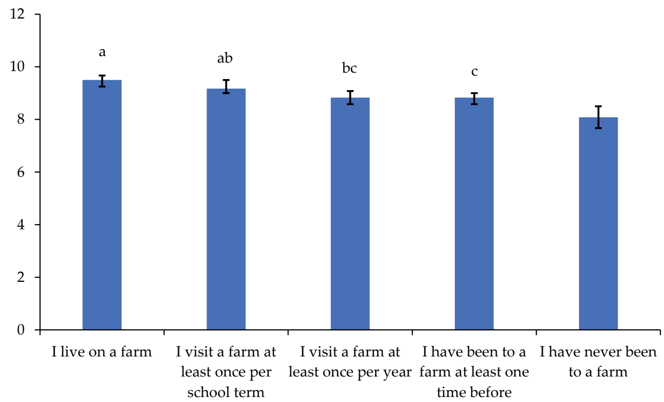


Figure 2: Group-wise median agricultural knowledge scores of **primary** students by farm exposure. Error bars represent the 95% CI calculated by the percentile method. Groups with a common letter are not significantly different (P > 0.05).

Location

For both primary ($P < 0.001$) and secondary ($P < 0.001$) students, school location also had a significant impact on agricultural knowledge. For primary students, this difference was found between students from major cities and inner regional ($P < 0.001$), and inner regional and remote ($P < 0.001$). There was no significant difference between the agricultural scores of students from major cities or remote areas ($P = 0.3$). For secondary students, all location groups were significantly different from each other (all $P \leq 0.003$).

A summary of the group-wise median scores for each year group are presented in Table 3. For both cohorts, inner regional students had the highest agricultural knowledge score, followed by remote and major city students.

Gender

For secondary students, there was also a significant difference in agricultural knowledge based on gender ($P = 0.004$). However, this likely reflects the unbalanced group sizes of male, female and other respondents (Table 1). Indeed, when comparing male and female knowledge scores, there was no significant difference for secondary students ($P = 1.0$). There was no significant difference for gender of primary school students ($P = 0.1$).

Table 3: Group-wise median scores including 95% CI for each location group. Knowledge scores were calculated out of a maximum of 13. 95% CI was calculated using the percentile method. Primary and secondary results were analysed separately. For primary students, groups with a common letter are not significantly different ($P > 0.05$).

	Location	Median	95% CI
Primary	Major city	8.7a	[8.3, 8.8]
	Inner regional	9.2	[9.0, 9.3]
	Remote	8.8 a	[8.7, 9.0]
Secondary	Major city	8.3	[8.0, 8.5]
	Inner regional	9.3	[9.1, 9.4]
	Remote	8.7	[8.4, 8.9]

What does this mean?

This research has highlighted the importance of developing adequate education programs for Australian school students. Previous research in this area has mostly been presented as descriptive statistics (Hillman & Buckley, 2011; PIEFA, 2020), with a limited discussion of the factors such as gender, year level, location and farm exposure may impact this knowledge. While agricultural knowledge is developed through both formal schooling and informal experience (e.g., social interactions, traditional or social media), formal education

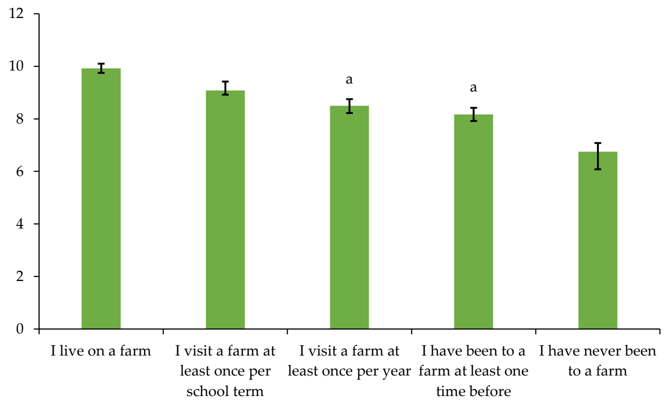


Figure 3: Group-wise median agricultural knowledge scores of **secondary** students by farm exposure. Error bars represent the 95% CI calculated by the percentile method. Groups with a common letter are not significantly different ($P > 0.05$).

is still considered critical to bridge the knowledge gap and to overcome negative perceptions of the industry (Cosby et al., 2022). This research has provided a more in-depth understanding of potential factors impacting student knowledge, which should be used in the development of both formal and informal agricultural education programs.

Farm exposure was found to significantly impact student agricultural knowledge for secondary school students. As expected, students with higher levels of exposure had greater agricultural knowledge compared to those with less exposure. This is reflective of existing literature, where previous experience with agriculture-related activities was reported to positively impact agricultural literacy (Jeong & Hmelo-Silver, 2010). Of interest, it appears that regular farm experience is necessary to impact student understanding, suggesting that consistent exposure across multiple year levels will be required to significantly improve knowledge levels.

In a previous report of agriculture-related school activities, Hillman and Buckley (2011) found that just over half of Grade 6 students reported an involvement in school vegetable gardens (53%), followed by a smaller proportion of farm visits (16%) and attending an agricultural show day (12%). This proportion was similar when surveying teachers, with primary (82%) and secondary teachers (58%) also reporting high participation in school vegetable garden activities, followed by marine discovery centres for primary teachers (23%), and competing at agricultural show days for secondary teachers (35%). Conversely, one in five teachers across both cohorts indicated that they had never participated in any school activities related to agriculture. This indicates a significant gap in student and teacher exposure to agriculture, and that this is consistent across both primary and secondary schooling. This may relate to either a scarcity of applied agriculture programs, inadequate opportunities for teacher professional development or a low level of uptake of existing resources in schools.

Several resource programs are available to assist teachers in the development of their agriculture teaching programs in schools. For example, the NSW Department of Primary Industries (NSW DPI, 2021) provides resources that cover a broad range of topics for secondary students, including livestock, aquaculture and grain production. Similarly, programs developed by industry bodies such as Meat and Livestock Australia (MLA, 2020) and Dairy Australia (DA, 2021a) seek to educate students about the red meat or dairy industry, respectively. Though these resources are available, the moderate agricultural knowledge found in this study suggest these programs are being broadly underutilised, perhaps due to an uncertainty in curriculum application or lack of teacher confidence. Additionally, industry-developed programs can often face several challenges, including time, budget constraints, inflexible schools and trust between parties and further research regarding the best approach to engagement is also recommended (O'Dea et al., In print).

In-school resources that tackle agricultural technology are also limited (Manning et al., 2022). The agriculture industry is in a period of transformation, with emerging technologies such as big data, artificial intelligence, robotics, drones and the Internet of Things becoming more pervasive (Rose et al., 2021). This has led to an increase in high-skill jobs in the sector and has a subsequent change in workforce requirements (Wu et al., 2019). In the current study however, it appears that students were not aware of these technological applications, with many students, for example, identifying milking by hand as a commercial dairy technique. Similarly, when asked directly about agricultural technology, a large proportion of students across both cohorts responded that cattle yards and taps and hoses were new technologies being used on-farm. This is consistent with PIEFA (2020), where 40% of students disagreed or were neutral when asked if farming relies on science, technology and innovation. Moreover, in YouthInsight Australia (2017), students from Years 10 – 12 and first-year university students readily identified stereotypical perceptions of agriculture created by television and pop culture, including that it involved hard manual labour and was 'boring'. Education programs specifically focusing on innovation in agriculture should attempt to correct this. For example, the GPS Cows Module (GPS Cows, 2020), a complete teaching resource developed in conjunction with the NSW Department of Education, introduces students to emerging technologies in livestock production and aims to increase their digital literacy skills (Cosby et al., 2019a).

In addition to in-school agriculture activities, increased opportunity for on-farm activities should also be encouraged to ensure students are being exposed to real farm experience. For example, the federally funded Kids to Farms program aims at increasing engagement of primary school students with agricultural workplaces and improving their understanding of the socio-economic role agriculture has in Australia (Department of Agriculture, 2022). Due to conclude later this year, evaluation of the Kids to Farms program will be important to determine success factors and barriers for application. The importance of direct engagement experience with the agricultural industry at both primary and secondary school levels has also been reported in the National Agriculture Workforce Strategy (Department of Agriculture, Water and the Environment, 2020), further noting that career education resources require direct engagement experiences to influence people's career aspirations.

Of note, the results of this research found that school location (major city, inner regional or remote) also impacted student agricultural knowledge. However, for both cohorts, inner regional students displayed the highest scores. This contrasts previous literature, where rural location was found to result in higher agricultural knowledge scores of secondary students in Nepal (Gartaula et al., 2020) and the US (Pense et al., 2006). This may reflect a limitation in the current study, including the difference in sample size for each group. Furthermore, location was generated based on the Australian Statistical Geography Standard Remoteness Structure (ABS, 2016a), which measures 'remoteness' based on the road distance to the nearest urban centre, rather than a measure of 'rurality'. This structure also excludes any consideration of other measures of remoteness, including socio-economic and population size. Future research should consider different definitions of remoteness/location, including access to education services. This could assist in understanding if the pattern of knowledge divide between rural and urban students exists in Australia. Nevertheless, while there is some evidence of city-based students falling behind their regional counterparts in terms of agricultural knowledge, these results challenge the longstanding assumption that rural students will have stronger knowledge and connection to agriculture (PIEFA, 2020), providing evidence that suitable education programs are still vital for development of agricultural knowledge for all students, regardless of location.

In summary

The need to educate today's students on agriculture is twofold. First, knowledge can impact an individual's choice to pursue a career in that field (Cosby et al., 2019b; Matthews & Falvey, 1999), and attraction of future workers into agriculture is essential for a productive and prosperous future industry. Second, today's students will be tomorrow's consumers, and therefore education is imperative to ensure future support of the industry through suitable purchasing decisions.

Previous research in this area has mostly been presented as descriptive statistics (Hillman & Buckley, 2011; PIEFA, 2020), with a limited discussion of the factors such as gender, year level, location and farm exposure that may impact this knowledge. This research has highlighted the importance of developing adequate education programs for Australian school students, irrespective of demographic factors, and suggests that consistent exposure is important to facilitate improved knowledge and awareness. This can be facilitated through access to agriculture experiences across all year levels, not just at higher year levels when potential career paths are being considered.

Furthermore, given the impact of emerging technology on the industry, there is a clear and obvious need to develop teaching programs that address this, providing students with both the opportunity to develop their digital skills and a broader knowledge of modern agriculture. To facilitate this, stronger industry and education partnerships are needed to develop adequate school programs. Development of a supporting assessment framework is also recommended, to allow for benchmarking and subsequent program evaluation over time.

References

ABARES. (2022). *Snapshot of Australian Agriculture 2022*. Retrieved 3 Mar 2022 from https://www.awe.gov.au/abares/products/insights/snapshot-of-australian-agriculture-2022

ABS. (2006). *Census*. Australian Bureau of Statistics. Retrieved 1 Jun 2022 from https://www.abs.gov.au/websitedbs/censushome.nsf/home/historicaldata2006?opendocument&navpos=280

ABS. (2016a). 1270.0.55.005 – Australian Statistical Geography Standard (ASGS): Volume 5 – Remoteness Structure, July 2016 Australia Bureau of Statistics. Retrieved 19 Jul 2022 from https://www.abs.gov.au/websitedbs/d3310114.nsf/home/remoteness+structure

ABS. (2016b). *Census*. Australian Bureau of Statistics. Retrieved 1 Jun 2022 from https://www.abs.gov.au/websitedbs/censushome.nsf/home/2016

ABS. (2017). 1270.0.55.004 – Australian Statistical Geography Standard (ASGS): Volume 4 – Significant Urban Areas, Urban Centres and Localities, Section of State, July 2016. Australia Bureau of Statistics. Retrieved 19 Jul 2022 from https://www.abs.gov.au/ausstats/abs@.nsf/mf/1270.0.55.004

ACARA. (2021). *Curriculum connections: Food and fibre*. Retrieved 28 Apr 2022 from https://www.australiancurriculum.edu.au/resources/curriculum-connections/portfolios/food-and-fibre/

ADIC. (2020). *Australian Dairy Industry Sustainability Report 2020: Towards Our 2030 Goals*. https://www.sustainabledairyoz.com.au/reporting

ANZSCO. (2021). *ANZSCO - Australian and New Zealand Standard Classification of Occupations*. Retrieved 15 Jun 2022 from https://www.abs.gov.au/statistics/classifications/anzsco-australian-and-new-zealand-standard-classification-occupations/latest-release

Azarias, J., Nettle, R., & Williams, J. (2020). *National Agricultural Workforce Strategy: Learning to excel*. https://www.awe.gov.au/sites/default/files/documents/national-agricultural-workforce-strategy.pdf

Bassett, K., Newsome, L., Sheridan, A., & Azeem, M. M. (2022). Characterizing the changing profile of employment in Australian agriculture. *Journal of rural studies*, *89*(316-327).

Botwright Acuna, T. L., Able, A. J., Kelder, J., Bobbi, P., Guisard, Y., Bellotti, B., McDonald, G., Doyle, R., Wormell, P., & Meinke, H. (2014). *AgLTAS: Learning and Teaching Academic Standards Statement for Agriculture*. Office for Learning and Teaching.

Brandt, M., Forbes, C., & Keshwani, J. (2017). Exploring Elementary Students' Scientific Knowledge of Agriculture Using Evidence-Centered Design. *Journal of Agricultural Education*, *58*(3), 134-149. https://doi.org/10.5032/jae.2017.03134

Cosby, A., Manning, J., Power, D., & Harreveld, B. (2022). New Decade, Same Concerns: A Systematic Review of Agricultural Literacy of School Students. *Education sciences*, *12*(4). https://doi.org/10.3390/educsci12040235

Cosby, A., Manning, J., & Trotter, M. (2019a). TeachersFX - Building the capacity of STEM, agriculture and digital technologies teachers in Western Australia. *International Journal of Innovation in Science and Mathematics Education*, *27*(4), 76-87. https://doi.org/10.30722/IJISME.27.04.006

Cosby, A., Trotter, M., Manning, J. K., Harreveld, B., & Roberts, J. (2019b). Opportunities and barriers perceived by secondary school agriculture teachers in implementing the GPS Cows learning module. *International Journal of Innovation in Science and Mathematics Education*, *27*(4), 67-75. https://doi.org/10.30722/IJISME.27.04.005

Dairy Australia. (2021a). *Picasso Cows*. Retrieved 10 Jun 2022 from https://www.dairy.edu.au/picasso-cows

Dairy Australia. (2021b). *Strategic Plan 2020-2025*. https://www.dairyaustralia.com.au/strategic-plan-2020-25/strategic-framework

Deloitte Access Economics. (2016). *Cross-Industry Innovation Scan* (National Rural Issues, Issue.

Department of Agriculture. (2022). *Educating Kids About Agriculture: Kids to Farms*. Retrieved 16 Jun 2022 from https://www.communitygrants.gov.au/grants/educatingkidsabout agriculturekidstofarms

Department of Agriculture Water and the Environment, N. A. L. A. C. (2020). *National Agricultural Workforce Strategy discussion paper*.

Gartaula, H., Patel, K., Shukla, S., & Devkota, R. (2020). Indigenous knowledge of traditional foods and food literacy among youth: Insights from rural Nepal [Article]. *Journal of rural studies*, *73*, 77-86. https://doi.org/10.1016/j.jrurstud.2019.12.001

GHD, & AgThenic. (2018). *Consumer perceptions around emerging AgTech* (AgriFutures National Rural Issues, Issue. https://www.agrifutures.com.au/wp-content/uploads/2019/01/18-048.pdf

GPS Cows. (2020). *GPS Cows*. Retrieved 27 Aug 2020 from https://www.gpscows.com/

Graham, S. M. (2021). Untapped Potential: The Neglected Urban Interest in Secondary Agriculture. *International Journal of Innovation in Science and Mathematics Education*, *29*(4), 11-21.

Hillman, K., & Buckley, S. (2011). *Report on surveys of students' and teachers' knowledge and understanding of Primary Industries*. https://www.piefa.edu.au/uploads/9/8/9/8/98986708/food_fibre_and_future_pief_report.pdf

Jeong, H., & Hmelo-Silver, C. E. (2010). Productive use of learning resources in an online problem-based learning environment. *Computers in Human Behavior*, *26*(1), 84-99. https://doi.org/https://doi.org/10.1016/j.chb.2009.08.001

Manning, J. K., Cosby, A., Power, D., Fogarty, E. S., & Harreveld, B. (2022). A Systematic Review of the Emergence and Utilisation of Agricultural Technologies into the Classroom. *Agriculture*, *12*(6). https://doi.org/10.3390/agriculture12060818

Matthews, B., & Falvey, L. (1999). Year 10 students' perception of agricultural careers: Victoria (Australia). *Journal of Internatioal Agricultural annd Extension Education*, *6*, 55-67.

Meat and Livestock Australia. (2020). *Red meat resources for schools*. Retrieved 11 Aug 2021 from https://www.mla.com.au/news-and-events/industry-news/red-meat-resources-for-schools/

Meischen, D. L., & Trexler, C. J. (2003). Rural elementary students' understanding of science and agricultural education benchmarks related to meat and livestock. *Journal of Agricultural Education*, *44*(1), 43-55.

National Center for Agricultural Literacy at Utah State University. (2020). *National agriculture in the classroom*. Retrieved 26 May 2022 from https://agclassroom.org/

NESA. (2017). *Technology Mandatory Years 7-8 Syllabus*.

NSW Department of Primary Industries. (2021). *School resources - Secondary schools*. Retrieved 11 Aug 2021 from https://www.dpi.nsw.gov.au/education-and-training/school-resources/secondary-schools

O'Dea, M., Cosby, A., Manning, J., McDonald, N., & Harreveld, B. (In print). Industry perspectives of industry school partnerships: What can agriculture learn? *Australian and International Journal of Rural Education*.

Peltzer, C. (2019). *Attracting youth into agriculture - Developing a strategic framework to encourage young people to pursue a career in agriculture - A model for Tasmania*.

Pense, S. L., Beebe, J. D., Leising, J. G., Wakefield, D. B., & Steffen, R. W. (2006). The agricultural literacy of urban/suburban and rural twelfth grade students in five Illinois high schools: An ex post facto study. *Journal of Southern Agricultural Education Research*, *56*(1), 5-17.

PIEFA. (2020). *Food, fibre and our future 2020: PIEFA student survey summary report on student knowledge, understanding and sentiment about primary industries*. Primary Industries Education Foundation Australia. Retrieved 28 Mar 2022 from https://www.piefa.edu.au/uploads/9/8/9/8/98986708/piefa_summary_student_survey_report__food_fibre_and_our_future_2020.pdf

Poole, R., van Delden, B., & Liddell, P. (2018). *Talking 2030: Growing agriculture into a $100 billion industry*. KPMG Australia. Retrieved

30 Dec 2021 from https://home.kpmg/au/en/home/insights/2018/03/talking-2030-growing-australian-agriculture-industry.html

Pratley, J. (2008). Workforce Planning in Agriculture: Agricultural Education and Capacity building at the Crossroads. *Farm Policy Journal*, *5*(3), 27-41.

Rose, D. C., Wheeler, R., Winter, M., Lobley, M., & Chivers, C. A. (2021). Agriculture 4.0: Making it work for people, production, and the planet. *Land Use Policy*, *100*, 1-5.

Spielmaker, D. M., & Leising, J. G. (2013). *National agricultural literacy outcomes*. Utah State University, School of Applied Sciences & Technology. Retrieved 26 May 2022 from https://www.agliteracy.org/resources/outcomes/

Terry, L., & Frances, Q. (2012). Rural high school students' attitudes towards school science. *Australian and International Journal of Rural Education*, *22*(2), 21-28. https://doi.org/10.3316/informit.846988583252088

Turner, L., & Spence, K. (2014). Pathways into agricultural science in Tasmania: How did students find the way? *Agricultural science (Melbourne)*, *26*(2), 47-53. https://doi.org/10.3316/ielapa.797910911358844

Whannell, R., & Tobias, S. (2015). Educating Australian high school students in relation to the digital future of agriculture. *Journal of economic and social policy*, *17*(2), 61-80.

Worsley, A., Wang, W., & Ridley, S. (2015). Australian adults' knowledge of Australian agriculture. *British Food Journal*, *117*(1), 400-411. https://doi.org/http://dx.doi.org/10.1108/BFJ-07-2013-0175

Wu, W., Dawson, D., Fleming-Munoz, D., Schleiger, E., & Horton, J. (2019). *The future of Australia's agricultural workforce*.

YouthInsight Australia. (2017). *Developing student interest in the agriculture sector*.

About the authors

Dr Amy Cosby is the Head of the Agricultural Education and Extension Cluster at CQUniversity Australia with a Bachelor of Agriculture/Bachelor of Laws (Hons) and a PhD in Precision Agriculture. Amy currently works with educators, students, researchers, and industry professionals to develop innovative programs to increase their skills and knowledge in agricultural concepts, tools and systems. Her objective is to use the knowledge derived from this research to design programs which attract and retain the next generation agricultural workforce to the industry from diverse backgrounds.

Dr Jaime Manning is a lecturer in Agriculture at CQUniversity Australia, with a B.AnVetBioSci (Hons 1) and a PhD in Precision Livestock. Her main research interests are technology use on farms to improve the level of monitoring and welfare of livestock, whilst providing invaluable information into how we manage livestock and detect issues in extensive production systems. Her experience in this area ensures activities, professional development opportunities and research outcomes derived by the Agri-tech Education and Extension cluster are industry relevant and highlight current issues facing the sector.

Dr Kristen Lovric is a CQUniversity research officer, with a Bachelor of Psychology (Hons 1) and Master of Psychology/ PhD (Clinical). Kristen's research interests include the vocational psychology of agriculture and specifically Women in STEM (Science, Technology, Engineering and Mathematics). Her current role encompasses an array of duties including data analysis, interpretation of results, and preparation of research reports and articles. She has experience undertaking both qualitative and quantitative research to form an evidence base for interventions agricultural sectors can implement to improve workforce attraction and retention.

Dr Eloise Fogarty is a Senior Research Officer within the School of Health, Medical and Applied Sciences at CQUniversity Australia, with a B.AnVetBioSci (Hons 1 & Medal) and a PhD in Precision Livestock. Her main research interests are the use of agricultural technology on farms to improve the health and welfare of livestock, particularly the use of machine learning to facilitate autonomous monitoring in extensive systems. Her experience ensures research outcomes derived by the Agri-tech Education and Extension cluster are industry relevant and provides support in data analysis where required.