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Can Virtual Reality Engage Students With Teamwork?

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Abstract

Graduates' ability to work well in teams is highly valued by employers, but teamwork is seldom taught as an explicit skill at the tertiary level. Rather, students tend to form and retain negative attitudes towards teamwork. Some proponents have proposed that immersive virtual reality (IVR) technology could make student learning more engaging. This study explored whether the immersive nature of VR headsets improved engagement with teamwork in a first-year science communication unit. We measured students' attitudes and motivation before and after completing a tutorial designed to develop teamwork skills, and asked students to assess their peers' teamwork behaviours. In small groups, students in IVR tutorials collaboratively solved a puzzle in an IVR maze, while students in control tutorials completed an equivalent paper-based activity. Both interventions resulted in students developing slightly more negative attitudes towards teamwork. The IVR group was slightly more likely to report their teammates displayed dominating behaviours. On most measures, students' attitudes and motivation toward teamwork remained fixed even when tutors reported positive experiences in class. Feedback regarding drawbacks (such as nausea and costs) suggests that the addition of IVR technology is not a panacea for student engagement with teamwork.

Introduction

The ability to work well in teams is highly valued by employers (Rayner & Papakonstantinou, 2016) and in some contexts – such as hospitals and design firms – teamwork is critical to success (Baker, Day, & Salas, 2006). The benefits of teamwork for students include greater comprehension and retention of material, higher levels of motivation, greater persistence when facing adversity, and higher achievement (reviewed in Hansen, 2006). Despite the benefits, university students tend to report negative feelings when asked about teamwork, including frustration (e.g., regarding distribution of work), stress (e.g., regarding deadlines), anxiety and disappointment (e.g., regarding final outcomes) and generally negative attitudes toward teamwork (Chapman, Meuter, Toy, & Wright, 2009).By comparison, positive attitudes toward teamwork have been associated with higher grades on group assignments (Kouros, Abrami, Glashan, & Wade, 2006), improved teamwork skills and self-efficacy (Cumming, Woodcock, Cooley, Holland, & Burns, 2015; Kouros et al., 2006), staying in contact with team mates during projects (Favor & Harvey, 2016), increased perceived learning from assignments (Burdett & Hastie, 2009) and improved attitudes toward future teamwork projects (Tucker & Abbasi 2016). Whilst team projects are often included in curriculums at a tertiary level, teamwork is infrequently taught as an explicit skill (e.g. Davidson, 2013; Tucker & Abbasi, 2016; Main, 2010). Given that students' attitudes toward teamwork are informed by previous experience (Burdett & Hastie, 2009; Ekimova & Kokurin, 2015; Forrest & Miller, 2003;

Kouros et al., 2006), finding ways to improve attitudes towards teamwork in universities could improve graduates' success in future teamwork situations.

One tool with potential for improving attitudes towards teamwork is immersive virtual reality (IVR) technology. Ott and Freina (2015) note that virtual reality can be non-immersive (e.g., simulations on computers) or immersive (e.g., headsets), in which one perceives oneself to be physically present in a virtual, non-physical world. IVR is defined as technology that provides a multisensory experience that is intuitively interactive (Mikropoulos & Natsis, 2011). IVR is generally constructed by placing users in a headset that allows their head movements to generate change in the virtual world; for example, when the user turns their head to the left, the onscreen view shifts to the left simultaneously.

Adoption of IVR technology has been slow in large-scale university education due to cost and availability: IVR hardware has up to now been quite expensive, and the software has largely been restricted to video games from large companies. However, recent advances in the technology have significantly reduced the cost of IVR hardware and software: Google Cardboard, specifically, uses headsets made of cardboard with smartphone apps IVR apps can be created by individuals with basic programming experience, making simpleIVR technology very accessible, affordable, and customizable.

Most virtual reality research thus far has primarily examined specific, knowledge-based applications for IVR or simulations in workplace education. Loftin, Engleberg, and Benedetti (1993) created a virtual environment in which students could alter the physics of the space (such as gravity, friction, and atmospheric drag) and then 'experience' the changed environment, but did not test comprehension against a control group. Vora et al. (2002) tested IVR against a control (computer simulations) for training aircraft visual inspectors in the workplace, and found IVR was better for teaching knowledge and preferred by students. IVR has also been shown to be a useful medium for role-playing to develop social skills for people on the autism spectrum (Parsons & Mitchell, 2002). Medical training, in particular, has been examined as a useful application for IVR education where reality is too complex to be captured by simple teaching exercises, but too unpredictable for practice on real patients (e.g. Mantovani, Castelnuovo, Gaggioli, & Riva, 2003).

It has long been proposed that IVR technology also has the potential to make student learning more motivating and engaging (Hoffman & Vu, 1997; Ott & Freina, 2015; Psotka, 1995). Although computer simulations have been shown to motivate students and improve knowledge retention and teambuilding behaviours (Aïm, Lonjon, Hannouche, & Nizard, 2016; Lee, Wong, & Fung, 2010; Miller, Riley, Davis, & Hansen, 2008; Sitzman, 2011; Virvou, Katsionis, & Manos, 2005), there is relatively little research that evaluates the newer IVR technology. In addition, research into immersive learning is frequently vague about their interpretation of 'engagement' and 'motivation' (e.g. Dede, 2009). Engagement is difficult to define and even more difficult to measure (Fredricks, Blumenfeld, & Paris, 2004; Lawson & Lawson, 2013). This is because engagement is a meta-construct of three related dimensions: emotional engagement, cognitive engagement and behavioural engagement (Fredricks, Blumenfeld, & Paris, 2004; Lawson & Lawson, 2013; McKinnon & Vos, 2015).

In this study, we directly compared IVR with an equivalent paper-based activity to develop teamwork skills. If IVR is effective, we would expect to see an improvement in student engagement, as measured by their attitudes toward teamwork, motivation and behaviour.

Method

Study Population

Participants in this study were students in a first-year science communication class at the University of Western Australia, in Perth, Australia (n=769). The unit covers introductory research, scientific report writing, orally presenting ideas to their peers, and collaborating in large teams to produce an educational, science-themed community event.

Teamwork Activity

Four weeks before running their community event, students participated in a tutorial focussed on explicit teamwork training. In 2016, teamwork training was introduced with an IVR-based activity in a subset of tutorial classes (8 out of 37 classes) and a traditional paper-based (PB) activity in the remaining classes. This provided an opportunity to evaluate the effectiveness of the new IVR activity. All tutors received detailed training in how to run both the IVR and PB activities, although only five tutors were assigned to implement the IVR activity in their classes due to limited IVR resources.

In the teamwork training tutorial, all students first completed a short (20-30 minute), structured activity introducing conflict management skills by roleplaying common conflict scenarios. For the remainder of the class (60-70 minutes) the students were asked to self-organise into groups of 4-6 people. The classrooms were large, with flexible seating, so that the groups could spread out across the room. The tutor briefly described the activity and instructed the students to assign roles within the group: directors (read the instructions), actors (perform the actions) and observers (analyse teamwork behaviours). Students were encouraged to rotate roles if they completed the activity and start a new round. During the activity, tutors roamed the classroom, observing students and clarifying the instructions as needed.

In the IVR tutorial, (n=167 students in 8 tutorial classes) students had to find puzzle pieces in an IVR maze created especially for this study (Fig. 1). One student (the actor) from each group was given a Google Cardboard Version 2 headset with the IVR Speak and Seek app loaded to a smartphone. The rest of the group (the directors) were given a paper map of the max and instructions on how to solve the puzzle. The actor had to communicate verbally with the directors to share knowledge and successfully navigate the IVR maze (Fig.1, below).

Control tutorials (n=602 students in 29 tutorial classes) completed an equivalent paper-based (PB) activity, in which the directors had to describe how to create an origami artwork based on pictorial Ikea-style instructions (no written words) to the actor/s, who then folded paper to create the artwork.

Both interventions required students to assign and perform certain roles within the group; verbally describe their own perspectives clearly (e.g. what they could see either on paper or in IVR); communicate effectively to solve the puzzle; and apply the conflict management skills they had just learned. At the end of the tutorial, tutors led a general discussion about which techniques were most effective and which behaviours students found frustrating.

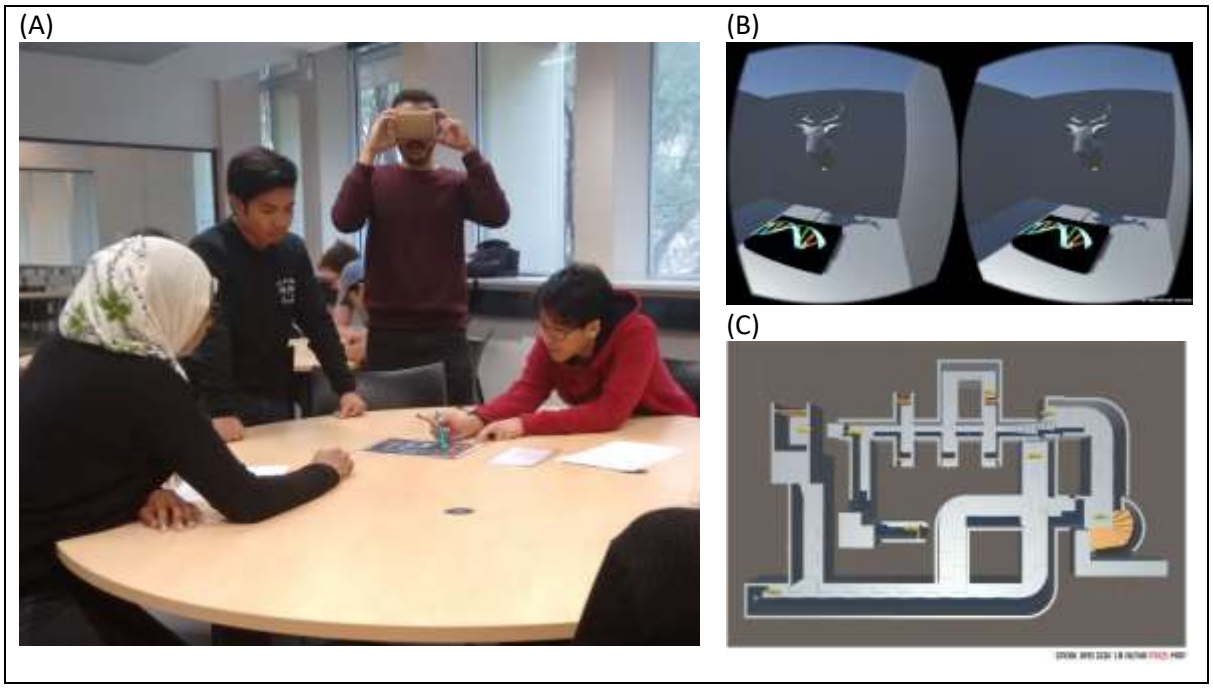

Figure 1: (A) Photo of students using immersive virtual reality technology for a teamwork activity in a first-year university science communication unit. (B) Photo of what users see in the immersive virtual reality app *Speak and Seek*, specifically designed for this study. On the virtual floor is one of the puzzle pieces which students must collect in the activity. (C) Map of the virtual reality maze given to team members outside the immersive virtual reality. Yellow labels indicate locations of puzzle pieces in the virtual maze.

Measurement

We attempted to measure each of the dimensions of engagement – emotional engagement, cognitive engagement and behavioural engagement (Fredricks, Blumenfeld, & Paris, 2004; Lawson & Lawson, 2013, McKinnon & Vos, 2015) – within online questionnaires before and after the tutorial.

Emotional engagement typically refers to student's affective reactions, such as enjoyment, interest or anxiety, and are commonly measured as attitudinal dispositions (Fredricks, Blumenfeld, & Paris, 2004). We used an established scale for teamwork attitudes created by Vance, Konak, Kultural-Konak, Okudan Kremer, & Esparragoza (2015), with an additional item on interest from earlier work by Kulturel-Konak, et al. (2014). This was added because scales for measuring emotional engagement typically include one or two items about interest (Fredricks, Blumenfeld, & Paris, 2004).

Cognitive engagement, defined as a student's investment and motivation to complete tasks, was measured using the California Measure of Mental Motivation (CM3) scale created by Giancarlo, Blohm and Urdan (2004). Both the attitudinal scale and the CM3 were chosen because they have high internal consistency and use 4-point Likert scales. Both questionnaires were shortened to better reflect the course and university context, and because shorter surveys have higher completion rates and gather better quality data (Galesic & Bosnjak, 2009). There

is some overlap between the two measures (for example, the attitudinal scale includes a question on motivation to participate), but this is not unusual given the difficulty of differentiating related measures in engagement research (Fredricks, Blumenfeld, & Paris, 2004; Lawson & Lawson, 2013).The attitudes and motivational data were collected both pre- and post- the teamwork tutorial.

As a proxy measurement for behavioural engagement with teamwork skills, students also noted observations of peer behaviours in the post-tutorial questionnaire. These observations of peer behaviours were measured using a shortened version of the seven-point Likert scale created by McClough and Rogelberg (2003). Additional data on behavioural engagement were collected from final group marks on the event assignment, feedback was solicited from tutors, and unsolicited comments were made by some students in the unit review about five weeks after the tutorial.

In the post-tutorial survey, we also requested data on university experience (first-year students vs second year and above) and study major (undeclared/general 'science' vs specific studies). We did not gather data on gender, age, English competency or other demographics, as these were not the focus of the study and have been well researched elsewhere (e.g. Espey, 2010; Moore & Hampton, 2015). Students completed the questionnaires as part of their online coursework requirements, but were able to opt-out of inclusion in this study.

The questionnaire data were analysed in SPSS (v24). The Wilcoxon Signed Ranked Test was used to compare students' attitudes towards teamwork and motivation before and after the class activity, because the Likert scale data required a non-parametric test that paired students' questionnaires. The Mann-Whitney U test was used to check for differences in students' attitudes, which required a non-parametric equivalent of a common t-test. Negatively-keyed survey items (e.g. 'I usually have a negative experience with teamwork') were reverse-coded for calculating average Likert scores. Final group marks on the event assignment were compared using t-tests. R-values are presented for all statistics to indicate the strength of the association (Cohen, 1988; Pallant, 2011).

Results

After excluding students who did not answer both surveys, or asked to be excluded from the study, there were 581 useable responses (76% response rate). There was no difference in response rate between IVR (n=126 of 167 students, 75.4% response rate) and paper-based (PB, n=457 of 602 students, 75.6% response rate). Most respondents (85%, n=496) were first-year students, but the sample group included students from all years. Nearly all students were enrolled in science courses, primarily unspecified science (40%, n= 238), with the next largest groups being 'biomedical science' (15%, n=87) and 'neuroscience' (7.5%, n=44).

Before the tutorial, students reported mostly positive attitudes towards teamwork, with an average Likert score of 3 across all items. All students were least likely to agree that they 'usually have a negative experience with teamwork' (Likert average 1.98) and most likely to agree that teamwork improves their communication skills (Likert average 3.46) (Table 1, below).

Table 1: Results of the attitudes toward teamwork and mental motivation scales given to students before an in-class teamwork activity. (Likert Scale from 1-4, where 1 is 'strongly disagree' and 4 is 'strongly agree'.)

Attitudes Towards Teamwork	Mean	SD	% Agree and Strongly Agree
I usually have a negative experience with teamwork	1.98	0.77	22.4
I would rather work on team projects than on my own	2.39	0.81	42.3
I like to participate in teamwork	3.08	0.73	80.6
I am usually motivated to participate in teamwork	3.15	0.77	80.8
Teamwork improves the quality of final project outcomes	2.96	0.84	69.6
Teamwork keeps me more engaged and interested in project tasks	2.89	0.85	71.5
Teamwork helps me improve my communication skills	3.46	0.66	90.9
How likely would you be interested in reading an article that is not so exciting but useful about teamwork communication?	2.25	0.82	32.4
Considering your previous teamwork experiences and how effective communication could have improved your team performance, please rate your level of interest in taking another unit which teaches teamwork communication skills	2.24	0.74	37.74
Motivation	**Mean**	**SD**	**% Agree and Strongly Agree**
I always look forward to learning challenging things	3.21	0.68	88.7
If given a choice, I would select a challenging activity over an easy one	2.85	0.75	70.0
I am good at making plans for how to solve difficult problems	3.05	0.66	83.4
My trouble is that I stop paying attention too soon	2.45	0.93	45.0
Thinking about other points of view is a waste of time	1.33	0.59	3.4
It's easy for me to stay focused when working on a problem	2.83	0.75	70.8
When I need to solve a problem, I have difficulty knowing where to begin	3.31	0.67	46.7
It's just not that important to keep trying to solve difficult problems	2.48	0.77	7.4
I only look for facts that support my beliefs, not for facts that disagree	1.57	0.66	9.4

In both the IVR (and PB, groups the majority of individual students reported no change in attitudes towards teamwork (Fig. 2, below). There were statistically significant changes after the intervention for some questions, with students reporting slightly more negative attitudes towards teamwork.

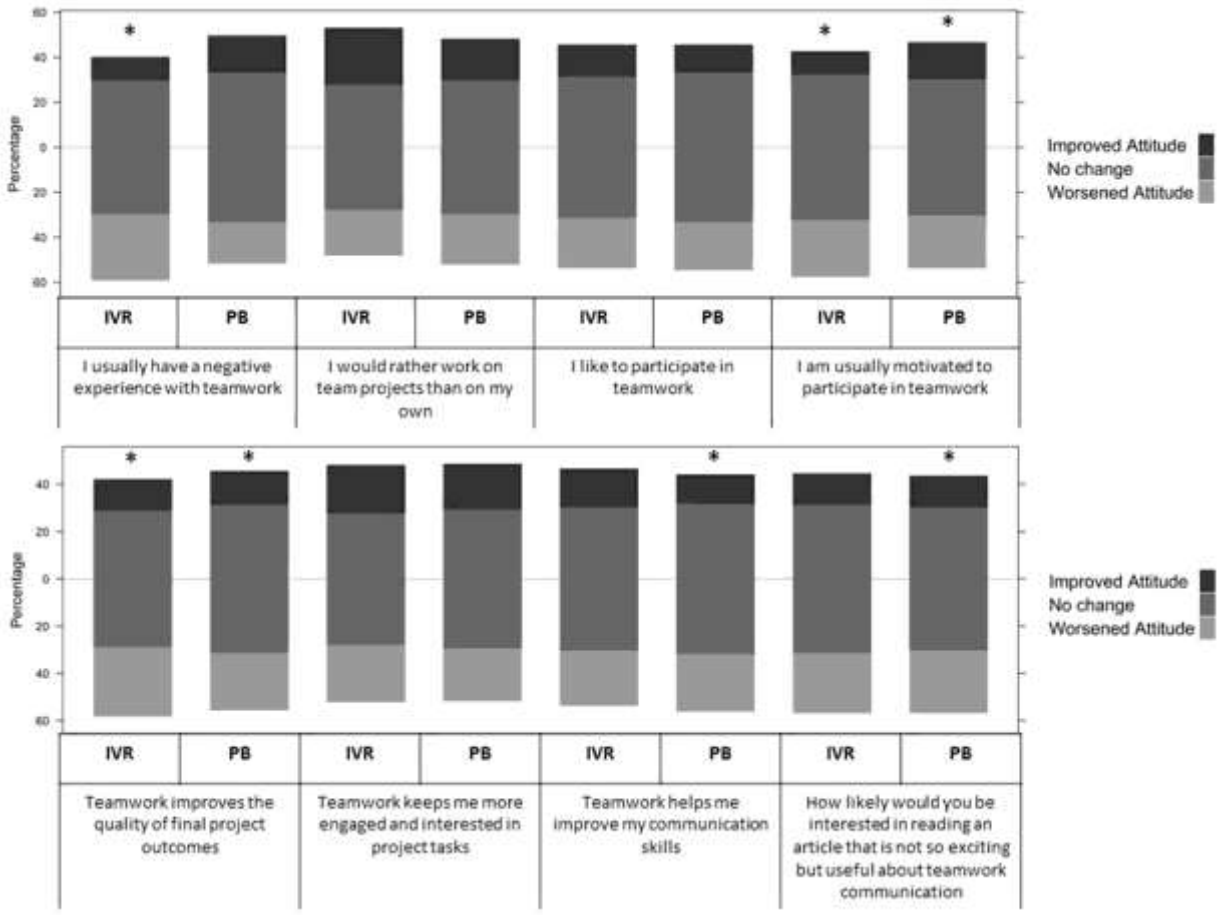

Figure 2: Change in student attitudes towards teamwork after teamwork tutorial intervention with either a paper-based activity (PB) or an immersive virtual reality (IVR) activity. Asterisks denote a statistically significant change between the pre- and post-surveys for each item.

After the intervention, all students were less likely to agree that they were 'motivated to participate in teamwork' (IVR $p=0.005$, $r=0.25$; PB $p=0.021$, $r=0.11$); and that 'teamwork improves the quality of project outcomes' (IVR $p=0.008$, $r=0.24$; PB $p=0.001$, $r=0.16$). The IVR group were more likely to report that they normally had 'negative experiences in teamwork' ($p=0.01$, $r=0.29$) while the PB group were less likely to agree that teamwork improved communication skills ($p<0.0005$, $r=0.19$) or that they would be interested in reading an article on teamwork ($p<0.0005$, $r=0.22$) (Fig. 2).

In the motivation measures, there were no significant differences between pre- and post-questionnaires in either IVR or PB groups on any of the items. Both groups reported largely positive attitudes towards motivation, agreeing that they 'look forward to challenging things' (88.7%) and are 'good at making plans to solve difficult problems' (83.4%) (Table 1).

In the peer observation measures, 20.2% of the IVR group reported frequently observing 'dominating' behaviours, compared to only 11.1% of the PB group ($p=0.013$, $r=0.10$). There was no statistical significance difference between the IVR and PB groups for any other peer behaviours (Fig. 3, below).

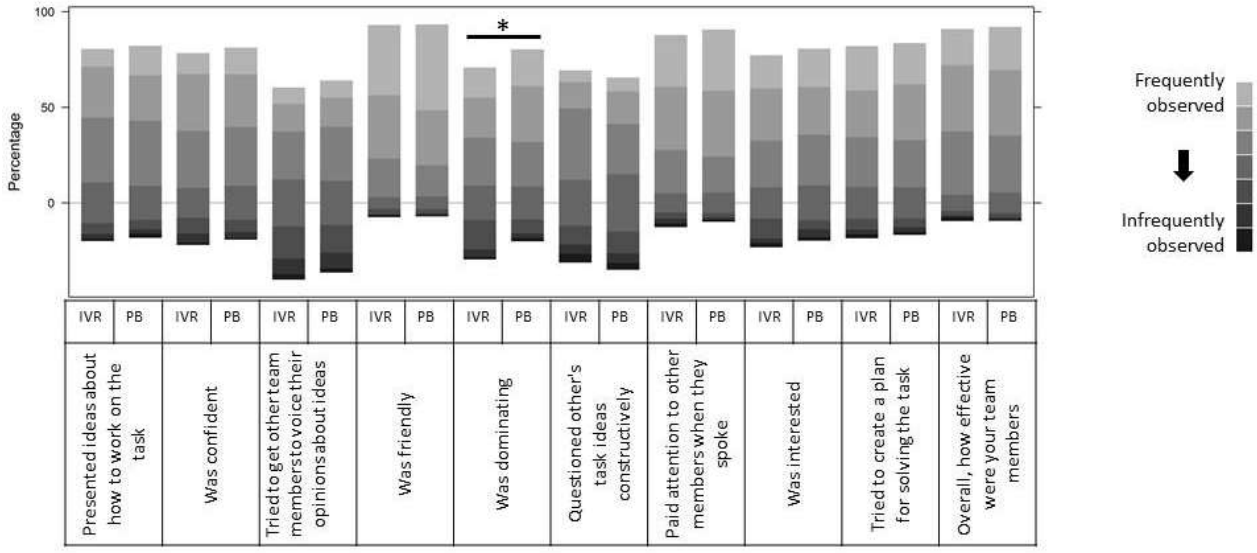

Figure 3: Frequency of student observations of their peer's behaviours. Asterisks denote statistically significant difference between the immersive virtual reality activity (IVR) and paper-based activity (PB).

Both the IVR and PB groups were very positive regarding teamwork behaviours, with 85% agreeing that their teammates were effective overall (Table 2, below). There was also no difference between the two groups in their overall team grades for the event assignment ($p=0.69$).

Table 2: Students' perceptions of how frequently their team mates displayed particular behaviours during the in-class teamwork activity. Likert Scale: '1' to no extent, '7' is to a great extent.

Observed Peer Behaviours	Mean	SD	% Agree and Strongly Agree
Presented ideas about how to work on the task	5.10	1.27	72.1
Was confident	5.10	1.27	71.5
Tried to get other team members to voice their opinions about ideas on the table	4.46	1.44	51.0
Was friendly	6.00	1.13	89.6
Was dominating	2.86	1.40	13.0
Questioned other's task ideas constructively	4.5	1.37	51.6
Paid attention to other members when they spoke	5.72	1.23	84.2
Was interested	5.16	1.40	70.5
Tried to create a plan for solving the task	5.33	1.35	74.6
Overall, how effective were your team members?	5.55	1.11	85.4

There were some small differences in attitudes and peer evaluations by year level. Students in second year and above were slightly more likely to agree that they usually have negative experiences with teamwork (p=0.037, r=0.07), but conversely were more likely to consider taking another unit that taught teamwork skills (p=0.013, r=0.1). First year students were slightly more positive about their peers' behaviours on several measures, including: 'was friendly' (p=0.02, r=0.09); constructive questioning (p=0.001, r=0.13); 'paid attention' (p=0.009, r=0.11); and 'create a plan' (p=0.049, r=0.08).

Tutors implementing IVR observed that students had positive interactions with their teammates and enjoyed the novelty of IVR, although many students experienced dizziness after using IVR for only a short while. One student contributed unsolicited feedback that the IVR 'gave most people a headache'. In the unit review, several students stated the tutorial was 'fun', 'interesting', 'exciting', 'new' and 'enjoyable', although one student described the activity as "just another example of confusing 'entertainment' and 'engagement'".

Discussion

Virtual Reality headsets such as Google Cardboard are frequently marketed as creating immersive experiences that will increase student engagement with learning (e.g. Abrosimova, 2014; Garcia Mathewson, 2016; Hicks, 2016). We compared an IVR activity with an equivalent paper-based activity for engagement as measured by attitudes, motivation, and behaviour. We found that neither intervention had any effect on students' motivation, and only had a small effect on behaviour and attitudes toward working in teams.

On average, students had mildly positive attitudes toward teamwork and were highly motivated in the pre-survey before they received the training. Our average Likert score of 3 was slightly higher than the means of 2.65-2.9 recorded by Vance et al. (2015), who developed the 4-point teamwork attitudes scale. It is also slightly higher than scores from similar teamwork attitudes scales (3.35 on a 5-point scale in Gottschall & García-Bayonas, 2008; 3.02 on a 5-point scale in Grzimek, Marks, & Kinnamon, 2014). Only 22% of students expressed a preference for individual work over group work, which is substantially lower than the 34-63% of students multiple surveys conducted by Gottschall and García-Bayonas (2008). As in other research (e.g., Espey, 2010), students further along in their degree were slightly more likely to report negative experiences with teams and were generally more critical compared to first years; however, they were also more likely to recognise the value of taking more units that taught teamwork skills.

Student attitudes towards teamwork mostly remained unchanged or declined slightly, despite highly positive teamwork behaviours evaluations from peers and tutors. All the changes between the pre- and post-survey had relatively small effect sizes of 0.1 – 0.25 (Cohen, 1988). Our research complements existing studies that demonstrate that attitudes toward teamwork are relatively fixed, even when students are provided with positive teamwork experiences and explicit training (Curran, Sharpe, Flynn, & Button, 2010; Favour & Harvey, 2016). Other studies have suggested that attitudes toward teamwork can be improved with training (e.g. Ekimova, & Kokurin, 2015) or completing more group work projects (e.g. Hillyard, Gillespie, & Littig, 2010; Payne, Guastaferro, & Mummert, 2011), however, it is not clear why some interventions affect attitudes positively and others have no impact or a slightly negative impact.

It is important to note that attitudes towards teamwork (emotional engagement) are not the same as teamwork skills (behavioural engagement). We found no difference in teamwork skills as measured by peer observations and team assessment grades. Chen, Donahue, & Klimoski

(2004) used more direct measures and found that students' knowledge about teamwork and teamwork competencies can improve even when their attitudes toward the activity remain unchanged. Chen et al. (2004) reflected that improving attitudes towards teamwork seemed to be more difficult than increasing knowledge about teamwork. Explicit training in teamwork skills is desired by students (Tucker & Abbasi, 2016) and has been shown to improve teamwork skills (Chen et al., 2004), so should remain part of the curriculum. However, we should recognise that specific procedural actions, such as fair marking and providing class time to work on assessments, are consistently more likely to improve attitudes toward teamwork than training (Burdett & Hastie, 2009; Gottschall & Garcia-Bayonas, 2008; Pfaff & Huddleson, 2003; Tucker & Abbasi, 2016). Adding a debriefing to the activity could point out positive teamwork experiences to students, thus improving attitudes towards teamwork; this may be particularly effective with simulation-based learning (Fanning & Gaba, 2007).

Compared to the paper-based group, more students in the IVR group reported that they frequently observed dominating behaviours from their team members. Dominating behaviour in groups is perceived as a problem by students and staff (e.g. Ehrlenspiel, Giapoulis, & Gunther, 1997) and certainly aggressive students decrease group cohesion (e.g. Bowler, Woehr, Rentsch, & Bowler, 2010). If wearing the IVR headset was considered desirable, it could have led to competition for the role, and therefore prompted an increase in dominating behaviour. Alternatively, as a student in Parratt, Fahy, and Hastie (2014) stated, it is difficult not to dominate the discussion where there is no clear direction or active participation from the whole group. It is possible that the roles in the IVR activity were not immediately apparent, and groups ended up with members providing or accepting strong leadership in order to achieve the task.

IVR headsets have recently become more affordable, more available, and more practical, making them more attractive for educational purposes. Nevertheless, IVR has certain limitations that educators should keep in mind, including health concerns, cost, and time and effort. The IVR activity was significantly more expensive than the equivalent paper-based activity. Although not everyone needs to develop their own virtual environment, it took approximately three months and a grant of $9900 to develop the app used for this study. In addition, the implementation was not seamless: it took longer to train tutors to run the IVR activity than the more familiar paper-based activity, and tutors had to troubleshoot many small technical problems with apps and phones to successfully run the IVR tutorial. Finally, many users in this study reported nausea and dizziness or disorientation whilst using the IVR headsets, which confirms observations from previous research (Ausburn & Ausburn, 2004; Mantovani et al., 2003; Norton et al., 2008), and may affect IVR's ability to increase motivation and engagement.

In this study, the IVR group was similar on all our measures – motivation, attitudes, and peer behaviour – to the paper-based group. This suggests that lecturers who do wish to use IVR can do so without risking worse outcomes. Students were able to effectively work as a group to use the technology, and tutors were able to replicate the activity across a large number of tutorials (8 tutorials involving 167 students). As the technology continues to improve, we anticipate that costs will decrease and nausea will be reduced. Although perhaps not useful for teaching teamwork, IVR has shown more promising results when used to teach specific concepts that require complex spatial understanding or detailed visual-based knowledge, such as chemical bonding (Limniou, Roberts, & Papadopoulos, 2008), safety procedures in the mining industry (Tichon & Burgess-Limerick, 2011), and kinaesthetic training (Yang & Kim, 2002).

Because attitudes towards teamwork are a determinant of future success in teamwork (e.g., Kouros et al. 2006), it is important that educators take steps to improve students' experiences of teamwork. However, our research suggests that IVR is not an antidote for poor engagement, as there was no improvement in student's motivation, attitudes or behaviour. As shown by other studies (e.g., Favour & Harvey, 2016), attitudes and motivation were relatively fixed and adding IVR did not change them. IVR is often claimed to improve engagement, but as researchers we need to be more explicit about what we mean by engagement, how we intend to measure the effectiveness of IVR, and how IVR compares to existing teaching methods.

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