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Teaching Multimodal Literacies with Digital Technologies and Augmented Reality: A Cluster Analysis of Australian Teachers' TPACK

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Abstract: Despite the proliferation of augmented reality (AR) apps, Australian primary teachers have yet to use them widely for the teaching of multimodal literacies. Conceptualising teachers' knowledge of using digital technologies to teach multimodal literacies as a form of technological pedagogical content knowledge or TPACK(ML), this study examined teacher differences through a cluster analysis of survey responses collected from a sample of 142 Australian primary school teachers. Two distinct clusters of teachers were derived. The first cluster with lower TPACK(ML) comprised teachers with lower self-reported confidence in facilitating new cultures of learning that are participatory and technology-driven in nature. In their open-ended survey responses, these teachers shared their unfamiliarity with AR, as well as concerns about their personal technical competency and how AR could be integrated into the curriculum. The second cluster of teachers rated themselves higher in TPACK(ML) and in how they used technology to support language learning pedagogies. They were able to propose different pedagogical strategies to engage students' multimodal literacies meaningfully with AR in their open-ended survey responses. The implications of the study's findings were discussed, and recommendations were proposed for designing and sustaining differentiated forms of teacher professional development for teaching multimodal literacies with emergent digital technologies.

Keywords: multimodal literacies; digital technologies; augmented reality (AR); technological pedagogical content knowledge (TPACK); cluster analysis

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1. Introduction

Sustainability and sustainable development are often treated as synonymous notions [1]. The former encompasses beyond environmental matters and includes related concerns associated with social and socio-economic issues that are increasingly driven by technological changes. With the rising importance of digital technologies in knowledge creation and building, digital transformation of education becomes a key aspect of sustainable development and makes lifelong learning an inevitable goal for all [2].

Equitable and quality education (Goal 4) is one of the targets outlined in the United Nations' 17 Sustainable Development Goals [3]. One goal target of Sustainable Development Goal-4 is that all young people should have achieved relevant technical skills for future employment. Such achievement could only be articulated by equal access to quality education in and through technology [4]. Therefore, access to and adoption of technology in education is integral to achieving and sustaining quality education.

It is often assumed that teachers will somehow naturally transition to using digital technologies, including more emergent technologies. The emergence of new media has

proliferated new kinds of digital texts that draw on multiple semiotic resources to convey meaning, resulting in an emergent need for teachers to develop multimodal literacies, i.e., "communication practices that use two or more modes of meaning" [5] (p. 1) such as the linguistic, audio, visual, spatial, and gestural modes. These kinds of learning resources can potentially enable more inclusive ways of learning, as students can use different modalities to understand and express their knowledge [6]. In addition, emerging technologies, including augmented reality technologies, are resources for sustaining supports to motivate student learning through interactive activities [7].

In the digital age, the teaching of multimodal literacies is gaining importance, and this requires teachers to be strong in integrating their technological knowledge with their pedagogical and content knowledge. This integrated form of knowledge, which is defined as technological pedagogical content knowledge (TPACK) [8], is often assumed by teachers, but has not been fully addressed in language and literacy professional development [9–11]. There remains a dearth of studies on teachers' TPACK for teaching multimodal literacies [henceforth, TPACK (ML)] [11,12].

In the context of Australia, despite the strong emphasis placed on multimodal literacies in the Australian Curriculum for English [13,14], teachers' profiles pertaining to their TPACK (ML) have not been reported. This knowledge gap is the missing link that presents a challenge in offering context-appropriate professional development. This study, therefore, sought to describe the underlying profiles of Australian language and literacy teachers' TPACK (ML) through a cluster analysis. It was drawn from a larger research project that aimed to investigate Australian language and literacy teachers' knowledge and concerns in teaching multimodal literacies using digital technologies in general, and specifically, augmented reality (AR). Drawing on a validated TPACK survey developed by Tan et al. [11], the results presented in this study were driven by the following research questions:

(i) Are there different clusters of Australian primary school teachers in terms of their TPACK for using digital technologies to teach multimodal literacies?
(ii) If yes, what factors predict teachers' TPACK for using digital technologies to teach multimodal literacies?
(iii) How do different clusters of Australian primary school teachers perceive their TPACK development associated with infusing augmented reality to teach multimodal literacies?

These baseline data are necessary for any interventions to be prescriptive in Australia's primary school contexts, as Chen, Li and Xu [15] have suggested that tracing teachers' TPACK development requires an understanding of the knowledge and its situatedness. The study ends with a discussion of the implications for developing Australian primary school teachers' TPACK (ML), which is increasingly being mediated by emergent technologies, specifically AR.

2. Literature Review

2.1. Teaching Multimodal Literacies in the Digital Age

Literacy is more than merely having basic skills in reading and writing; there are economic and moral dimensions and consequences of literacy [16]. Literacy, from a sociocultural perspective, also needs to consider and adapt to changes in communicative purposes, technological changes, and community knowledge [17,18]. Taking into consideration technological changes and the prevalence of personal digital devices, literacy in the 21st century is becoming unavoidably digital and multimodal. Schools and teachers, therefore, play a vital role in shaping our students' social futures that are mediated by digital technologies [19,20].

Literacy with digital competence has been conceptualised within the framework of multimodal literacies [21], and was coined as a pedagogy of multiliteracies by the New London Group [22]. Since then, everyday reading and writing have changed with the ubiquitous presence of visual culture and multimodal texts [23]. The need to incorporate multimodal literacies into formal learning is clear as texts viewed, read, and written in and beyond the school setting have changed significantly since the 2000s.

Emergent digital technologies such as augmented reality produce textual forms that offer new learning opportunities that have not been adequately explored in multimodal literacies [19,24–26]. Due to technological advancement, meaning-making using emergent digital technologies is becoming more immersive with the high multisensory and multimodal engagement of three-dimensional manipulations of learning tasks in mixed realities [19,26]. Specifically with AR, students are presented with three-dimensional multimodal texts that offer real-time interactions with virtual objects and characters when the virtual and the real worlds blend. Students need to move around to explore the space where the virtual and the real worlds are combined. When using AR, students look around with their mobile devices, listening and touching virtual content. These multisensory and multimodal engagements heighten the role of the body and the affordances of integrating a rich repertoire of meaning-making resources [27]. A rethink of how multimodal literacies should be developed to prepare students to be digitally and critically literate is necessary. Nevertheless, such corporeal ways of developing multimodal literacies are gaps that require attention in the current body of literature, particularly in primary education.

2.2. TPACK for Teaching Multimodal Literacies [TPACK (ML)]

The integration of new technology "often raises fundamental questions about content and pedagogy", and requires teachers to "reconfigure not just their understanding of technology but of all three components", i.e., technology, pedagogy, and content [8] (p. 30) and their inter-relationships with these three domains of knowledge. Unless teachers are competent in manoeuvring these different aspects of TPACK, innovative practices that involve emergent technologies, such as augmented reality, remain lacking in classroom practices.

Mishler and Koehler [8] developed a TPACK model as an epistemic framework to describe teachers' knowledge of technology integration across disciplines. TPACK is not only constituted from its three basic knowledge sources, i.e., technological knowledge, pedagogical knowledge, and content knowledge, it is also influenced by how teachers interconnect these into the intermediary knowledge forms of technological content knowledge (TCK), technological pedagogical knowledge (TPK), and pedagogical content knowledge (PCK) [8]. In other words, TPACK is a knowledge form that is externalised in terms of how teachers use technology for their actual teaching practices. It has been widely acknowledged that the understanding of TPACK, the depth of TPACK competence, and teachers' beliefs about technology and pedagogy are determining factors of teachers' integration of technology into their teaching practices [28–31].

Teacher technology integration does not happen in a vacuum, and the first possible starting point is understanding teachers' knowledge [32]. In a recent review of TPACK research in language teaching, it has been reported that little is known about developing language teachers' TPACK competence for the past decade, particularly in Australia [10,11,30,33]. Within the limited but increasing body of TPACK research in language teaching, the review highlighted that "language teachers' TPACK was associated with using technology to drill students, motivate them, and display content in teacher-centred instructions" [30] (p. 9). It has also been shown that language teachers' professional experience may not correlate to their TPACK knowledge; yet, understanding that correlation is vital for designing sustainable professional development [34,35]. In diverse contexts of teaching English, these reported studies paid attention to the teaching of English as a foreign language, in which the traditional four language skills remained the key priorities [11,36]. However, teachers may also have developed and demonstrated their understanding and knowledge of the dimensions of multimodality differently, with a greater focus on viewing than composing multimodally [9]. What has been ignored is the development of teachers' TPACK in language and literacy teaching that goes beyond print literacy [10,11]. The review studies generally agree that we have a very limited understanding of teachers' TPACK prior to integrating technology into the classroom.

In the context of Australia, the lack of understanding and development of teachers' TPACK can be a barrier to effective implementation of the Australian Curriculum for

English [13,14] which places multimodal literacies at the core of its content. Without a baseline knowledge of Australian language and literacy teacher clusters, any pedagogical interventions may be implemented with an assumed knowledge of teachers' competence. Knowledge of Australian language and literacy teacher clusters remains unknown, but such knowledge is essential in order to provide customised and appropriate professional development that caters to the needs of each teacher cluster. This study geared itself toward filling this gap by first profiling Australian primary school teachers' TPACK in the context of teaching multimodal literacies using more familiar digital technologies. The validated survey makes a distinction from other TPACK instruments by measuring the following aspects of teaching multimodal literacies [11]:

(i) The content knowledge (CK) alludes to meta-semiotic awareness, i.e., the awareness of the knowledge of meanings realised by a range of semiotic modes for meaning-making.
(ii) The pedagogical content knowledge (PCK) emphasises the key practices of deconstructing and composing multimodal texts in multimodal literacy practices.
(iii) The technological pedagogical content knowledge (TPACK) focuses on facilitating students' multimodal meaning-making in both the deconstruction and construction of multimodal texts using technology.

Based on these key factors, it can be argued that TPACK for teaching multimodal literacies, i.e., TPACK (ML), refers to the knowledge teachers require for facilitating students' deconstruction and construction of multimodal texts using digital technologies to enhance students' meta-semiotic awareness; this awareness is vital for a more participatory culture of learning in which students are positioned as critical text analysts and producers of meaning-making choices represented in multimodal texts, including digital texts. TPACK (ML) warrants further research in emergent digital textual practices that put pressure on teachers to constantly develop new competencies and literacy pedagogies.

Using the quantitative findings as a starting point, this study was also interested in investigating what concerns Australian primary school language and literacy teachers had, and what TPACK (ML) would be needed to broaden the use of AR in primary language and literacy education. The survey findings, including the open-ended responses, provided the baseline data on teachers' knowledge and concerns in teaching multimodal literacies using digital technologies in general, and AR more specifically. The insights gained from the survey were then utilised to develop contextual and pragmatic classroom interventions in the larger research project that aimed to enhance multimodal literacy teaching using AR.

3. Methodology

3.1. Sample and Data Collection

This research was funded by one of the largest professional teaching associations for primary educators in Australia. The online survey was disseminated in 2020 via the association to its members and subscribers via their communication platforms, such as the association's website, eNews, Facebook, and Twitter. The association's members and subscribers could forward the invitation to participate in the survey to their personal and professional networks of Australian primary school language and literacy teachers. After cleaning the survey data, the final number of participants for this study was 142 Australian primary school language and literacy teachers.

3.2. Instrumentation

The survey instrument drew upon items assessing TPACK for multimodal literacies that were validated with 220 pre-service teachers across three institutions in Indonesia, China, and Australia from the first author's previous research [11,28]. This survey instrument was based on the teaching and learning cycle [37] to teach multimodal literacies. There were 45 questions that cut across eight domains. The first seven domains were based on Mishler and Koehler's [8] TPACK framework, and are defined as follows [10]:

(i) P1: Pedagogical content knowledge (PCK): knowledge of adopting appropriate approaches to teach multimodal literacies, e.g., Without using technology, I can facilitate students' deconstruction of the multimodal meanings of the mentor (exemplary) text.
(ii) P2: Technological pedagogical knowledge (TPK): knowledge of how technology mediates learning, e.g., I am able to guide my students in constructing representations of knowledge using technology.
(iii) P3: Technological knowledge (TK): knowledge of the technological tools available for learning and teaching and ways of using it, e.g., I am able to use web-based collaboration tools.
(iv) P4: Technological content knowledge (TCK): knowledge of using technology to represent ideas or a theme, e.g., I can use appropriate technology (e.g., multimedia resources, online writing and representing tools) for language and literacy learning.
(v) P5: Technological pedagogical content knowledge (TPACK): integrated knowledge of using technology to represent, teach, and facilitate meta-semiotic awareness, e.g., Using technology, I can sequence the teaching and learning phases to facilitate students' multimodal meaning-making.
(vi) P6: Content knowledge (CK): knowledge related to how semiotic modes such as linguistic mode, visual mode, spatial mode, gestural mode, and aural mode make meanings in texts.
(vii) P7: Pedagogical knowledge (PK): methods of facilitating learning and teaching, e.g., I am able to guide my students in discussing effectively during group work.

An eighth domain, P8—Beliefs about New Culture of Learning [BNCL]—was assessed with five items from Chai et al.'s [28] survey of TPACK in facilitating the 21st century new culture of learning that was validated with 223 pre-service teachers in Singapore. BNCL refers to a more participatory culture of learning that is learner-generated [28,38]. All of the items in the survey were scored on a 7-point Likert-type scale, with a score of 1 for strongly disagree to 7 for strongly agree.

Although this study used the validated instrument from the first author's previous research, the sample used for this was different. The previous research focused on pre-service teachers across three countries, whereas this study solely focused on Australian primary school teachers with teaching experience. Furthermore, the open-ended questions used in this study focused on teaching multimodal literacies with emergent digital technologies, specifically AR. This focus was not covered in the first author's previous validation study. The open-ended questions were optional in capturing how teachers envisioned using technology to teach multimodal literacies and the tools they used:

(i) Augmented reality (AR) combines virtual objects and the real world. It is interactive in real time in 3D forms, such as Pokémon GO and IKEA Place app. What do you think about using AR to teach language and literacy in the primary school contexts?
(ii) If you have tried using AR for language and literacy teaching, describe what AR apps you have used and how you have used these apps.

Since TPACK constitutes teachers' technology integration strategies [8], these qualitative descriptions outline their considerations for using technology to teach multimodal literacies. This data were intended not only for triangulating the quantitative results, but also for providing deeper insights into the different facets of teachers' TPACK.

Cronbach's α and the average variance were extracted (AVE), and the reliability of the survey items for each domain was analysed based on $\alpha < 0.8$ or $AVE < 0.5$ (See Table 1). One TCK item pertaining to specialised software was removed from subsequent analysis to improve its reliability. There were no questions on TK that could be removed to increase the reliability of this domain, thus all of the questions were retained for subsequent analyses.

Table 1. Reliability statistics.

	Cronbach's α	Average Variance Extracted
PCK	0.87	0.61
TPK	0.86	0.52
TK	0.74	0.43
TCK	0.81	0.58
TPACK	0.94	0.73
CK	0.88	0.59
PK	0.89	0.59
BNCL	0.92	0.65

3.3. Data Analysis Methods

To answer research question 1, the statistics software, R Version 4.2.1, was used to perform a cluster analysis for developing a profile of Australian primary school language and literacy teachers. Using all of the scores for PCK, TPK, TK, TCK, TPACK, CK, PK, and BNCL to categorise the groups, the following clustering methods were implemented: k-means, hierarchical and Partitioning Around Medoids (PAM) [39]. The k-means method with 2 clusters showed the optimal measures of connectivity (measured by the Dunn measure) and compactness and separation (measured by the Dunn Index and Silhouette Width) (see Appendix A). The clusters were compared according to their age, years of experience, number of casuals, and the eight domain scores, using the mean, standard deviation, and a 95% confidence interval of the means.

To answer research question 2, a correlation coefficient matrix was generated for the eight domains, and Pearson's correlation coefficient was used to assess the strength of the correlations. Following this, four multiple regression models were generated to find the best predictors of the domain scores and TPACK separately for the two clusters. For each predictor, the beta-coefficient (B), the standard error of B, the standardised beta-coefficient (β), the p-value and the relative importance (%) were reported. The relative importance of each predictor was calculated using R^2 partitioned by averaging over orders [40]. To answer research question 3, a content analysis was adopted, and the definitions for the eight domains in the survey instrument were used as apriori categories to code the open-ended survey responses to the first question. Each response from a respondent was used as the unit of analysis. The first author and another coder coded the open-ended responses. Cohen's kappa was computed to measure the inter-rater reliability. After two rounds of coding, Cohen's kappa was improved from 0.71 to 0.90. An additional category termed 'General' was created to account for concerns such as time, resource allocation, professional development needs, and classroom management, which were raised by the teachers.

Some areas of coding discrepancies arose from differentiating TCK and TPK, as well as in differentiating TPACK and TPK. These discrepancies were resolved through mutual negotiation. This process also clarified evidence of BNCL when teachers expressed beliefs that emphasised aspects of learning that were more participatory and involved students mobilising digital resources for creative works. Once there was full agreement in the coding, a frequency count of these knowledge domains was calculated. The attributes of each knowledge domain in each cluster were further interpreted to identify similarities and differences in the teachers' perceived TPACK in each cluster. Although all of the open-ended responses were coded using the TPACK domains, investigating how the commonalities might paradoxically consist of differences in each cluster [41] thickened the profiles of the teachers in each cluster.

4. Results

4.1. Cluster Analysis of Australian Primary School Teachers' Perceived TPACK(ML)

A *k-means* cluster analysis derived two clusters with 63 teachers in cluster 1 and 79 teachers in cluster 2 (See Table 2). The means of all the domains were significantly higher in cluster 2 relative to cluster 1, whilst age, teaching experience, and the number of

casuals were not significantly different between the clusters. This suggested that the cluster 2 teachers were more confident in their TPACK (ML) for teaching multimodal literacies with technology, regardless of age or teaching experience.

Table 2. Comparisons between clusters.

	Cluster 1	**Cluster 2**	**Test for Difference, Cluster 2 vs. Cluster 1**
Cluster Size	*N* = 63 (44%)	*N* = 79 (56%)	
Casual/permanent teacher	Casual *N* = 3 (5%) Non-casual *N* = 60 (95%)	Casual *N* = 3 (4%) Non-casual *N* = 76 (96%)	Fisher's Exact Test Odds Ratio Casual = 1.26 *p*-value = 1.0
Age (years)	*M* = 47.19 (44.22–50.16) *SD* = 11.81	*M* = 44.48 (41.91–47.06) *SD* = 11.5	*t*-value = −1.38 *p* = 0.17
Experience (years)	*M* = 17.26 (14.12–20.39) *SD* = 12.23	*M* = 17.46 (14.86–20.05) *SD* = 11.58	*t*-value = 0.1 *p* = 0.92
PCK	*M* = 4.88 (4.61–5.16) *SD* = 1.09	*M* = 5.65 (5.39–5.9) *SD* = 1.15	*t*-value = 4.03 *p* < 0.001
TPK	*M* = 5.42 (5.24–5.59) *SD* = 0.69	*M* = 6.32 (6.2–6.44) *SD* = 0.54	*t*-value = 8.74 *p* < 0.001
TK	*M* = 5.11 (4.84–5.39) *SD* = 1.09	*M* = 6.32 (6.18–6.46) *SD* = 0.63	*t*-value = 8.29 *p* < 0.001
TCK	*M* = 4.6 (4.34–4.87) *SD* = 1.05	*M* = 5.95 (5.79–6.11) *SD* = 0.71	*t*-value = 9.09 *p* < 0.001
TPACK	*M* = 5.13 (4.87–5.39) *SD* = 1.04	*M* = 6.3 (6.16–6.44) *SD* = 0.62	*t*-value = 8.36 *p* < 0.001
CK	*M* = 5.27 (5.03–5.51) *SD* = 0.97	*M* = 6.28 (6.16–6.41) *SD* = 0.56	*t*-value = 7.78 *p* < 0.001
PK	*M* = 5.71 (5.57–5.86) *SD* = 0.57	*M* = 6.47 (6.37–6.57) *SD* = 0.45	*t*-value = 8.91 *p* < 0.001
BNCL	*M* = 5.42 (5.2–5.64) *SD* = 0.87	*M* = 6.3 (6.16–6.44) *SD* = 0.64	*t*-value = 6.88 *p* < 0.001

4.2. Predictors of Teachers' TPACK (ML)

Table 3 shows the Pearson's correlation coefficients among the domains. TPACK had a strong or moderate correlation with all factors except for PCK. Therefore, multiple regressions were carried out with the TPACK (ML) as the dependent variable, and the other six domain scores as independent variables for each cluster.

Table 3. Pearson's correlations between 8 domains.

	PCK	**TPK**	**TK**	**TCK**	**TPACK**	**CK**	**PK**	**BNCL**
PCK	1							
TPK	0.21 *	1						
TK	0.26 **	0.26 **	1					
TCK	0.21 *	0.46 **	0.35 **	1				
TPACK (ML)	0.16	0.63 **	0.30 **	0.40 **	1			
CK	0.31 **	0.37 **	0.24 **	0.55 **	0.43 **	1		
PK	0.38 **	0.49 **	0.34 **	0.53 **	0.37 **	0.68 **	1	
BNCL	0.05	0.53 **	0.22 **	0.35 **	0.50 **	0.25 **	0.26 **	1

** $p < 0.01$, * $p < 0.05$.

In Table 4, the regression analysis shows that the most important predictor of high TPACK for the more confident teachers in cluster 2 was TPK, explaining 31% of the vari-

ation in TPACK. For the teachers in cluster 1, TPK, BNCL, CK, and the casual status of employment significantly predicted TPACK (ML). On the other hand, TPACK (ML) for cluster 2 teachers was significantly predicted only by TPK.

Table 4. Linear regression analysis for predictors of TPACK.

	B	Std. Error of *B*	*p*-Value	Beta	Relative Importance (%)
Cluster 1					
Intercept	1.55	1.98	0.44		
TPK	0.46	0.19	0.02 *	0.31	9.7
BNCL	0.32	0.15	0.04 *	0.27	8.6
Casual (Y/N)	−1.39	0.56	0.02 *	−0.29	6.6
CK	0.45	0.17	0.01 *	0.42	5.6
PK	−0.49	0.28	0.09	−0.27	2
PCK	0.08	0.12	0.51	0.08	0.9
Age (years)	−0.07	0.06	0.21	−0.16	0.8
TK	0.01	0.12	0.96	0.01	0.4
TCK	−0.03	0.12	0.78	−0.03	0.1
Cluster 2					
Intercept	1.86	1.13	0.1		
TPK	0.74	0.13	<0.01 **	0.64	30.6
BNCL	0.02	0.1	0.88	0.02	1.9
PCK	−0.02	0.06	0.74	−0.04	1.9
Casual (Y/N)	−0.24	0.3	0.43	−0.08	1.8
CK	0.21	0.12	0.09	0.19	1.8
TCK	−0.09	0.09	0.35	−0.1	1.5
PK	−0.13	0.15	0.38	−0.1	0.9
Age (years)	−0.02	0.03	0.41	−0.08	0.3
TK	0	0.09	0.97	0	0.3

* $p < 0.05$, ** $p < 0.01$.

4.3. TPACK Development Associated with Infusing AR

The qualitative analysis of the open-ended responses provided further insights about the TPACK (ML) of both clusters of teachers. When asked about their thoughts on using AR to teach language and literacy in primary school contexts, teachers in cluster 1 were concerned about students' readiness (associated with BNCL), and teachers' lack of content knowledge (associated with CK). They questioned the relevance of using AR for teaching language and literacy (associated with TPK). Teachers in cluster 2 were not concerned with CK. Their concerns about BNCL and TPK were different.

For BNCL, the cluster 2 teachers were interested in resonating with students' digital cultures and keen on finding out what AR could offer for learning to bridge students' digital practices with formal learning. Instead of questioning the relevance of using AR for teaching language and literacy, they could envision themselves using AR to promote learning that would be engaging, meaningful, interactive, experiential, and independent. Specifically, there were comments about the role of the whole body in learning when using AR, and developing creative and critical thinkers with its use.

Both clusters of teachers identified the potential of using AR to develop oracy or oral language (TCK), but the teachers in cluster 2 were specific in expressing their interests in the development of oracy in more authentic and meaningful ways using AR. Being unfamiliar with AR was a common thread in the responses from both clusters of teachers (associated with TK). Whilst teachers in cluster 1 were more concerned about their competence in using AR, teachers in cluster 2 were interested in finding out more about the benefits of AR. There was no doubt that the effective use of AR to teach language and literacy was unsurprisingly a common concern expressed by both clusters of teachers (associated with TPACK); teachers in cluster 2 were more specific when they thought about integrating AR

into language and literacy teaching. They highlighted scaffolding and skills development, particularly for storytelling and creating narratives.

Equity, access, and professional development needs were the common priorities when both clusters of teachers expressed their general concerns pertaining to using AR for language and literacy. Whilst the teachers in cluster 1 were concerned about the problem of not providing students from a lower socio-economic status adequate exposure to AR in learning, the teachers in cluster 2 were more interested in the promises of AR for students who might be isolated or disadvantaged. The teachers in cluster 1 were worried about adding to the already 'crowded' curriculum, but the teachers in cluster 2 were thinking about the time investment, particularly for creating AR experiences for student learning and achieving buy-in from parents and colleagues. Whilst there were teachers in cluster 1 who dismissed the potential of using AR in the primary school contexts without experimenting with it themselves, teachers in cluster 2 were mindful of age-appropriate use, and one teacher was very specific when she commented that AR might be more suitable for Stage 3 students (aged 11 and 12 years of age).

One teacher from cluster 1 indicated that she had tried using AR apps, Metaverse and Figment. Six teachers from cluster 2 listed the following AR apps: AR Makr, Colour Mix, Quiver, Air Paint AR, Swap Bots, Google Lens with IKEA Place and Augment, and Merge Cube. Below are the descriptions of the use of AR apps from those who provided further details:

(i) "Colour Mix—where students colour in an image and then view through the app, and it comes alive—we created narratives around that. Students in Year 9 creating AR fairy tales for younger students."
(ii) "I have used Quiver to experiment with creating learning experiences with special needs students."
(iii) "Ikea Place and Augment (I think this is the name of a very early app for AR) for building descriptive sentence structure and language, including focus on grammar points, and persuasive language."

Although only 7 out of 142 respondents had personally experimented with AR, it was clear that teachers had already expanded their repertoire of resources by experimenting with AR. It was also apparent that teachers who had spearheaded the use of AR in primary school contexts in Australia were from cluster 2, which was the more confident group.

5. Discussion and Implications

Based on Australian primary school language and literacy teachers' self-reported TPACK (ML), this study showed that there were two distinct clusters of teachers with different confidence levels in integrating technology into their teaching of multimodal literacies. In order to have sustainable technology-enhanced pedagogies in language and literacy classrooms, it is essential to understand these two clusters of teachers. Similarly to Tan et al.'s [11] and Chai et al.'s [28] studies, the positive correlation found between TPACK (ML) and teachers' confidence in technology integration remained evident in this study. The statistical analyses pointed out that the clusters did not differ in their demographic backgrounds, e.g., age, gender, and years of experience. This was distinctive from the study byHuang et al. [34] that showed that age was a factor in TPACK and consequent interest in sustaining professional development in technology-infused pedagogies. Rather, they were distinct in their perceived confidence in the various TPACK (ML) constructs. Similarly to Chandler's [12] study that aimed to measure Australian primary school teachers' preparedness to teach multimodal authoring, this study did not find any evidence that younger teachers (measured by both age and years of experience) were more confident in using technology to teach multimodal literacies.

Within Australia, these findings are useful for scoping language and literacy teachers' TPACK (ML). They serve as baseline knowledge in designing future pedagogical interventions for enhancing the teaching of multimodal literacies in the context of primary education. Beyond Australia, these findings have added to a growing body of research that

tends to place technical knowledge, pedagogical knowledge, or content knowledge at the heart of professional development without considering their complex inter-relationships when investigating how digital technologies, including emergent technologies such as AR, can impact a teacher's TPACK (ML).

The teachers in cluster 1 were less confident of their TPACK perceptions. They were not distinctly characterised by casual employment. For them to be confident in integrating technology to develop multimodal literacies, they had to feel confident about their TPK, BNCL, and CK. This cluster of teachers might have been more confident in engaging students in language-dominant literacy practice. They were less confident in closing the chasm between a teaching practice that placed more emphasis on the written language as the central mode of representation and one that demanded them to develop metalanguage to negotiate the meaning potentials of a range of semiotic modalities beyond the written language [12,42]. This cluster of teachers might have felt less confident in developing new literacies. Such literacies not only embrace new technologies but a new ethos of language and literacy learning [12,42,43].

When asked about infusing AR to teach language and literacy, students' readiness was their key concern, in addition to their own confidence level. New literacies require teachers to be confident in promoting a new culture of learning where learning is more participatory by leveraging the affordances of technologies to mobilise and remix digital resources for creative works [38]. Hence, for this cluster of teachers to enhance their perceived TPACK (ML), they needed more professional development to increase their own knowledge in integrating technology and meta-semiotic awareness concomitantly. This increased knowledge would be vital for them to facilitate more participatory learning that could develop students' multimodal literacies through the critical interpretation and creative composition of complex multimodal texts for various purposes. This finding coheres with substantial research indicating that for multimodal literacies to be effectively developed in school practices, a culture of developing an explicit use of metalanguage to negotiate more complex and multimodal texts is needed [12,44,45].

The teachers in cluster 2 were more confident of their perceived TPACK (ML). Their perceived TPACK (ML) was predominantly driven by their perceived TPK. Unlike the teachers in cluster 1, their open-ended responses also suggested that they were more targeted and forward-looking when asked to consider AR for their teaching. Specifically, the epicentre of their attention was not on students' readiness, but the potential AR might bring to students' learning; they envisioned students using AR in an experiential way that could bring insights to the role of the body in students' learning. The potential of engaging students in more interactive and meaningful uses of AR so that they would be creative, critical, and independent was the vision of learning held by the teachers in cluster 2. This envisioning could be due to the teachers' prior experience in integrating technology for language and literacy learning and teaching, and they were confident in transferring this knowledge to AR-mediated learning environments. This cluster of teachers seemed to need less professional learning in integrating technology to develop multimodal literacies, bearing in mind that content knowledge (specifically meta-semiotic awareness) was not a knowledge domain that they identified as a concern when they considered using AR for their teaching.

From Table 3, it was clear that both clusters of teachers acknowledged their lack of knowledge about AR. Although teachers are expected to support students in learning, both with and through new digital forms, there has been a slow uptake of new media, such as AR, into Australian contexts. This lack of teachers' knowledge about AR and its educational affordances remains an impeding factor to effective explorations of AR in education [46]. Both clusters of teachers also reported concerns related to access. Access to technology has been the first-order barrier to technology integration, followed by teachers' beliefs, and then teachers' design capacities [47]. When teachers participate in designing pedagogical interventions, their design practice and dispositions are likely to change, which tends to result in active contribution to innovative technology integration [48].

TPK played a key role in contributing to the TPACK of both clusters of teachers. The teachers in cluster 2 were more specific about improving their knowledge in developing strategies, skills, scaffolds, and using technology, including AR, to support processes of learning language and literacy, such as in planning, drafting, and composing narratives. Collectively, both the quantitative and qualitative analyses suggested that both clusters of teachers would benefit from professional learning opportunities that could provide them with AR apps that they could experiment with, and pedagogical strategies such as a framework that could guide them in integrating AR to develop multimodal literacies.

Seven teachers amongst the survey respondents had already started experimenting with AR, although its use is still at an infancy stage in Australian contexts within primary language and literacy education. Drawing on Niess's [49] five stages of mathematics teachers' TPACK, this study suggested that the teachers in cluster 1 were at the recognising and accepting (albeit conditional acceptance) stages: they acknowledged the use of AR in everyday practices and the emergent use of AR in education in Australian contexts. There were teachers who could accept the use of AR to develop multimodal literacies in primary school contexts if and only if key issues related to access, equity, effective uses, and professional development are put in place.

On the other hand, the teachers in cluster 2 seemed to include teachers at the accepting and adapting stages. Teachers in this cluster showed positive attitudes towards the use of AR for developing multimodal literacies (accepting stage). From the open-ended responses, three teachers indicated that they had already engaged their students in using AR (adapting stage). The different TPACK stages perceived by the teachers in this study supported the argument that it should not be "assumed that teachers [would] somehow naturally transition to using [new technologies]" [50] (p. 7) such as AR. Future professional development needs to consider the teachers' perceived TPACK stages.

Additionally, for the teachers in cluster 1, professional development needs to be differentiated and targeted at rudimentary aspects of integrating technology, namely the following: (i) understanding a new culture of learning and new literacies; (ii) pedagogical strategies for incorporating technologies, including AR, for meaningful learning; and finally (iii), a strong building of meta-semiotic awareness of the meaning potentials of a range of semiotic modalities often encountered in complex digital texts. On the other hand, the teachers in cluster 2 need more advanced learning that allows them to transfer and apply their prior knowledge of integrating technology to design AR-mediated learning environments. This may include professional development opportunities where teachers are positioned as co-researchers, in order to institute an inquiry into their own practices of shaping the teaching of multimodal literacies in AR-mediated learning environments.

6. Limitations and Future Research

We acknowledge the limitation of the sample in representing a wider population of Australian primary school teachers. This study used a validated survey instrument and a sample that was substantial enough to undertake a cluster analysis of Australian primary school teachers' TPACK. With the use of both quantitative and qualitative data, the study was able to find predictors of two clusters of teachers' TPACK in the contexts of using more familiar technologies, and solicited initial responses of their TPACK and concerns in the contexts of using AR to develop multimodal literacies. Despite the value of this study, it could not provide a more in-depth measurement of teachers' perceived TPACK regarding their meta-semiotic awareness of specific semiotic modalities; Moreover, the study could not measure the difference in teachers' perceived TPACK in the multimodal interpretation of texts and multimodal designing of texts. The overview of teachers' perceived TPACK in the context of using AR calls for a research agenda to develop a survey to measure teachers' TPACK for teaching multimodal literacies, specifically using AR. This new agenda will determine potential differences in teachers' TPACK (ML) when harnessing AR in classroom practices.

7. Conclusions

To equip young students for a future of constantly expanding horizons, new pedagogies are required whereby emerging technologies such as AR are integrated into schooling from their early learning stages, so that students can reap more educational benefits through opportunities to develop their multimodal literacies. Teachers play a key role in developing students' multimodal literacies in the digital age. Current multimodal and digital learning environments point to the need to understand teachers' TPACK when reframing literacy, in order to better respond to the multimodal nature of communication and text.

This study recognised the importance of developing teachers' capacity to support multimodal literacy development with digital tools, and conceptualised this as a unique form of TPACK. Unlike other TPACK research that pertained to language and literacy learning, this study acknowledged that language is only one semiotic resource for meaning-making [11]. In the context of literacy research in Australia, this research spearheaded a large-scale measurement of Australian primary school language and literacy teachers' perceived TPACK using a validated survey instrument. Unlike most case studies about Australian teachers' vignettes of teaching multimodal literacies, this study provided a cluster analysis of Australian primary school language and literacy teachers in the context of teaching multimodal literacies.

The baseline data derived in this study can inform future interventions that involve integrating technologies, including AR, into language and literacy teaching in the primary context in Australia. The two clusters derived suggest there are clear differences in the TPACK(ML) confidence among Australian teachers. The cluster of teachers with lower confidence requires more support to develop basic technical and pedagogical vocabularies about multimodal literacies. The cluster of teachers with higher confidence was also more familiar with digitally-mediated practices for language and literacy learning. They can benefit from professional development that may enable them to explore more advanced uses of AR apps. These findings suggest that differentiated forms of teachers' professional development can enhance the sustainability and quality of teachers' preparation for multimodal literacy teaching. This aligns with the findings of Niess [51] who suggested that the constructs of the TPACK model can be used as factors to identify and design professional development programmes that are targeted at the specific pedagogical knowledge gaps of teachers in digitally-mediated teaching.

This study also paved the way for first understanding teachers' concerns about using emergent technologies, specifically AR, to teach multimodal literacies. As evidenced by a proliferation of publications on teachers' professional development in the digital turn of teaching literacies, this study provided teachers' initial response in teaching multimodal literacies in AR-mediated learning environments. The cluster analysis presented in this study provided reasons for the slow uptake of AR in Australian primary literacy education, and their implications for teachers' professional development. The insights reported in this study are useful for paving future research and sustainable professional development. Future educational interventions built upon this study have the potential to bring social impact by expanding teachers' capacity to teach innovatively which in turn enhances students' competence in responding to and composing digital texts. These skills create a future workforce that is digitally literate and globally competitive, thus creating national economic impact and sustainability.

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Appendix A

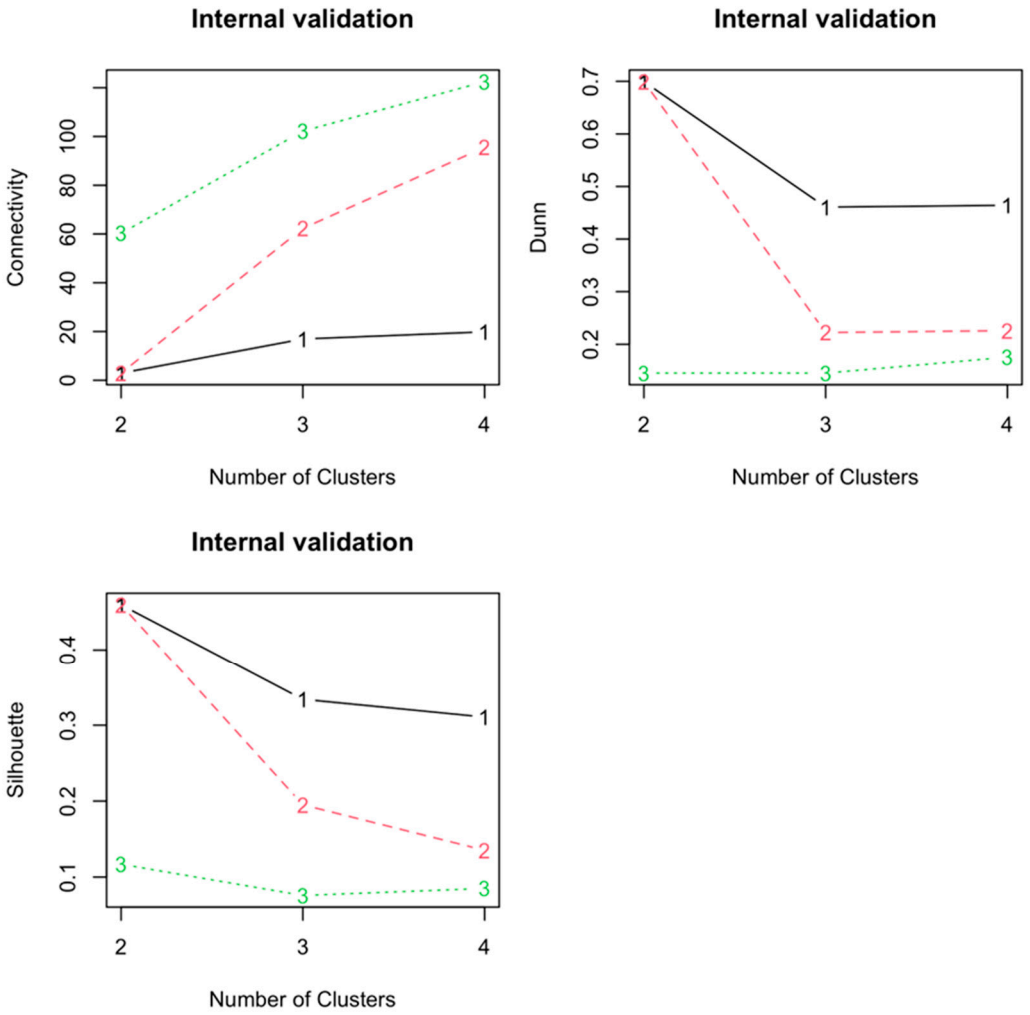

Figure A1. Comparison of Cluster Methods: The three graphs compare the performance of cluster methods; hierarchical (1, black), K-means (2, red) and Partitioning around Medoids (PAM) (3, green) methods. The performances were measured using connectivity, Silhouette Width and Dunn index. Lower connectivity and higher Silhouette Widths and Dunn Indices indicate better cluster performance.

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