Enhancing Communication and Participation within Mathematical Inquiry Communities through New Zealand Sign Language

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ABSTRACT

In this paper we unpack some possibilities around the importance of language within mathematical inquiry communities in mainstream settings. Recognising that multiple forms of discourse and language can be used as a resource for facilitating mathematical communication within collaborative group work experiences, we explore the impact of a school-based intervention that incorporates visual features of New Zealand Sign Language (NZSL). Drawing on the experiences of introducing a range of vocabulary within mathematics lessons across Years One to Four in a mainstream school, we demonstrate some of the ways sign-supported communication can be used by teachers and students as part of everyday communication in the mainstream mathematics classroom. Using data from surveys and interviews, the community of learners report many positives regarding communication practices. These include increased access to communication by previously hesitant students, increased teacher awareness of students' thinking, and generally a more productive and collaborative community of inquiry experience within the classroom.

Research paper

Keywords:
communication; mathematical inquiry; NZSL

INTRODUCTION

In New Zealand, recent Trends in International Mathematics and Science (TIMSS) studies of mathematics outcomes for primary level students (Caygill, Hanlar & Singh, 2016) report wide disparity in student achievement levels. Given the unacceptably high number of students at the 'low' end of the continuum, providing more equitable learning spaces to learn and communicate mathematics is urgently needed. Establishing equitable learning environments is vital to address persistent and systemic levels of underachievement in mathematics education (Hunter et al., 2016).

Learning opportunities that focus on participation in communities of mathematical inquiry are regarded by many researchers (Hunter, 2007; Sengupta-Irving & Enyedy, 2015) as a key equitable mathematics teaching practice. As part of the movement towards mathematical inquiry, mathematics education reforms advocate opportunities for students to engage in collaborative problem-solving experiences involving tasks centred on mathematical argumentation and sense-making (Franke et al., 2015; Hunter & Anthony, 2011). Within the collaborative problem-solving activity, access to language (Spencer & Marschark, 2010; Swanwick, Oddy & Roper, 2005); to status (Gresalfi, Martin, Hand & Greeno, 2009), and to 'funds of knowledge' (Civil & Hunter, 2015) are seen as key aspects that mediate productive participation. To enable such access, it is essential that teachers establish appropriate norms for participation and discourse (Hunter, 2007), position students as capable and press for academic success (Esmonde, 2009), attend to each student's mathematical thinking (Kosko, Rougee, & Herbst, 2014), and explicitly value diversity within the classroom (Bartell et al., 2017).

To support the development of this ambitious agenda, we unpack some possibilities around the importance of language within mathematical inquiry communities. In recognising that multiple forms of discourse and language can be used as a resource for facilitating mathematical communication within collaborative group work experiences, we explore the impact of a school-based intervention involving the development of New Zealand Sign Language (NZSL) capability. Drawing on the experiences of introducing a selection of contextually-appropriate signs from NZSL within mathematics lessons across Years One to Four in a case study school, we firstly present some of the ways that sign language can be used by teachers and students as part of everyday communication in the mathematics classroom. We then present the perspectives of the teachers and Year Four students towards using these signs with the aim of informing ways that could enhance language practices and social norms related to status, participation and agency, and communication of mathematical thinking in the future.

Before presenting our research findings, we begin with an overview of mathematics inquiry classrooms with a focus on communication and participation practices. We then introduce the reader to NZSL and its potential for use in mainstream mathematics classrooms.

COMMUNICATION WITHIN MATHEMATICS INQUIRY CLASSROOMS

Mathematical education reform over the last 10 years has seen a pedagogical shift away from transmission-based teaching practices built on Initiate-Response-Evaluate (I-R-E) discourse patterns (Meehan, 1979) towards more relational practices focused on communities of mathematical inquiry. Drawing on socio-cultural learning theories, students in mathematical inquiry classrooms collaborate to socially construct mathematical understandings and develop mathematical proficiencies through rigorous mathematical discourse (Anthony, Hunter, Hunter & Duncan, 2015; Boaler, 2008). The teacher's role is key to facilitating rich mathematical discourse through both the planning and enactment of collaborative group problem-solving activities and whole class discussions (Franke et al., 2015).

Participation in collaborative group work activities requires the establishment of social norms that promote a range of bi- and multi-directional communication – norms that support the explicit and strategic valuing of each student's mathematical thinking, multiple strengths and diverse needs. To date, an auditory/oral mode of communication is historically assumed and valued as the norm for discourse within mainstream educational communities in New Zealand. With increased focus on collaborative learning, alongside moves to shifting the physical landscape of schools towards larger shared learning spaces, it is timely that we look to the potential of additional communication modes to enhance the participation of diverse learners.

Inequitable participation levels have long permeated educational circles and can be the outcome of a range of factors such as social or academic status and taken-for-granted systemic practices or norms. For example, in-class ability grouping (Anthony & Hunter, 2017) has meant that in some classes only students labelled 'higher ability' have opportunities to engage in argumentation associated with rich problem-solving activities. Moreover, the traditional practice of students raising their hand to indicate an intent to speak often results in inequitable access to the conversational floor, with some students of higher perceived status often dominating the discourse and therefore influencing the direction of an inquiry. More recently, teacher practices, such as asking students to raise or lower a thumb or randomly selecting students to enter the discourse, have been incorporated to alleviate this inequity.

In mathematics education, research has identified some key discourse tools which can be used by teachers to enhance students' mathematical sense-making and argumentation. Teacher tools such as invitational talk moves (Chapin & O'Connor, 2007), support moves (Franke et al., 2015), probing questions (Kosko et al., 2014) and sequences of specific questions (Franke et al., 2015) have all been found to support students to engage more critically with each other's mathematical thinking. Moreover, explicit attention to extending thinking time affords equitable opportunities to students who require more time to process information before responding.

Embedding these discourse tools within the five practices model for orchestrating discussions (Stein, Engle, Smith & Hughes, 2008) allows teachers opportunities to assign competency and status to specific students, to address inequities and disabling practices, and create a mathematical community with greater student autonomy. However, from an equity lens, student autonomy is entwined with developing the capabilities of participation and communication for each student. With this in mind, an impetus for this study arose from wondering how the provision of additional visual discourse tools associated with NZSL would mediate students' access to communication and participation practices within a mathematical inquiry community.

WHO GETS TO COMMUNICATE IN NEW ZEALAND CLASSROOMS?

In classrooms, barriers to communication arise when equitable access to information is not addressed. Many students have limited access to auditory information due to temporary or permanent deafness[1] or auditory processing disorder (APD). The National Screening Unit (2006) put the incidence rate of deafness at birth as 135 to 170 new-borns each year with Māori accounting for 46 percent of this figure (Anderson, 2006). Studies have shown that a lack of access to daily incidental communication from birth[2] impacts on development of conceptual understanding and productive citizenship (Powell & Hyde, 2014).

The incidence rate of APD is estimated to range from 5 percent for the general population to 35 percent for Pacific Island populations (Esplin & Wright, 2014). Students may also experience degraded access to auditory information due to the acoustical designs

[1] Deafness is both a term and a cultural identity which embraces a diverse group of people. As a term, it covers a broad spectrum of inaccessibility to particular frequencies.

[2] 90% of deaf children are born into hearing families (Anderson, 2006).

of their education settings whereby background noise produces poor signal-to-noise ratios and/or reverberation. Another group of students who face barriers when oral communication is valued and promoted as superior to visual modes of communication are those who experience verbal communication anxiety. This apprehension to speak can affect oral delivery, impact on the frequency of participation in mathematical discourse, the quality of the discourse, and the development of conceptual understanding (Richmond, Wrench & McCroskey, 2012).

Until recently, however, the use of NZSL was considered as holding an inferior status to spoken communication. Banned in schools up until 1979, it was not until the 1990s that NZSL was recognised for use in deaf education and a bilingual-bicultural pilot class was established (Powell & Hyde, 2014). There is no doubt that this historical positioning of sign language as inferior to oralism has had a profound disabling and marginalising effect for those students who are deaf or hard-of-hearing. For these students, the right to access communication in other modes must be addressed and realised. A literature search into effective teaching practices for students experiencing barriers to receptive and productive communication highlights studies promoting the regular use of problem-solving (Spencer & Marschark, 2010), and the use of metaphoric, iconic and representational gestures and sign language, not only to facilitate communication, but also to support vocabulary development and conceptual understanding (Alibali & Nathan, 2012; Krause, 2016; Rosborough, 2014).

BACKGROUND TO CASE STUDY

The aim of this professional inquiry research was to inquire into the potential of NZSL as an alternative and additional mode of communication within a mathematical community of inquiry. In particular, it was conjectured that the introduction of a range of NZSL vocabulary may support increased student participation and access to mathematical discourse.

Situated in a Decile 10 primary school, initial gross analysis of the school's mathematics achievement data revealed that students who were identified as being at-risk due to under-achieving National Standard benchmarks, also had one or more of three other factors in common:

1. A large percentage of these students identified as Māori and/or Pasifika.
2. Many of the students self-reported high levels of communication anxiety.
3. Some of the students presented with auditory barriers to learning and communication, such as auditory processing disorder which is exacerbated by background noise levels, were hard of hearing, or had temporary auditory hearing loss due to illnesses affecting the auditory canal (N.B. exact data for auditory processing is unavailable as some students were in the process of being diagnosed or referred for auditory testing).

INTERVENTION NZSL STUDY

Ten teachers from the Year One to Four syndicate volunteered to introduce basic NZSL as part of their focus on developing communication and participation norms within their communities of mathematical inquiry. All members of the learning community (teaching staff, students and senior management) were taught signs that would indicate not only an intent to speak but convey what they were thinking about in response to a mathematical idea. Typically, this involved teachers in a total of three hours of sign tuition presented in 15 to 30 minute tutorials during staff professional development days and staff or team meetings. Further teaching and learning support was accessed online through the NZSL Online Dictionary (McKee, McKee, Pivac Alexander, Pivac & Vale, 2011). The signs that were initially taught were:

- IDEA
- QUESTION
- CONFUSED
- ADD ON
- REPEAT?
- AGREE
- DISAGREE

Support from staff at Kelston Deaf Education Centre ensured signs were taught correctly and appropriately. Moreover, attention to aspects of deaf culture such as behavioural norms and non-manual signs when communicating with the hands, eyes and facial expressions, were also incorporated into the teaching and learning of these signs. Teachers and students were prompted to ensure they physically positioned themselves to have clear access to both oral and visual language modes including facial expressions and lip pronunciation cues of all community members. This required deliberate attention to seating arrangements that would facilitate both large and small group multi-directional communication. Circular seating or horseshoe formations for large groups and triangular

or square seating arrangements for groups of three to four students were identified through classroom trials as being optimum for facilitating access to communication.

Within classroom mathematics discussions, the teachers were encouraged to prompt students to sign without speech whether they agreed or disagreed, were confused, had more to add, or had a question, rather than raise their hand to enter the conversation. Students were then invited, initially by the teacher and then other students, to elaborate verbally and visually, responding to questions such as, "Why do you disagree with that idea?" or "Which part are you confused about?"

OBSERVABLE OUTCOMES

While an observer in the classroom might notice the obvious changes in participation around turn-taking – in that the introduction of signing replaced the practice of students and teachers raising a hand to speak, or that students themselves might ask another student to enter the conversation – teachers were keen to report back on changes that occurred in both the social norms and mathematical norms for discourse. A common shift that teachers noticed was that previously non-communicative students were not only keen to sign and contribute but were willing to sign if they were confused, agreed, or disagreed with mathematical ideas being shared by other students.

As the social norms for participation in discourse shifted, at the teachers' and students' requests, some new signs were added to the community's repertoire:

- CHANGE MY MIND
- WONDER
- (I have) DIFFERENT/ SAME IDEA

In addition to the new communication prompt signs, two of the Year Four classes were also taught to sign numbers, fractions and operations.

EVALUATION OF INTERVENTION

In 2016, six to nine months after introducing these signs, an online survey was distributed to 54 Year Four students and 10 teachers from the school. With the aim of examining their perceptions about using NZSL within mathematical classrooms, the survey questions explored the impact of sign-supported communication on the development of levels of participation and communication in mathematical discourse, willingness to communicate, social and mathematical norms, and attitude to learning and continuing to use sign language within mathematics. Six teachers and 18 students completed the survey.

An analysis of survey items revealed that five of the six teachers reported using signs always or nearly always in their maths lessons since they were introduced. Four of the six teachers were using signs during the lesson warm-up, the problem launch, and the student reporting phases. Students noted that they did the most signing when other students were reporting back their solutions to the wider group. All respondents (teachers and students) noted that the signs most commonly-used by students were [I] AGREE and [I] DISAGREE. They also reported a high usage of [I have an] IDEA, [I'm] CONFUSED and [I want to] ADD ON.

Overall, teachers were very supportive of the use of sign language. All teachers expressed agreement with the statement: S*ign language helps students with communication barriers to participate in mathematical conversations.* Likewise, students survey responses were positive about the introduction of sign language. It was noteworthy that support from students included a variety of responses that indicated that signing helped them to overcome communication anxiety:

- I didn't share in class before I knew how to sign (S13)
- I feel more confident and not as nervous about talking (S1)
- It allows me to be able to share my thinking without speaking (S17).
- No one talks over each other and interrupts my learning (S9)

Likewise, teacher responses noted a similar theme of reducing communication anxiety:

- Sign "removes barriers for some kids who struggle with words" (T2)
- Sign "seems less intimidating ... stops the calling out" (T1)

Teachers also noted that sign language impacted on the norms for discourse:

- Students are more willing to converse, discuss, (and) argue in a supported and accepted environment. They know it is expected and welcomed. (T5)
- Someone will disagree - then explain why … it also encourages growth mindset and changing your mind. Making mistakes can be celebrated (T4)
- They are more willing to say they don't know and to change their minds (T6)

Interviews and informal discussions with teachers after the survey was completed allowed teachers to elaborate further on the impact they perceived sign language was having on shifting socio-cultural norms. For example, one teacher remarked that her students frequently signed when they were confused. She noted that "this didn't happen before where they'd just pretended that they understood. It's no longer a bad thing to say you don't understand".

Moreover, several teachers spoke of how the private mathematical thinking of each community member could be revealed simultaneously. That is, with the introduction of signing, teachers were able to make a collective assessment-based on the response of individuals – as to the progress of the class understanding. For example, T4 noted that she could "tell if we've lost half the class if they're all signing that they're confused" and Teacher Y noted that "when the kids all sign what they are thinking it helps me decide what we need to do next". These teacher reflections were affirmed through classroom observations (by the first author) in instances where teachers praising and responding to gesture, eye contact and signing were taken as valued forms of communication and evidence of engagement and understanding.

Teachers were also observed supporting students to invite another student to clarify or elaborate their signed communication by explicitly naming the sign being used; for example, "Sarah, why do you disagree?" Moreover, teachers encouraged students to invite other students to speak (as a response to signing). This appeared to be shifting the mathematical talk from being teacher-directed or bi-directional to a more multi-directional mode of discourse. In turn, this afforded more equitable opportunities for student engagement within the classroom. As T6 noted: "For children whose voices are never heard, sign has enabled them to share their learning in a more equitable way".

DISCUSSION AND IMPLICATIONS

Collectively, the survey responses indicate the participants' growing recognition of NZSL as a valued norm for supporting communication within a mainstream learning community. Specifically, responses suggest that the introduction of NZSL shifted the socio-cultural norms of the inquiry community to value visual communication; it also increased awareness and acceptance of socio-mathematical norms and practices around mathematical argumentation, and facilitated students with previous low levels of participation or high levels of anxiety to communicate and participate more. However, it should be noted that this data is confounded by the simultaneous introduction across the school of teacher-talk moves, moves towards more flexible, non-ability based grouping practices, and development of the five practices model for orchestrating discussions within a mathematical inquiry (Stein et al., 2008). The study also faces limitations in terms of reliance on self-report data and sample size.

Importantly, this case study raises the possibility of reciprocal benefits to both deaf and hearing cultures of raising the status and visibility of NZSL within mainstream educational settings. The unique potential that NZSL could have in providing mathematical inquiry communities with enhanced insights into groups of students' thinking, individual cognitive awareness and conceptual understanding, alongside challenges to inequitable participation practices at any point in time, is presently untapped and unexplored. Raising awareness of the validity and value of visual communication within communities of inquiry has been researched in terms of attending to gesture and embodiment (Alibali & Nathan, 2012; Rosborough, 2014) but very little data is available on the use of sign language within mainstream mathematical communities. This experimentation to move to incorporate more sophisticated levels of signing than the commonly-used gesture of 'thumbs up/down' suggests there is an untapped potential for sign language to support the development of mathematical argumentation, justification and sense-making. Moreover, the incorporation of alternative and wider forms of communication may go some way to address access for currently underserved students within discourse-rich learning environments. This small-scale study suggests that further research is required to investigate the role that sign language could play in realising the linguistic rights of all community members to engage equitably within communities of inquiry.

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