Staging a Numeracy Performance

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Abstract

Improving middle years students' engagement in mathematics and their numeracy skills has been an educational focus for many years. One approach is to utilise teachable moments in contexts beyond traditional mathematics classrooms that engage students in using mathematics in real world contexts, thereby developing their numeracy. This paper reports on student numeracy engagement through theatre staging workshops. Year 7 students were led by a professional stage manager to understand the role and the practicalities of stage management. While observing the workshops, it was realised that there were multiple opportunities to engage students in numeracy. Interview and observational data were collected to identify numeracy teaching opportunities and the nature of the mathematics involved. The workshops immersed students in a rich, real-world context that required them to apply mathematical knowledge and skills, especially in measurement, estimation and sequencing. The theatre context also gave the students opportunities to apply practical and logical reasoning skills that align with the Australian Curriculum general capability of numeracy. This paper provides teachers and schools engaging in contexts such as stage productions, an insight into how this creative focus presents a powerful real-life context that gives middle years students an imperative to use their mathematical knowledge and skills.

Introduction

For many years it has been recognised that there are issues around the literacy and numeracy of students in the middle years of schooling. The research literature abounds with studies and reports pointing to increased disengagement and disorientation of students in the early years of secondary schooling (e.g., Luke et al., 2003; Ministerial Council on Education, Employment, Training and Youth Affairs [MCEETYA], 2008; Main & Pendergast, 2017) and the accompanying drop in achievement in literacy and numeracy, as well as specific subjects such as mathematics (Doig, 2005; Lokan, Greenwood, & Cresswell, 2001; Luke et al., 2003). Gibbs and Poskitt (2010) conducted an extensive literature review and identified eight factors that influence engagement and achievement of students in the middle years namely, (a) relationships with teachers and other students, (b) relationship learning, (c) dispositions to be a learner, (d) motivation and interest in learning, (e) personal agency/cognitive autonomy, (f) self-efficacy, (g) goal orientation, and (h) academic self-regulated learning. Of particular interest in the context of the study described in this paper are motivation and interest in learning. According to Gibbs and Poskitt, these attributes are fostered by engaging students in learning activities that are enjoyable and by making learning meaningful to students.

In recent years, there has been increased recognition that the middle years in particular are a crucial period in which to develop students' numeracy prior to post-compulsory schooling and that numeracy is essential for success in life beyond school (Dole, 2017). The promotion of numeracy is not solely the responsibility of mathematics teachers and indeed, in Australia, it is recognised as a general capability and the responsibility of teachers across all key learning areas (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2017). According to ACARA (2017), teachers in all subjects are required to

> identify the specific numeracy demands of their learning area/s; provide learning experiences and opportunities that support the application of students' general mathematical knowledge and skills; and should be aware of the correct use of

> mathematical terminology in their learning area/s and use this language in their teaching as appropriate (paragraph 2).

Identifying opportunities and using mathematical terminology can be a challenging requirement for teachers of subjects beyond mathematics and for teachers who are not trained in mathematics. However, it is vital that all teachers capitalise on those moments in their classrooms when mathematics is used and where students can use it in authentic ways and real-world contexts. The rationale for this approach is strongly supported by literature, which shows that numeracy is more than mathematical knowledge – it relies on the use of mathematics in context (Goos, 2007). Contextualising mathematics learning is important because when students use mathematics in context they are likely to have a stronger understanding than if they learn it in isolation (Zevenbergen & Zevenbergen, 2009). While context is an essential component of numeracy and an important aspect of mathematical learning, we also know that students find it difficult to transfer their mathematical knowledge across contexts (Bransford, Brown, & Cocking, 2000). This understanding requires teachers to be able to recognise and capitalise on promoting the use of mathematical knowledge across as many contexts as possible. Often these teachable moments in numeracy can arise in diverse and unexpected contexts (Thornton & Hogan, 2005).

This paper presents a small case study that illustrates the multiple opportunities in a series of performing arts workshops that capitalised on teachable moments to promote numeracy in an authentic context. This case study developed during the course of a much larger project when it was realised that the activities in these workshops were engaging the participating students in using mathematical knowledge and skills to solve authentic problems. The paper aims to prompt teachers of all curriculum areas to reflect on the potential teachable moments within their own subject areas.

What is Numeracy?

Numeracy is variously described in the literature and the early definitions were criticised for their limited focus on mathematical knowledge and number use (Dole, 2017). A succinct definition of numeracy was provided by Willis and Hogan (2002): "numeracy is intelligent, practical mathematical action in context" (p.7). A more detailed definition was presented by the Australian Association of Mathematics Teachers (1997). This definition acknowledged the importance of using mathematics knowledge and skills in real world applications and the importance of having a positive disposition to do so. In response to the diverse and numerous definitions proposed over the latter half of the 20th Century, Goos (2007) offered a more detailed description of the key elements that contribute to 21st Century numeracy. According to Goos, there are five key elements that together constitute what is means to be numerate. These are *mathematical knowledge* (the mathematical skills and concepts that are usually articulated in the mathematics curriculum); *tools* (digital and physical mathematical tools as well as mathematical representations); *dispositions* (positive attitudes to mathematics, confidence, willingness to take risks, flexibility, and perseverance); a *critical orientation* (preparedness and ability to question, scrutinise, and challenge the use of numerical data); and *contexts* (real world and authentic situations as well as those related to multiple curricula). The centrality of contexts in this model and other definitions highlights the context-dependent nature of numeracy and the fact that it occurs when mathematics is used in authentic situations rather than in contrived situations such as those often encountered by school students. By exposing students to opportunities to use and apply what they know in authentic ways or by providing students with an imperative to apply their mathematical knowledge and skills, different contexts can move students from mathematical thinking to numeracy applications. Moreover, once a student can see reasons, through practical applications, for what

they are learning in the mathematics classroom, their knowledge becomes more embedded in the real world.

The teaching of numeracy is the responsibility of all teachers, which requires teachers of all subjects to take the concepts and skills that their students learn in mathematics classrooms and assist students to apply them in new contexts. In practice, however, this requirement can be challenging for non-mathematics teachers. In describing the Australian Curriculum, Goos, Dole, and Geiger (2012) argued that it "lacks a theoretically informed model for characterising numeracy, and as a result, teachers have little guidance in recognising the numeracy demands of subjects other than mathematics and in embedding numeracy learning opportunities across the whole curriculum" (pp. 314-315).

The Importance of Numeracy Engagement in the Middle Years of Schooling

Students are likely to develop attitudes to mathematics while they are still in primary school and these attitudes (whether positive or negative) may influence their engagement in mathematics (Dowker, Bennett, & Smith, 2012; Eccles, Wigfield, Harold, & Blumenfeld, 1993). Research has shown that when students have positive attitudes to mathematics they are likely to have higher levels of engagement and are more willing to persist when challenged. Further, these factors also influence achievement in mathematics (Adelson & McCoach, 2011; Barkatsas, Kasimatis, & Gialamas, 2009; Commonwealth of Australia, 2008; Goos et al., 2012; Pintrich & Zusho, 2002; Usher & Pajares, 2006).

Many students in the middle years of schooling exhibit low levels of engagement in mathematics and this has been of concern in Australia for many years (Attard, 2011). International results have provided significant evidence that addressing this concern is an imperative. For example, the 2011 Trends in International Mathematics and Science Study (TIMSS) showed that only 16 percent of Australian students in Year 8 had an interest in

mathematics (Mullis, Martin, Foy, & Arora, 2012) and that Year 8 students were underperforming in mathematics with 37 percent failing to achieve at a proficient standard (Australian Council of Educational Research [ACER], 2012).

Low levels of engagement have been attributed to students not enjoying mathematics or seeing no personal relevance in mathematics. Interestingly, while the TIMSS 2011 findings revealed a concerning level of disinterest in mathematics, they also showed that 86 percent of students see at least some value in learning mathematics. Other research has found that even successful mathematics students dislike the subject because they do not see it as relevant to their own lives. That is, they do not identify with it (Boaler, Wiliam, & Zevenbergen, 2000).

Doig (2005) argued that making mathematics more relevant to students' interests is an important approach for addressing students' disengagement from mathematics. One approach to helping students see more relevance and to allow them to apply their mathematics knowledge and skills for a real purpose involves taking mathematics learning beyond the mathematics classroom. Indeed, Steen (2001) insisted that numeracy must be learned in multiple school subjects and not only in mathematics if it is to be of use to students. According to Dole (2017), experiencing success in applying mathematics in contexts beyond the mathematics classroom, such as in other subject areas, can also assist students who experience mathematics anxiety. Experiencing this success can have a positive influence on one of the most important aspects of numeracy in the middle school: having a positive disposition to using mathematics.

Background to the broader study and impetus for the case study

The theatre staging workshops that are the focus of this paper were part of a larger programme known as *Sky High,* which aimed to engage students in meaningful curriculum-based learning in a range of contexts beyond school. This program was a philanthropically

funded program and was conducted through the University of Technology Sydney (see acknowledgements). The program involved lower secondary school students from a number of Western Sydney schools. The students who were chosen were selected by their schools on the basis that they came from backgrounds of disadvantage and were at risk of not achieving their educational potential. Many of the students were disengaged or have negative attitudes to school. The program ran for two years and aimed to promote school engagement, develop confidence, enhance a sense of options for futures as well as building social and life skills. The educational activities emphasised real world experiences and contexts. To facilitate these goals, 12 full-day activities were offered to students in the first year of the program and a further 12 in the second year. Several of the workshops included follow-up activities in the schools. The Sky High program has been an ongoing research project since 2012, however, more recently, the research focus has been on ways to engage students and to enhance skills, including literacy and numeracy. The authors of this paper are involved with the project as researchers, and the third author also acts as events facilitator and in addition to her role with Sky High, she is a professional stage manager at the Sydney Opera House (SOH).

In the case of the theatre staging workshops, more than 60 students from six different schools were taken to the SOH with the stage manager for a behind-the-scenes tour. The students experienced a 'bump in' of a show, witnessing the set-up of lighting rigs, sound systems, and stage furniture, while cross-referencing their progress with a provided floor plan. This experience was the catalyst for subsequent practical theatre staging workshops within each of the six schools. The focus of the workshops was to role-play the responsibilities of the stage manager and technicians and to focus attention on staging placement, sequencing, and timing while effectively communicating with each other to deliver a dramatic scenario.

While conducting an earlier theatre staging workshop, the authors of this paper realised that beyond achieving the initial stated goals, this context provided a very rich opportunity for the application of students' mathematical knowledge: It was a powerful numeracy teaching and learning opportunity. As mentioned previously, these workshops and the focus on numeracy were not planned as a separate study. The idea for this case study and the data that are presented in this paper arose incidentally when the third author accompanied the students to a SOH event. Interestingly, when attention was drawn to this, the stage manager, whose background is in theatre and stage management, not mathematics education, was surprised at the amount of numeracy that was involved, stating that her intention had not been to focus on mathematics in the workshops. As a result of these observations, it was decided that at subsequent events, data would be collected to allow the researchers to identify numeracy teaching opportunities that might commonly be presented to students engaging in a performing arts context of this kind.

This article describes the different mathematical concepts and skills that were evident in the theatre staging workshops at both the SOH and the follow-up at one of the schools, and provides examples of how students engaged in using them. The purpose of this paper is to illustrate to teachers the multiple ways that a seemingly non-mathematical context offered rich and varied opportunities to engage students in the meaningful use of mathematics.

Method

Workshop Participants and Setting

Approximately 60 Year 7 students from six different Western Sydney schools participated in the behind-the-scenes tour of the Sydney Opera House (SOH) with a resident stage manager. Subsequent practical theatre staging workshops were conducted with groups of students in each of the six participant schools. The data presented here were collected during

the SOH workshop and at a subsequent workshop involving 12 students in one of the participating schools. This article focuses on the ways in which the stage manager engaged the students to use various mathematical skills and concepts during the workshops.

Study Design

A case study was designed to focus specifically on the numeracy elements of theatre staging workshops as a means of identifying opportunities for engaging students to use mathematical skills and knowledge in authentic ways. Since this small-scale study grew out of a broader study not focused on numeracy development, the decision to use a case study approach was based on the opportunity to observe this stage manager with the group of students with whom she was working at the time. The case study focuses on the activities and the opportunities to use mathematics rather than on the stage manager herself. According to Merriam (1998), a case study is a particularly useful design if the focus of interest is process. Further, it is a useful approach when dealing with a unique situation for which it is important to describe an implementation or program. Yin (2003) argued that case study design is suited to situations in which the phenomenon cannot be separated from its context or when the single case represents a context not previously accessible. This view was reiterated by Flyvbjerg (2006) who argued that the case study is especially suited to producing context-dependent knowledge.

In the case of this study, the context was the theatre staging workshops. The research question addressed in the study was: What are the mathematical skills and concepts utilised by students when they engage in theatre staging workshops and how do these align with the organising elements of the Australian Numeracy Learning Continuum (ACARA, 2015b)? The broad aim of the study was to illustrate to teachers the ways in which every day, seemingly non-mathematical contexts can in fact be rich and valuable for engaging students in numeracy.

Data Collection

The third author, who in addition to her role as professional stage manager at the SOH is also a theatre educator and education researcher, acted as facilitator of the workshops. The first and second authors collected data during the workshops and conducted interviews with the stage manager to clarify and expand on notes made during the workshops. At the theatre staging workshops, observations were made and field notes and photographs were used to record the instances in which students were required to draw on mathematical knowledge or skills in order to participate in the workshop activities. The workshop planning documents and other artefacts used in the workshops were also collected. The facilitator of the theatre staging workshops was later interviewed by the other authors (both mathematics education researchers) to elaborate on the specific numeracy abilities required of students when participating in the workshops. This elaboration also allowed for validation of the observations made and to ensure the accuracy of the descriptions of the context and activities involved.

Data Analysis

All field notes, interview transcripts, and artefacts were analysed to identify instances in which mathematical ideas and skills were used. Each of these instances was mapped these against the Australian Numeracy Learning Continuum (ACARA, 2015b) to identify the organising elements to which they related (i.e., Estimating and Calculating with Whole Numbers; Recognising and Using Patterns and Relationships; Using Spatial Reasoning; Interpreting Statistical Information; Using Measurement; and Using Fractions, Decimals, Percentages, Ratios and Rates). After identification of the relevant organising elements, the instances were also aligned with the descriptors of the key ideas within each of the organising elements. The first and second authors conducted this analysis independently in the first instance. The team members then compared their analyses to ensure alignment of their

interpretations.

Results

When mapped against the six organising elements from the Numeracy Learning Continuum, the activities aligned with three, namely, Estimating and Calculating with Whole Numbers, Using Measurement, and Using Spatial Thinking. The activities and the organising elements and key ideas to which they align are summarised in Table 1.

Table 1

Summary of Results: Theatre staging activities and curriculum links

Numeracy Continuum Organising Element and Key Ideas	**Activities**
Estimating and calculating with whole numbers: Students • estimate and calculate with whole numbers to solve everyday problems in authentic contexts • use efficient mental, written and digital strategies	• Estimation of seating numbers: counting rows, multiplying by numbers of chairs • Checking answers by calculating using written strategies and calculators
Using spatial reasoning: Students • use symmetry, shapes and angles to solve problems in authentic contexts • interpret maps and diagrams • use scale and directional language	• Using symmetry to mark out stage • Using angles to make decisions about lighting, position of performers • Interpreting scale diagrams to position performers, actors, props, etc. on stage • Understanding directional language (e.g., upstage, centre stage) to follow stage directions
Using measurement: Students • estimate, measure, compare and calculate when solving problems in authentic contexts (length area, time) • identify and sequence events, operate with clocks and use timetables	• Estimating dimensions of stage and location of centre stage, position of actors, orchestra, etc. using benchmarking and checking with tape measures • Sequencing events for a performance using cueing involving timing of multiple processes performed simultaneously

All of the activities required students to draw on a range of mathematical knowledge and skills, which were combined in diverse scenarios to allow students to solve real problems for the smooth running and coordination of the stage management tasks in which they were engaged. In the following section, these key ideas are elaborated with further descriptions of the activities. The purpose of this is to support teachers to recognise numeracy opportunities within their own contexts.

Measurement of Distance and Area

Following the staging workshop at the SOH, the students needed to take their knowledge and translate it into a school setting, which meant that they had to downscale the stage and audience areas. Theatre staging requires a combination of exact measurements and estimations. For example, the students used a tape measure to accurately position centre stage but often estimated approximate locations by pacing out. Photos of this activity at the SOH are shown in Figure 1. An example of the discussion from a school-based workshop follows. In this scenario, three students have volunteered to mark out the stage.

Stage Manager: Find the centre stage – how do you know you're in the centre?

Student 1: We could count the audience chairs – there would be half on each side.

Stage Manager: That's a good idea. What if I don't have a tape measure – what else could we do?

Student 2: Estimate? We could count our steps. (The student paced out 10 steps across the marked-out stage).

Student 3: So, there would be five steps to centre stage.

The students finally used a tape measure to determine the accuracy of their estimations and marked centre stage.

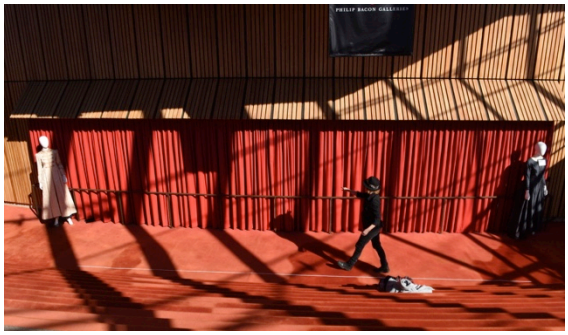


Figure 1. Using benchmarking and pacing out to create mark up of stage (left), marked-up stage showing centre stage and wings (right).

Defining spaces on the stage or for the audience or orchestra also required the students to use a combination of measuring skills. For some, tools such as a tape measure were used; for others, informal measurement units or estimating by benchmarking were used; or sometimes a combination of all of these was used, for example, the area for the audience was measured in terms of chairs (informal use of units) by making one row of chairs, measuring it and multiplying it to determine how many chairs would fit in the available space. In the school-based workshop, the students were working in the school theatre, which is a much smaller space than the SOH theatre they had previously experienced. The discussion centred on the number of chairs in the school theatre compared to the SOH and why the seats in a large theatre are raked:

> Stage manager: How many seats are in this theatre? How could we find out without counting all of them?
>
> After some discussion, a student answered, ‘there are 13 rows and there are 9 chairs on this side and the same on the other side.’

Stage manager: Good, so how many is that altogether?

A student using a calculator answered, ‘13 times 18 is 234.’

Stage manager: What if we have 10 times that many seats, how many would that be?

Student: 2340

Stage manager: So, would it be easy to see from the back? Why? What could we do?

The students agreed that it would not be easy to see the stage and the conversation turned to the use of tiered or raked seating so that the audience could see the stage. This conversation was also used to describe the origins of terms such as upstage and downstage from early theatres in which the stage rather than the floor was raked. This discussion led to a series of activities that utilised spatial reasoning.

Using Scaling and Spatial Reasoning

An extension of the estimation of locations using stage measurements requires stage managers to mark out positions of performers, props, or musicians using a scale drawing (a mathematical representational tool). In a school performance space, such as a classroom or outdoor area, there is often no stage as such. The space must be seen as a whole and then plans must be drawn to represent the relative sizes and locations of the performance area, music area (if needed) and audience area. These must be considered in relationship to each other with a clear understanding of the size of the cast and the number of people expected to attend. These areas must be kept in practical proportions to facilitate the performance. An actual floor plan of a show was used to set up the space. Students used measurements of spaces to draw plans to scale. These scale drawings were then used by students and teachers to plan various stage movements of the actors and props. Figure 2 shows an activity conducted with the students, which involves the translation of a two-dimensional scale drawing of a floor plan to a marked-up stage to position musicians on stage.

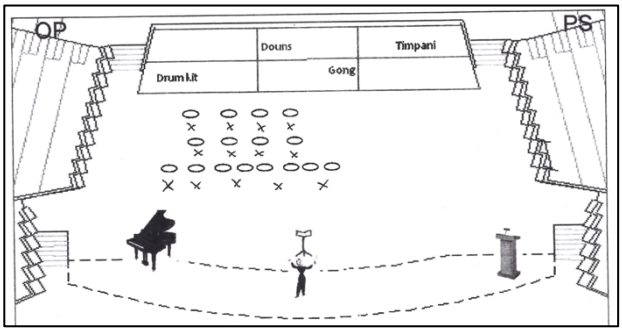


Figure 2. Defining positions using a floor plan (left), floor plan (right).

Measurement of Time

One of the keys to successful stage production is timing. There are many elements that need to be drawn together in the correct sequence with timing elements, from running sheets (simple order of events) to cueing, and timing of sound effects and lighting. Precise timing allows the coordination of the director, conductor, cast and crew. The stage manager directs the timing using a complex arrangement of timers, monitors and intercom systems as shown in

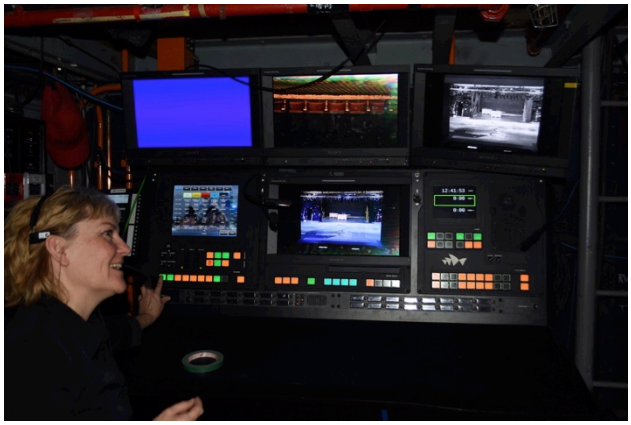


Figure 3. Stage manager explaining the cueing process and procedures involved.

The students were given the opportunity to develop these schedules for the production. This activity began with a discussion of a familiar situation that has a sequence of events (topics included birthday parties, going to the movies and the school's morning routine). These discussions were used to develop the language used in the theatre to communicate to those responsible for particular cues (e.g., 'Cue 1 lighting stand by'; 'Lighting standing by'; Cue 1

lighting go'). The students were then asked as a group to create a timed sequence of cues for a medal award ceremony. This required the students to role play those responsible for sound, lighting, announcements, medal presentation and recipients. This activity provided a powerful experience of the need for precision and coordination of timing in a complex situation.

Measurement of Angle

The understanding of angle is a major aspect of any stage performance. Cast and crew need to be very aware of angles in many circumstances. For example, performers need to be aware of how they orient themselves to the audience and each other; lighting crew must understand the positioning of the lights and the cast. In fact, lighting crew need to co-ordinate many important mathematical concepts simultaneously, including the constantly changing distance and angle from the cast members or adjusting the aperture of spot lights to cover different positions and areas, as well as the timing of each of their actions. Workshop activities that exposed students to these elements of mathematics are shown in Figures 4 and 5.

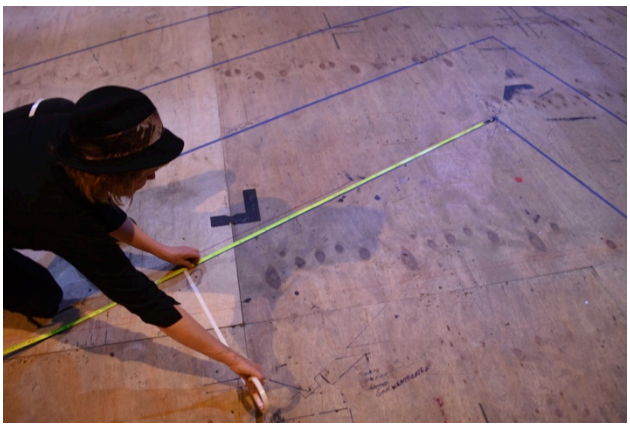


Figure 4. Measuring distances and angles on stage.

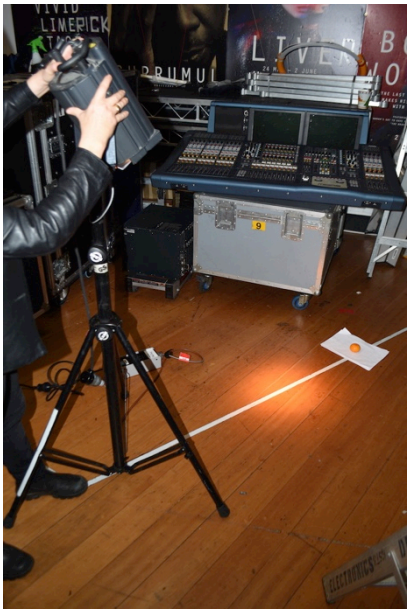
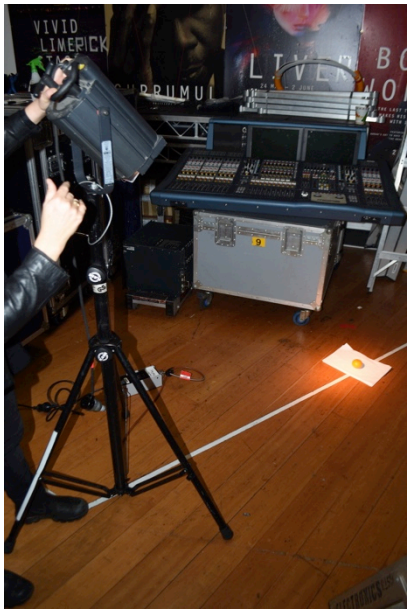


Figure 5. Estimating angles for stage lighting.



Discussion

This study explored the nature of the mathematical skills and concepts utilised by students when they engage in theatre staging workshops. It also focused on identifying the alignment between the mathematics used and the organising elements of the Australian Numeracy Learning Continuum (ACARA, 2015b). The findings of the study show that performing arts activities such as learning about stage management can indeed engage students in mathematical reasoning and that such activities provide teachers with opportunities to expose their students to the use of mathematics in rich and real-world contexts. In particular, the workshops engaged students in the key numeracy elements of measurement, spatial thinking, and estimation and calculation. While only three of the six organising elements of numeracy were identified in the staging workshop activities, this finding aligns closely with the Arts Curriculum document (ACARA, 2013) which identified the use of number to calculate and estimate; use of spatial reasoning to solve problems involving space and 2D shapes; using scale to describe positions; and using measurement to explore length, angles, and time as the key elements of numeracy to be developed through the Arts.

While identifying the mathematical elements in what may appear to be non-mathematical learning tasks can be a challenge for teachers, it is important that all teachers are

aware of the potential within their subject areas and that they capitalise on them when possible. This need not be an onerous task. This study has shown that often the mathematics reveal themselves, and while the use of mathematics may seem incidental, it is nevertheless important. Often, non-mathematics teachers need not change the content of their lessons but rather, when the students are using mathematics the teacher should make this explicit to the students. Foregrounding the mathematical thinking in this way helps students to make connections between their mathematics knowledge and its use in the new context. This approach makes a significant contribution to students' learning as it is well known that students don't find it easy to transfer knowledge from one subject to another (Bransford et al., 2000).

In terms of the Goos (2007) model of numeracy, four key elements of the model were evident in the workshops. The students were required to use *mathematical knowledge* (such as mathematical concepts and estimating and measuring skills) to solve problems in a new *context*. They utilised a range of *mathematical tools* (including calculators, measuring tools, and diagrams) in authentic situations and perhaps most importantly, they did so enthusiastically, thereby demonstrating positive *dispositions*. While it is clear that new mathematics learning must be the realm of the mathematics classroom, this article has highlighted an example of an authentic context that allows teachers to support and reinforce students' numeracy and provided an example of an approach that fulfils the call of researchers such as Doig (2005) and Steen (2001) to engage in numeracy across subject areas. Having an explicit focus on students using mathematics in activities such as the stage management workshops is also an effective means of helping students see the relevance of mathematics in everyday real-world situations and promotes interest and motivation because mathematics is used in a meaningful way for a real purpose. This approach aligns with the work of Gibbs and Poskitt (2010) and addresses the imperative to move away from contrived situations.

This was a small-scale case study and, as such, the findings are limited due to the small sample size and the unique context in which the study was conducted. It is however, this uniqueness that allowed us to focus on a specific example of a performing arts activity that offered multiple opportunities for students to engage in authentic uses of mathematics in a context that did not overtly appear to be mathematical in nature. We hope that through this study we have been able to shed some light on the importance of being cognisant of mathematical opportunities to promote numeracy in all our subject areas to support our students' development of this very important life skill.

Conclusion

Being numerate is an advantage for people's work life and opportunities, their role as active and engaged citizens, and for their success in their personal and social lives (Goos, 2007). As all teachers are responsible for the teaching of numeracy, engaging students in authentic activities can provide a rich encounter in numeracy to the benefit of students. As numeracy is a general capability articulated in the Australian Curriculum and is the responsibility of all teachers, it is important for teachers to recognise the teachable numeracy moments in varied contexts. If appropriate numeracy teaching opportunities can be recognised by teachers in the diverse activities in which they engage throughout the year, then powerful numeracy learning opportunities can be enjoyed by students. Keeping some middle years students engaged in school can be difficult. Providing them with exciting real-life opportunities in which their learning has relevance to them can help in the process of motivating their continued engagement. However, once engaged, there are often rich opportunities to extend their learning beyond the initial focus of the activity.

Acknowledgements

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2. Photographs were taken by the authors in the Joan Sutherland Theatre, Sydney Opera House.

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