“I think it’s a smash hit”: Adding an audience to a critical mathematics education project

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Although critical mathematics education has been promoted as supporting learners to engage with social justice issues, there has been little research on how learners anticipate using mathematics to make a case for a change in behaviour by an audience. The aim of this study was to identify how small groups of preservice teachers discussed the kinds of mathematical representations needed to convince specific audiences to change their behaviour. It was found that the preservice teachers took into consideration their chosen audience’s background experiences and mathematical knowledge. As well as considering the kinds of representations which were most likely to be convincing for these audiences, the preservice teachers discussed whether their calculations should be available for scrutiny in their presentations.

Introduction

Critical mathematics education has as one of its aim to make students aware of the role of mathematics in social justice issues (Meaney & Lange, 2013). To achieve this aim, Frankenstein (1998) described four stages of what she labelled a *criticalmathematical literacy* curriculum: understanding the mathematics; understanding the mathematics of political knowledge; understanding the politics of mathematical knowledge; and understanding the politics of knowledge. In our project Learning about Teaching Argumentation for Critical Mathematics Education in multilingual classrooms (LATACME), one focus is on how preservice teachers can engage their future students by “facilitating the exploring and learning about the world through mathematics” (Lange & Meaney, 2019, p. 2). As part of developing their understandings about the mathematics of political knowledge, learners have to consider the needs of specific audiences, outside the classroom situation, when determining appropriate mathematical representations to include in their arguments about social justice issues:

> The purpose underlying all the calculations is to understand better the information and the arguments and to be able to question the decisions that were involved in choosing the numbers and the operations. (Frankenstein, 1998, p. 309)

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However, very little is known about how learners' knowledge of specific audiences affects their mathematical choices. This is partly because considering the needs of audiences, apart from examiners, is the domain of literacy subjects, rather than mathematics education. If literacy is connected to mathematics, it is usually in regard to the reading and writing skills needed to engage with mathematical ideas in textbooks, etc. (see, for example, Murray-Orr & Mitton-Kukner, 2017). In contrast, an interdisciplinary approach in which, for example, mathematics is used to argue the case for something, requires an understanding of how to write and interpret a persuasive text, thus blending mathematics with the literacy skill of persuasive writing. Williams et al. (2016) defined interdisciplinarity as involving two or more academic disciplines, integrated together in a teaching unit. Interdisciplinary approaches are usually based on a theme which has three essential components:

> (a) concepts should be appropriate and important to the individual disciplines,
> (b) interdisciplinary/integrated instruction should enhance the learning of the concepts and
> (c) the theme should provide a lens to recognize and understand larger issues and go beyond subject disciplines. (Williams et al., 2016, p. 20)

In the new Norwegian curriculum, implemented in 2020 (Utdanningsdirektoratet, 2019), interdisciplinarity is promoted, alongside developing students' democratic citizenship. However, in most research on interdisciplinary projects, mathematics is combined with science (see, for example, the overview provided by Williams et al., 2016). From our perspective, it is difficult to fulfill Frankenstein's (1998) requirement for criticalmathematical literacy's consideration of the mathematics of political knowledge without developing understandings about how mathematics is used to persuade an audience or manipulate its viewpoint.

In this article, we investigate preservice teachers' discussion in small groups about how to design a poster or brochure that would reduce the amount of cigarette butt litter, the theme we chose for the interdisciplinary project. To gain insights in the preservice teachers' understandings about the mathematics of political knowledge, we focus in this paper on how their awareness of their chosen audience's needs affected implicitly or explicitly the mathematical representations they included in their poster or brochure.

Using mathematics to argue for a change in behaviour

Research in mathematics education about how learners produce texts in which mathematics is used to argue for people to change their behaviour is uncommon, particularly where the focus is the learners' consideration of a specific audience's needs. Nevertheless, some research studies on critical mathematics education projects do touch on this. In a Norwegian study in which junior secondary students undertook a traffic investigation, they had to make an in-class presentation and write a letter to the local municipality about changing the existing road conditions to prevent serious accidents (Herheim & Rangnes, 2015). The teacher used the letter as a motivation for having the students determine whether wild sheep on the road was an issue serious enough to be included. The letter's audience affected the

students' mathematical thinking, in that they discussed how their collected data, should be presented to make a strong argument for raising the height of the crash barriers.

In her PhD project in the US, Pennell (2019) combined critical literacy with critical mathematics education in a study in which small groups of middle school students investigated various social justice issues. In one project about same-sex marriage, the students decided to set up a website that focused on the suicide rates of LGBTQ+ people in states which allowed same-sex marriage and those which did not. The three students in this group discussed how to present information so the audience would support same-sex marriage and so reduce the suicide rate. One student wanted to make more of the slight correlation between the data sets than the other students thought was appropriate. Pennell (2019) stated that the subsequent discussion about the importance of the message and its factual basis increased their understandings:

> This conversation further allowed the boys to reflect on their feelings about how information is displayed, how information can be manipulated (at worst) or structured (at best) to emphasize a point, and what language is necessary to get an argument across. (p. 84)

Although Pennell (2019) remained concerned about the use of exaggerated statistics to present the message, through for example the inclusion of a graph that over-emphasised a difference between suicide rates in states that did and those that did not allow same-sex marriage, she concluded that the students had addressed an authentic audience as was required in most language arts courses in the US. Having an authentic audience contributed to the students double-checking the correctness of their calculations and data.

Although these examples indicate that responding to an authentic audience did contribute to different kinds of conversations about critical mathematics education, the link between audience considerations and mathematical representations was not the focus of these studies. To provide more information about the impact of the audience, we investigate preservice teachers' discussions about the mathematical representations that they would include in a poster or brochure for changing people's behaviour.

Methods

The data came from one mathematics education workshop, designed and implemented by the second author, in the fourth year of a five-year Master teacher education course. It was part of the normal teaching programme and provided the preservice teachers with an introduction to possible research projects. It also allowed us to explore aspects of the LATACME project. In a survey of first-year preservice teacher, we had found that there was uncertain about aspects of implementing a project on air pollution that required students to engage with mathematical understandings in a real-world context. This workshop provided an opportunity to investigate preservice teachers' understandings about such projects at the end of their education.

One task in this workshop, which took about an hour, was to find out how the preservice teachers would tackle similar projects. This task was based on a virtual challenge started by

French young people of collecting cigarette butts in soft-drink bottles. A short video was shown of a young child discussing the dangers to the environment of cigarette butts (https://no-smoke.org/environmental-impact-of-cigarette-butts/). The preservice teachers were then given information about how on a 500 metre walk between the campus and the nearest light rail station, a bottle was completely filled with 254 cigarette butts. They were then asked to present a brochure or a poster that would use mathematics to convince an audience to reduce the amount of cigarette butts that ended up in the storm water drains ("Lag et argument med matematikk som vil overtale publikum til å redusere mengden sigarettstumper som blir skylt ned i avløpsvannet").

Four groups allowed their discussions to be audio-recorded. These groups had three (Group 1 and 4), four (Group 2) and five members (Group 3). Initially, all three authors read the transcripts and identified aspects of the discussion, which were loosely connected to Skovsmose's (1994) six entry points to reflective knowing. These entry points can identify the kinds of reflections that the preservice teachers engaged in about mathematics. However, it became clear that adding a requirement to choose an audience affected these reflections in ways not discussed by Skovsmose. In this paper, we do not discuss the mathematical arguments as such, but instead focus on the impact of adding a requirement to consider a specific audience.

Consequently, we focused on analysing the transcripts of the audio-recordings to identify how having to choose an audience affected the mathematical representations the preservice teachers included in their argument. Initially all three authors went through one transcript, identifying implicit or explicit references to the audience and connections to the mathematical representation to be included in their brochure or poster. After agreement was reached on what constituted a discussion (more than one statement) and an implicit and an explicit reference to audience, the first and third authors analysed the remaining transcripts. From this analysis, we then identified the foci that seemed to be brought out in discussions that connected audience needs with mathematical representations. These results are discussed in the next section.

Results and discussion

In this section, we begin by describing briefly the different audiences, before discussing the points raised in regard to how to incorporate mathematical representations into the presentations. Each group had extensive conversations, in particular Groups 2 and 4 whose discussions lasted for 42 and 33 minutes respectively. Nevertheless, the groups tended to raise similar issues in regard to why particular representations of mathematics should be included. These were to do with: the impact on the reader; and how much of the modelling, calculations or thinking should be included in the presentation. In the next sections, we describe the choice of audience and the points about the inclusion of the mathematics, with relevant examples from the transcripts.

Audience

Each of the four groups chose a different audience, sometimes as a result of an explicit discussion and at other times through an implicit assumption that there was an agreement on who the poster or brochure would be for. Group 1 explicitly chose the mayor of Bergen; Group 2 implicitly focused on those who throw away cigarette butts; Group 3 focused on parents who might worry that children could pick up and eat a cigarette butt; Group 4 discussed the managers of the main bus station and the areas around it, but with the intention of getting their support so that cigarette smokers could be approached to change their behaviour in regard to throwing away cigarette butts. Group 3 had the most extensive discussion about choosing an audience which seemed to stem from their own lack of knowledge about the polluting damage of cigarette butts.

G3S1: Jeg tipper det er veldig mange av de voksne som ikke bryr seg fordi de ikke vet.	G3S1: I guess there are a lot of adults who do not care because they do not know.
G3S5: Ja.	G3S5: Yes.
G3S1: Det var masse her jeg ikke visste.	G3S1: There was a lot here I did not know.

They went on to discuss how adults, which seemed to exclude themselves, were disinclined to listen to information about the environment because they felt bullied by climate change activists. Focussing on parents, grandparents and others who care about children would allow them to use their emotions to draw them in and then perhaps present the important environmental information.

G3S1: Ja. Vi må liksom ha en sånn der setning som vi får oppmerksomhet på da. Eller så fortsetter de å lese og da får de litt den der miljøgreia uten at de vet det.	G3S1: Yes. We must somehow have such a sentence where we get the attention then. Or so, they continue to read and then they get a little of that environmental thing without knowing it.

In each group, there were discussions about the mathematics that should be included in the poster/brochure presentations. As seemed to be the case in Herheim and Rangnes (2015), having a specific purpose for communicating to an audience did contribute to the kinds of mathematical discussions that occurred in the groups. The two main themes from these discussions are described in the next sections.

Making an impact

In considering the needs of their audience, the major concern was how to use mathematics to make a strong point that would convince the audience to change their behaviours. This seemed to be similar to the aim of the students in Pennell's (2019) study. However, our results provide other insights into different aspects of this choice. Sometimes, the discussions were about the visual impact that could be achieved with a poster or brochure that would result in the audience having a strong reaction to it. At other times, it was about finding numbers which an audience would consider relevant and so would contribute to changing behaviours.

In some groups, the need to make an impact with their presentation was implicit in the discussion. For example, Group 1 considered including a graph in their PowerPoint presentation. Their audience was the mayor of Bergen, but there is no discussion about whether the mayor would need information conveyed in a graph. Instead, it seems that implicitly they considered that a graph would look more formal and make the point they wanted to make more convincingly. Initially, they thought to include a bar graph but realised that it would only have one bar and hence not convey their point, so they then chose to include a line graph to show an increase of the number of cigarette butts against the amount of area, "Ja, at den bare øker med meterene. Så ser man bare at den stiger. Et linjediagram." ("Yes, it only increases with the metres. Then you see that it only rises. A line graph.") The impact that they wanted their audience to respond to was that the more area of Bergen, that was considered, the greater number of cigarette butts which would be found. Having a graph that showed a rise seemed to be considered a way of supporting the audience to see the urgency for doing something about it. However, the reasoning for the choice of a line graph is not discussed explicitly.

In the other groups, the focus seemed to be on finding a big number or on ways of presenting a big number, which would engage their audiences. For example, Group 2 focused on how to present "a big number" in a visually dramatic way. This seemed to be connected to their view that the (undefined) audience of their poster may not have the skills to interpret a lot of mathematics. However, they struggled to calculate a sufficiently large number that would allow them to compare, for example, the length of bottles or cigarette butts against the length of a light rail carriage or the height of a local mountain:

G2S1: Shit. Vi må ha litt høyere enn det, da.	G2S1: Shit. We must have a little higher than that, right.
G2S2: Vi må gjøre det litt mer dramatisk.	G2S2: We need to make it a little more dramatic.

Later they discussed how to situate the visual aspects into a coherent presentation:

G2S2: Fem bybanevogner, det.	G2S2: Five light rail cars, that.
G2S1: Fem bybanevogner! Per time!	G2S1: Five light rail cars! Per hour!
G2S3: Per time.	G2S3: Per hour.
G2S2: Fylles med røyk istedenfor mennesker.	G2S2: Filled with smoke instead of humans.
G2S1: Okei, det var litt kraftig, da.	G2S1: Okay, that was a little bit over the top, right.

The link to the audience is implicit but it is clear that shocking their audience in some way is viewed as important, if they are to affect the audience's behaviour towards the environment.

Group 4 also considered how to make an impact on their audience, who explicitly were the management of the bus station area, but implicitly seemed to be cigarette smokers. Within this discussion, they began to discuss whether the numbers would seem reasonable to the readers of their poster. They first decided in which area of Bergen, they should situate their efforts to change smokers' behaviours. In the end they chose the main bus station in Bergen which has a light rail stop and is close to the railway station. After some calculations of the area covered by the bus station light rail stop, Group 4 determined that there were a lot of cigarette butts in the area.

G4S1: Det er greit. Men det er heftig. Da er det titusen sigarettstumper på Bystasjonen. Okei. Da har vi det.	G4S1: It is okay. But that's a bit much. Then there are ten thousand cigarette butts at the bus station. Okay. Then we have it.
G4S2: Mhm.	G4S2: Mhm.
G4S1: Mer enn titusen. Det hørtes mye ut. Det hørtes veldig mye ut.	G4S1: More than ten thousand. It sounds a lot. It sounds like too much.
G4S2: Vi får regne på nytt da.	G4S2: We have to calculate again then.
G4S1: Eh, nå har jeg målt og. Skal vi se da.	G4S1: Eh, now I have measured too. Shall we see then.
G4S2: Det er jo, det stemmer jo for alle tallene.	G4S2: Yes, it's true for all the numbers.
G4S1: Nå har vi jo laget en veldig, dette her er en veldig forenklet modell. Det er jo derfor.	G4S1: Now we have made a very, this is a very simplified model. That's why.

Although they were initially happy with having such a large number to present to their audience, it soon raised concerns about whether the number was reasonable. This resulted in them checking their measurements and calculations, with the information provided earlier, to determine the rate of cigarette butts per square metre and multiply this by the area of the bus station. When the calculations seemed correct, they then considered how their simple model may have led to them obtaining an inappropriate number. Although not discussed explicitly, they seemed to fear their audience would not consider such a large number as being reasonable.

Similar discussions about the correctness of the calculations occurred in the other groups, but it was not always connected to concerns about whether their chosen audience would find the numbers too large. Instead, these discussions were more often to do with whether their peers and the teacher educator would expect some discussion of their calculations.

The amount of mathematics included in the presentation

The other main connection to the audience was in how the groups discussed what mathematics should be included in the presentation. This was related implicitly or explicitly to the knowledge and skills the audience might have.

Group 1 discussed using the greater Bergen area of 458 km^2 to determine how many cigarette butts could litter the area, if the density was the same as for the ones which had been collected. This then led them to similar concerns raised by Group 4, in the previous example, about whether their assumptions about the area were appropriate. They then considered both what areas would have more litter and those which would have less. Although they knew that the fjords around Bergen which were included in the 458 km^2 would also have cigarette butts, they decided to exclude this area because they could not be sure of how many there would be. They followed this discussion by thinking about who was their audience, "Men hvem er det vi vil liksom vise tallene våre til da? Er det kommunen eller er det?" ("But who are we to show our numbers to then? Is it the municipality, or is it?").

A similar discussion that linked determining an appropriate number to choosing an audience occurred in Group 4, where one preservice teacher stated, “Nei, jeg synes jo den er ganske bankers da, egentlig. Men det jeg lurer på er, hvem kan vi bruke disse tallene på?” (“No, I think it’s quite a banker then, really. But what I’m wondering is, who can we use these numbers on?”) Banker is an idiom which means that it is a good thing, in that it is “as safe as banks”. These discussions suggest that only the final number was worth sharing, which then led to the groups deciding who the numbers should be shared with.

There were also discussions about presenting numbers in ways that the audiences would understand. For example, Group 3 decided to give an approximate amount of cigarettes, for a particular area, because they considered it would be easier for the audience to relate to or for them to present.

G3S1: Kan vi ikke bare skrive over to hundre tusen?	G3S1: Can’t we just write over two hundred thousand?
G3S5: Ja.	G3S5: Yes.
G3S1: Det er litt sånn lettere å forholde seg til.	G3S1: It’s a little easier to relate to.

These discussions about how to present the numbers in a simple way could have been related to what they considered were the audience’s interests or skills in understanding mathematics. Group 2 discussed this explicitly as being about critical thinking skills.

G2S1: Også kan vi jo tenke at de som leser dette, de	G2S1: We can also think that those who read this, they
G2S2: Er dumme?	G2S2: Are stupid?
G2S1: De har ikke den der matematisk kritiske tenkningen på plass, så	G2S1: They do not have that mathematically critical thinking in place, so

In Group 4, the need for including more of their calculations so they could be checked by others came after they had decided that they had a strong argument to present with the numbers of cigarettes that they had calculated. A “smash hit” is a Norwegian idiom for something considered to be fantastic, something that will surely capture the audience’s attention.

G4S1: Jeg tenker det er en smash hit. Sånn, så kan folk stille spørsmål om hvorvidt det stemmer eller ikke etterpå. Sant, det handler jo om kritisk matematikk ikke sant? At her smeller vi i bordet med et tall og en modell også kan folk stille spørsmål ved hvor i all verden kommer det tallet fra.	G4S1: I think it’s a smash hit. That way, people can ask questions about whether it’s true or not afterwards. True, it’s about critical mathematics, right? That here we slam the table with a number and a model and then people can ask questions about where on earth that number comes from.
G4S2: Men, skal vi bare vise at vi regner, altså, regnemåten vår. Må vi ikke ta utregning med. Lag et	G4S2: But, should we only show that we calculate, that is, our way of calculating. Shouldn’t we include the calculation. Make a
G4S1: Jo, bruk løsningen din.	G4S1: Yes, use your solution.

Although they highlighted that including the final amount perhaps would open themselves up to people asking critical questions about where the amount came from, they did, in the end, decide to do just that.

Some of these discussions, whether explicit or implicit, about providing background to the total amounts, such as their calculations, did lead to some of the groups reflecting on how mathematics was used in what they read online or in news articles.

G2S1: Jeg skjønner jo nå at folk liksom lurer folk i artikler og sånn på nett og sånn, for det er jo veldig fristende å bare	G2S1: I understand now that people kind of trick people in articles and online, because it is very tempting to just
G2S2: Pynte på litt og	G2S2: Decorate a little and

These reflections led to considering how school students could made aware of this manipulation, "Det er en fin oppgave for elevene å gå tilbake til og se, og være litt kritisk til" (It's a nice task for students to go back to and see and be a little critical of). At least for members of this group, being involved in developing an argument using mathematics led to them considering how their own and their future students' understanding of the presentation of arguments using mathematics could be manipulated, particularly if the basis for calculations is not included. This was very similar to the point made by Pennell (2019) from her study of high school students tackling social justice themes.

Conclusion

One of the aims of critical mathematics education is to use mathematics to understand social justice issues as part of Frankenstein's (1998) understanding the mathematics of political knowledge. In this paper, we have considered how having preservice teachers consider the needs of a specific audience affected their development of an argument which used mathematics to change people's behaviour.

Williams et al. (2016) identified three components necessary for interdisciplinary projects. The theme to do with identifying an audience to convince to reduce cigarette butt litter did involve the preservice teachers integrating mathematics education with persuasive writing. Insights from the two subjects were combined when doing this project but led to considerations which would normally be outside of each of the individual subjects. Mathematics is not usually included in persuasive writing and writing persuasive arguments are not usually included in mathematics education. The addition of the requirement to choose and respond to the needs of a particular audience led to discussions about what was needed in order to persuade an audience as well as a need to check their calculations. Yet this combination was necessary in understanding how persuasive texts could mislead. For example, when Group 2 recognised that their numbers were not likely to withstand a critical scrutiny from others, there was a realisation that material that they were being presented with, such as information online, could also have been manipulated to make a specific point. Given that the Norwegian curriculum has both a focus on developing democratic citizenship

and interdisciplinary projects, critical mathematics education provides a fertile ground for inclusion in projects with these foci.

However, although all the groups were engaged with the task, the willingness to manipulate the mathematics to ensure that the audience had an emotional reaction, which was deemed important if they were to change behaviour, raises some issues. As Pennell (2019) found in her study, manipulation of numbers seemed to be accepted by some of the preservice teachers as appropriate if it ensured the desired result was achieved. It may be that wider acceptance of fake-news tactics has become normalised. This means that in discussions with preservice teachers about instigating such projects in their future classrooms, there is a need to explicitly discuss how to use the logic of mathematics, rather than just the inclusion of large numbers, in persuasive arguments.

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