Investigating How Students Grapple With Scale and Slope During an Urban Park Redesign Mapping Task

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Abstract

Humans use space as a lens to navigate and make sense of the world, thus successfully applying spatial concepts is an important life skill. Spatial thinking and developing spatial concepts are core components of school Geography curricula. Teachers teach geographical skills systematically aligning to the curriculum; however, students can struggle to understand and apply some spatial concepts and less is known about how students use conceptual skills in open-ended tasks.

Set alongside a larger study (Kriewaldt et al., 2021), this paper reports on how young people were challenged to employ and develop spatial thinking during an open-ended task situated in place. We examine how students approached two challenging geospatial concepts: scale and slope. This article argues that Year 7 students were less consistent and precise in applying scale than the Year 9 cohort, with Year 9 students more advanced in awareness and comprehension of slope than those in Year 7. As well, it points to the actions of teachers to foster the long-term understanding of geographical concepts.

Keywords: spatial concepts, scale, slope, geography education, pedagogy, geographical skills, inquiry learning, instructional support.

Introduction

Geospatial technologies are increasingly pervasive in everyday life, however many people have limited spatial thinking abilities to use these technologies effectively (Metoyer et al., 2015). Spatial thinking concepts are essential to explaining real-world matters and posing changes that are grounded in space and place. Many children do not develop strong spatial thinking skills in their natural home and school environments, thus explicit spatial education is needed (Liben, 2017; National Research Council, 2006; Robertson et al., 2019). School geography is a key setting in which spatial concepts and thinking are developed (Havelková & Hanus, 2021; Jo & Bednarz, 2009; Liben, 2017; Metoyer et al., 2015). Teachers play an important role in supporting students' spatial thinking development (Pilato et al., 2023) by providing quality instruction using tools of representation that enhance and develop strategies for spatial thinking regardless of the differing spatial thinking approaches and preferences that students may bring to the classroom (Metoyer et al., 2015).

Spatial concepts consist of key knowledge that help us to make sense of our world, to develop understanding and to make generalisations, which are essential for developing spatial thinking skills. Developing an understanding of each concept is foundational to spatial thinking and fostering capacity to use them concurrently is ultimately the goal to promote spatial thinking. As Dal (2008) argued, it is difficult to think, make simple or complex relations or explain mechanisms if you do not understand the terminology and underpinning concepts. Concepts can be classified according to their complexity (Golledge et al., 2008; Jo & Bednarz, 2009), forming the basis of a possible learning progression (Mohan et al., 2014). Golledge et al. (2008) argued that other than four spatial primitives (identity, location, magnitude and space-time), all geospatial concepts involve *inheritance* characteristics from *lower order* concepts that must be defined and understood first, with complex abstract concepts having many more inheritance links than simple concepts. They classified geospatial concepts as primitives, simple, difficult, complicated and complex, suggesting that primitives be taught in preschool to Year 1, simple concepts in Years 2 to 4, difficult concepts in Years 5 and 6, complicated concepts in Years 7 to 10, and complex concepts in Years 11 and 12 (Golledge et al., 2008). Concepts need to be incorporated into lessons using direct instruction and progressively applied at more advanced levels of complexity to foster stronger long-term acquisition.

As Pilato et al. (2023) highlighted, most studies investigating spatial thinking skill instruction take place in laboratories rather than in classrooms, with laboratory training of cognitive skills often failing to transfer to improved academic outcomes in school-based settings. Also, interactive tasks requiring students to construct understanding and to convey their understanding to others can lead to deeper processing that supports students' spatial thinking skills (Pilato et al., 2023). The degree of challenge presented by a shared geographic experience is affected by differences in students' experiences, capabilities and interests (Bennetts, 2005).

This paper explores how secondary school students considered site slope and plan scale during a collaborative urban park redesign mapping task. Scale and gradient were classed as complicated concepts by Golledge et al. (2008) and complex concepts by Jo and Bednarz (2009), with Bell (2006) detailing many specific complexities in understanding scale. The work forms part of a broader study into secondary student collaborative geographic inquiry, with earlier papers examining the actions of the teacher and teacher-student interactions whilst students engaged in collaborative inquiry (Kriewaldt et al., 2021), and student use of core geographic concepts and spatial reasoning (Kriewaldt et al., 2023). Our study is useful to augment the limited research on how children collaboratively apply complicated concepts in a classroom setting.

The mapping task involved student groups producing a scaled design for Lincoln Square that addressed specified required and optional parameters. Over the course of a day, students first visited Lincoln Square to observe and experience the existing layout, then in a nearby classroom laboratory worked in groups to brainstorm and research ideas, produce a detailed scaled design, and then presented their mapped design to the class, justifying how their design addressed the specified parameters. Students from a Year 9 and a Year 7 class undertook the task on separate days, supervised and supported by their usual humanities teachers.

One key task feature was its grounding in reality: rather than designing a hypothetical park to suit hypothetical users, the work focused on an actual site with distinctive characteristics. Lincoln Square is a 100 m by 150 m rectangular open space in Carlton in inner Melbourne, featuring a perceptible natural slope due to an 8 m change in elevation between the north-east and south-west corners of the park. This affects movement through the park and connectivity to the surrounding area; views and sightlines of park features; as well as potentially constraining the siting and installation of park elements requiring extensive flat surfaces, such as formal sporting facilities. At the time, the park was undergoing a controversial redesign to dissuade skateboarders from congregating at the site, in a separate consultative process managed by the City of Melbourne.

This paper examines how the two student cohorts dealt with scale and slope during the design task, exploring similarities and differences in their approaches and understanding. Its focus is on addressing (1) How did two student cohorts grapple with scale and slope during a design task? and (2) How did teachers provide assistance/guidance in response to these differing capabilities?

Methodology

This study draws on the filmed actions and dialogue of teachers and students undertaking a collaborative problem-based inquiry task in a secondary school geography classroom. The participants came from a government secondary school located in inner northern metropolitan Melbourne, Australia, with the school classed as having students from advantaged socio-educational backgrounds and academically performing above average compared to benchmark testing scores across Australian schools. The participants were a class of twenty-two Year 9 students, aged fourteen to fifteen years old and taught by a teacher with over twenty years' experience in teaching geography and humanities subjects, and a class of twenty-one Year 7 students, aged twelve to thirteen years old and taught by a teacher with eight years' experience.

The task, developed by the Year 9 teacher, involved students redesigning a local inner-city park whilst addressing specified core and optional parameters. For the Year 9 students, the five core parameters were: (1) including accessibility for people with disability, (2) reflecting and respecting the indigenous Wurundjeri culture, (3) incorporating sustainability, (4) including commercial activity, and (5) offering something for a wide range of users. In addition, students could optionally choose to (1) reflect the park's proximity to the University of Melbourne, (2) reflect the area's multicultural history, and/or (3) include use for public events. The task was simplified for the Year 7 class, who addressed only the first three core parameters with the other two parameters becoming optional considerations.

The task was introduced to students during a humanities class at their school, with students then spending a full day outside their school setting completing the activity. The students first visited the park with their teacher to observe site characteristics. Next, students spent three sessions in the University of Melbourne classroom laboratory, working on the design task collaboratively in groups of three to four students. Groups had access to iPads to assist with research and general stationery items. The Year 9 teacher also provided measuring tapes. In the first session, students undertook Brainstorming and Research, with an A4 1:400 scale map of the existing park layout and an A3 gridded brainstorm sheet provided to guide their thinking. Session 2 involved students creating a Detailed Design, which included negotiating priorities and incorporating ideas onto an A2 blank 1:250 scale park plan with only trees marked. In session 3, students finalised their designs, planned their four-minute presentations and presented their designs to the whole class, justifying how they had addressed the criteria. Peer assessment using the task criteria also enabled reflection on their own endeavours in the process.

During each session, the teacher first outlined what students were expected to do and then systematically circulated amongst table groups, monitoring global progress on the task and providing targeted and differentiated support to groups (Kriewaldt et al., 2021). At times, the Year 9 teacher used short periods of explicit teaching to the whole class to refocus student attention, reinforce geographic concepts such as scale, or highlight possible approaches to the task (Kriewaldt et al., 2021), whereas the Year 7 teacher's communications to the whole class during sessions focused on improving student behaviour or highlighting the time remaining in the session. The students spent about 80% of each session working independently in their groups without teacher presence.

As students were required to prepare a scaled design to fulfil the task, both teachers commenced the Detailed Design session by explicitly explaining the scale of the provided 1:250 maps, then described an example item's dimensions and how that would be represented on the scaled plan. They recommended that students cut out scaled templates of design elements and then manipulate these on the plan to assess size and determine optimal position, providing scissors and coloured paper for this purpose. Slope as a concept was not raised or taught by the teachers to the whole class over the day, however the site accessibility parameter indirectly prompted students to consider what made the existing park design inaccessible and how they could address this. At the time, Lincoln Square featured a centred paved flat area adjacent to Swanston Street that stepped down to three paths to Bouverie Street, these being a short steep central path and two longer flatter paths connecting to the western corners of the Bouverie Street edge. There was no direct route for wheelchair movement through the park from Swanston Street to Bouverie Street. The provided maps did not include elevations or contours. Students had to reconcile their memories of the three-dimensional sloped space from their site visit with the two-dimensional site representation on the provided maps, then consider any implications for their design or design elements.

This study focuses on the data generated and recorded in the classroom laboratory, which has ten unobtrusive video cameras and microphones mounted on the ceiling in addition to table microphones. This captured teacher movements and interactions with groups as well as all dialogue, gestures and work by students at their tables. Student work samples produced during the lesson were digitised. Video footage of table group discussions during the first two sessions and student presentations during the final session were analysed, specifically focusing on any consideration of scale, slope and topography. This totalled 14 and 11 hours of footage for the Year 9 and Year 7 class respectively, as the Year 7 class had a shortened first session. Henceforth the table groups are referred to as 9A, 9B, 9C, 9D and 9E or 7A, 7B, 7C, 7D, 7E and 7F, with the students within a group referred to as 9A1, 9A2, 9A3 and 9A4, etc. The two teachers are referred to as Y7T (Year 7 teacher) and Y9T (Year 9 teacher).

Teacher perspectives on their actions, motivations, student work and what they might do differently were gathered during semi-structured interviews conducted after the inquiry. These interviews were transcribed and analysed thematically using the topics covered in the interview as themes.

Results

Working with scale

Preparing a scaled design posed two challenges for students. First, they had to decide the actual dimensions of planned items, then had to apply the scale to represent the items accurately on the 1:250 map.

This first aspect proved challenging for both cohorts, with many students struggling to visualise how large an item should be or the actual distance that a length such as ten metres physically represented. While it was relatively simple for students to research the standard dimensions of a basketball court or the typical size of a food truck using the iPads, the size of other items such as fountains, playgrounds, stages, cafes, greenhouses and toilet facilities can vary enormously depending on the context. Following the field visit, all students from both cohorts felt that the existing playground (8 m x 8 m) was too small and argued that their designs should have a larger playground that accommodated some accessible equipment. While some groups, such as 7F and 9C, investigated the dimensions of wheelchair-accessible play equipment and then sized their playgrounds based on these data, others focused on playgrounds they had visited elsewhere that they felt were a better size and researched them using Google Maps, while many made judgements based on the measured or estimated size of the classroom. All Year 9 playgrounds were designed larger than the existing one, while half of the Year 7 groups proposed playgrounds that were larger and the remaining half were the same size as the existing one. Part of the difficulties stemmed from student perceptions of space, with 7C2 and 7D3 openly admitting that they didn't know what a metre looked like, appealing to their peers and the teacher for assistance. Here teacher experience came into play: Y9T anticipated that student perceptions of size might need support, bringing tape measures so that students could physically measure out distances as they discussed them and measure the classroom dimensions for reference. Y7T did not provide tape measures, instead provided approximations e.g., "*that wall [pointing with hand] is probably close to eight to ten metres long*", "*that whiteboard is about 1.5 metres*", or when a student started pacing to estimate a wall length "*So each of your steps is probably just under a metre naturally, so you could step it out slightly more, that's about a metre*".

One potential pitfall for students was confusing different length units in their discussions, as they used metres when talking about actual item size and centimetres when drawing on the map. Several Year 7 students stated lengths without explicitly stating the unit used, which led to misunderstanding about item size on the scaled map. For example, having just drawn a 3 cm x 3 cm rotunda shape (representing 7.5 m x 7.5 m), group 7F then discussed coffee cart dimensions. 7F2 proposed that it should be 5 by 2 (meaning metres), to which 7F1 stated that "*I'm saying the coffee cart, like the actual size. Not the centimetres. It should be one metre by two metres, that's how big the coffee cart is*", with 7F3 arguing "*But that's still not very big. It would be 2.5 by three, wouldn't it?*", and 7F1 responding "*But then like the rotunda is as small as the coffee cart!*". However, other Year 7 students and all the Year 9 students avoided mixing length units when discussing dimensions and applying the scale, specifying both the quantity and its units as they discussed possible sizes. For example, 7A1 suggested "*So what about if it's 7.5 metres by 7.5 metres, that's three centimetres by three centimetres, that's quite a lot*". During discussions with students Y7T and Y9T always specified both length and units, particularly if a student had omitted that detail.

For most students, length conversions from metres to centimetres using mental calculations, iPads and phones and then using that on the plan, appeared less challenging than deciding item dimensions. One behaviour observed in both cohorts was to choose item dimensions that simplified both the scale calculation and drawing of the item on the map. For example, group 9B initially proposed a 22 m x 9 m dog park to fill available map space but adjusted that to 20 m x 10 m because it was "*easier*" and they didn't have to "*do the maths to work it out*". Most groups deliberately or subconsciously adopted dimensions that were multiples of 2.5 (or 5) metres so they could be drawn easily as whole centimetres on the map. A notable example of this is group 7F's final design featuring a 7.5 m x 7.5 m rotunda, a 25.0 m x 12.5 m playground, a 12.5 m x 7.5 m stage, a 5.0 m x 2.5 m coffee cart and a 55.0 m long flying fox.

Some students from both cohorts chose to copy items across from the 1:400 existing layout map to their designs on the 1:250 map. The Year 7 students who did so fitted by eye, comparing the equivalent positions of map elements and then sketching shapes in on the 1:250 plan to match those on the 1:400 plan, with 7E1 explaining to Y7T that "*I'm just copying it off this one. Because the scale of the trees is the same*". In contrast, Year 9 students who transferred items across from the 1:400 map to the 1:250 map consciously made the necessary scale conversion calculations, as illustrated by 9D3 stating that "*I want to see how wide the path is, so we can copy. It's about half a centimetre, one centimetre is 4 metres, so that means . . . about 2 metres wide, okay. So this needs to be, ah, a bit less than a centimetre*".

This detailed investigation of path width was typical of the Year 9 students and a notable point of difference from the Year 7 students. As seen in Figure 1, the path widths adopted in Year 7 designs were generally wider than those in Year 9 designs. Although conscious of the scale requirements when designing items, the Year 7 students frequently ignored scale constraints when drawing paths. Y7T noticed this, asking some students "*How wide is this path?*" or "*How wide is this path in centimetres?*" to flag the issue. This had mixed results: 7D students then investigated the width of food trucks to determine the necessary path width and the equivalent scaled distance, whereas 7E kept 3 cm (i.e., 7.5 m) wide paths in their final design without contemplating whether that was excessive.

Students often queried item sizing once they had drawn it to scale either directly on the map or cut out a scaled shape to position on the map, based on how it looked on the page or relative to other items. Sometimes items were much smaller than they had anticipated, as illustrated by group 7D doubling the size of their fountain after 7D4 sketched the original sizing and argued that "*look, one centimetre is fairly small*". Similarly, after having earlier argued that the coffee cart should be 1.25 m x 2.5 m, 7F1 looked at the cut shape and exclaimed "*That! Is that how small it is? That's wrong!*", with 7F2 responding "*That's one by point five, that's 2.5 by 1.25*" and 7F1 then realising "*We need it larger than that*", adopting a final size of 5 m by 2.5 m. Other students were concerned that items appeared too large. When drafting in a basketball court based on standard dimensions, 7E2 objected that "*Ten centimetres! That's almost as big as that!*", with 7E1 then suggesting "*Maybe do it a bit smaller then, maybe do eight centimetres*" and 7E2 deciding "*I'll do like seven*", with 7E1 then proposing "*Do seven by like four*". Their final court was 17.5 m x 10 m, which was not the international standard 28 m x 15m and would not satisfy stipulations that scaled down basketball courts maintain those set proportions. Some Year 9 students were also concerned that items took up too much space but adopted differing approaches to resolve their concern. 9D3 proposed having a 10 m by 5 m gallery, then once it was drawn on the map told 9D2 that "*The art gallery is using up a tonne of space*", but 9D2 replied that was okay and they kept it at that size. When 9E3 was concerned that 9E's 12.5 m by 12.5 m playground was "*way too big*" 9E2 reassured them, pointing out "*Look how small it is relative to the rest of the park! The playground can be that big!*", then appealed to Y9T who was passing by to confirm this interpretation. As a final example, group 9A wanted to include the existing Bali memorial in their design but did not refer to the 1:400 map as a guide, with 9A4 instead estimating from memory that it was about 20 m wide. After drawing that distance to scale on the map, 9A4 commented "*That would be that wide. And that's like a big space. Let's just check*". and searched for satellite imagery of the site on the iPad to investigate further.

In summary, students grappled with scale within the parameters of a visited site, using two provided maps at different scales. Year 7 students understood that the size of their elements mattered but did not universally apply this scale to all elements and were often less precise in considering scale when determining size. Their vocabulary often included *big*, *small* and other similar variants. The Year 9 students used similar vocabulary when discussing object sizing. However, they more often precisely checked elements using the scale, measuring a reference point in the room or referring to supplementary information that they sourced from the internet using the provided iPad or their phone.

Envisaging the vertical dimension: considering slope and topography in designs

The concept of slope was not explicitly raised or discussed, nor were any measures of vertical dimensions included on the provided maps. However, maximising park accessibility was a core parameter to be satisfied for both cohorts. This section focuses on how the two student cohorts perceived, discussed and accounted for the park's natural slope in their designs.

While at Lincoln Square, Y7T told the Year 7 class that all the existing paths were too steep for wheelchair access and that this was something they would need to address in their designs. Later during the brainstorming and research session in the classroom, some students recalled this advice as they discussed options for accessibility, but most group discussions focused on accessible playgrounds, accessible toilets and including Braille on signs, rather than considering pathways and constraints on movement through the park in any detail. In group 7A, 7A1 suggested that "*if you're in a wheelchair you need a ramp, something more safe, flatter, less hills*" and 7A2 proposed that a large area become flat concrete, then realised that "*Oh, but we can't really get rid of the trees so we can't make it flat, unless we do it around the trees*", with the group then moving on to other topics. 7B2 commented that "*We'll make this one [pointing at one path on plan] less steep and then put in a ramp*". When 7B4 queried "*How are you going to make it less steep?*", 7B1 replied "*Make the ramp go more up here*". 7B4 thought briefly, then suggested "*Because the things are too steep, we could have the path in a zigzag pattern, because that means it won't be as steep*". However, this contribution was not captured on the brainstorm sheet and the group did not pursue it any further. Group 7C weighed up the relative merits of a wheelchair lift and use of ramps in the context of their proposed accessible playground, with 7C2 stating "*We don't want to exclude people, so won't have just a wheelchair lift. Like, not a wheelchair lift to get up, it's a ramp, which anyone could use*" and 7C1 agreeing, adding "*If it's just like flat with* *slowly gradual up and at different checkpoints have different things to play with, anyone can use it*". Group 7D discussed accessibility briefly within the first ten minutes, with 7D2 stating "*For accessibility, there should be ramps on, like half the stairs should be stairs and half should be ramps. Have a wheelchair playground. Make the paths longer so they're not as steep*". then they moved on to other topics for the rest of the session. While group 7F's initial discussion was also brief, with 7F1 suggesting "*For accessibility, could do like more ramps. Or like, not steep ramps*". and 7F2 murmuring "*Make western ramp less steep*", later 7F considered how they might change the paths. 7F2 suggested "*We'll make that swell out [mimes a zig zag pattern over the plan] because this is too steep*" but 7F3 cut in, proposing to "*Make it like level [demonstrates a flatter slope with arm]*". 7F2 responded that:

> Well we can't, because then it would just drop at the end. So what we're going to do, we're just going to go diagonally I suppose . . . Maybe here and here can go down to the actual end making it a longer distance so the angle isn't as steep, [demonstrates with arm], so you can go less steep which will help because it's too steep.

These dialogue snippets show that the Year 7 students were working at a basic level when considering how slope affected accessibility, with their suggestions limited to providing flat spaces, providing ramps or making paths less steep by making them *longer*. Their initial designs also reflected this. Most groups that included ramps within their design did not consider how practical they were for wheelchair users. While 7A2 sketched in ramps that were zigzagged, telling 7A1 "*See like this, it goes here, and then down, and then like that . . . You enter here, go around there, and then back. You know what I'm saying?*", others only specified to have ramps next to the stairs (e.g., 7B) while 7D drew their ramp as a strip in the middle of stairs covering the same horizontal distance without considering how steep that would make the ramp.

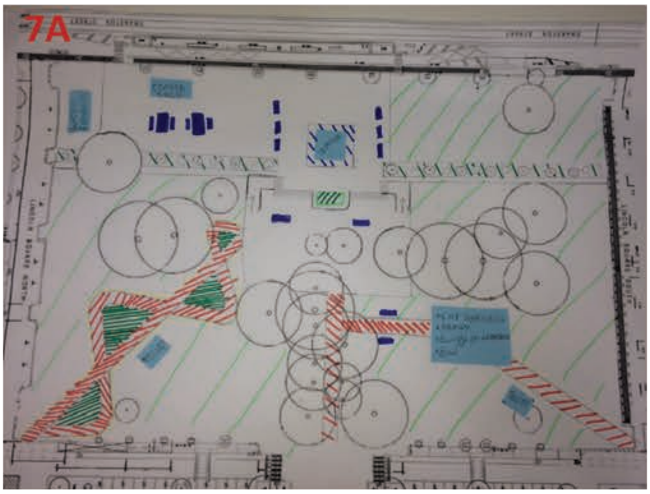
During the detailed design stage, Y7T noticed that many groups were still not considering path accessibility or else were using a longer paths approach to address it. With each group except 7E, Y7T spoke to them at their table using an experience travelling on winding roads up Mount Buller on the way to their school camp as a prompt to consider alternative solutions. For those that had adopted the longer path approach, Y7T emphasised the point a little further. When 7D4 argued that "*We're making them longer, so there's more . . .*", Y7T cut in with "*But the slope isn't going to change. So curving it [mimes with fingers in air] means you can get up without having to [mimes arm as steep slope] be as steep, you can come around more gradually . . . So maybe you need to think about amending your path, so it's more accessible*". With group 7F, when 7F1 stated "*We're going to have like little paths going like this, so it's more gradual*" and 7F2 added that "*instead of going straight down, because that will take some of the steepness out, [mimes with arm in air], because you have to travel further*". Y7T used the Mount Buller anecdote and 7F2 responded that "*So go slowly up, [pointing back at their plan] that's what we're doing*". Y7T pointed out that their longer diagonal paths were "*not really taking out too much of the incline, [mimes angle with arm]. You might want to think about winding it up a bit more, like have it wind in between the coffee and the rotunda [drawing a possible path with finger in air above the plan] perhaps*". 7F2 agreed that "*Yeah, that's actually a pretty good idea*" and so 7F adopted winding paths in their design (Figure 1). Most groups altered their path designs after this interaction with Y7T.

In contrast, the Year 9 students worked at a much more detailed level when discussing how to improve park accessibility, drawing on their personal observations and experiences as well as undertaking further research using the iPads. During the brainstorming session all groups discussed how providing ramps or changing path design might help improve accessibility. Most groups then researched ramp design standards to see what was legally required. For example, 9C decided that "*We need wheelchair ramps next to every set of stairs*" with 9C3 discovering the required slope was "*5 degrees max*" and 9C4 writing "*wheelchair ramps with 5 degree incline*" on the brainstorm sheet. Separately, 9A2 reported that the maximum gradient allowed for ramps was "*8 to 14 metres across for every metre you go up*" and 9B3 discovered "*every one metre up you need to allow twelve, that's so low!*". However, the groups were unable to use these details later when drawing their scaled plans because there was no specification of site slope on the provided maps.

As an illustration of the more sophisticated nature of Year 9 discussions, consider two group discussions about using ramps and the final design decisions they made. Group 9A contemplated including ramps in their design but 9A4 argued against this

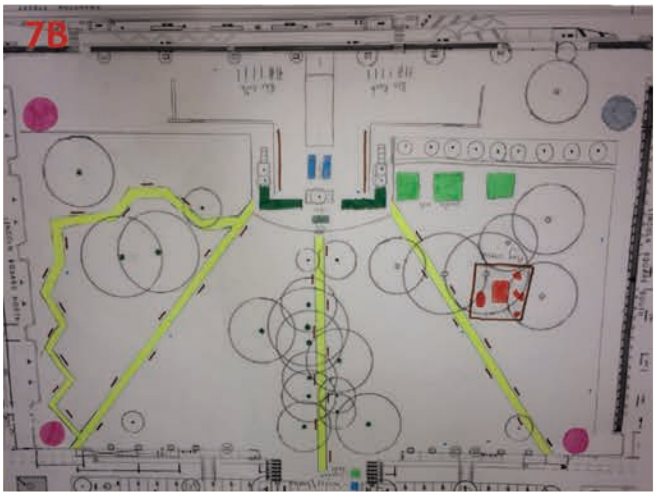
> because it would take a lot of work to level it out, you'd have to put steps at one of the ends or you'd have to have the path winding [demonstrates a zigzag pattern above the map, moving hand from left to right], which would take up a huge amount of park.

Figure 1: Selected Year 7 and Year 9 designs for Lincoln Square, with the accompanying verbal description of path accessibility given during their presentations to the class.

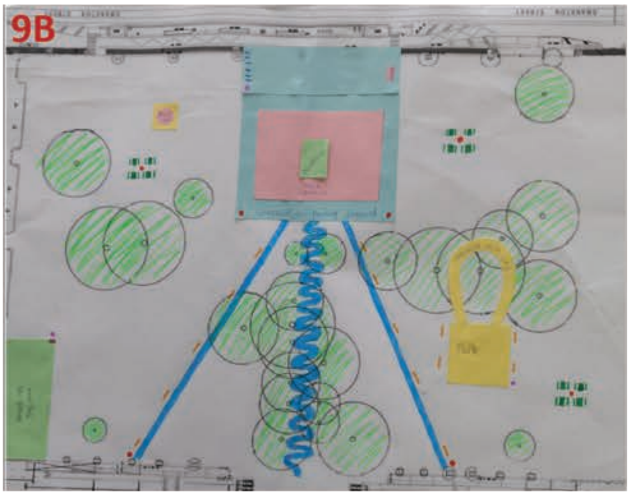


"The path that goes around is for wheelchairs, so it's easier for them to go up, the steeper one is for people who are walking. We've curved the corners so it's easier for turning."

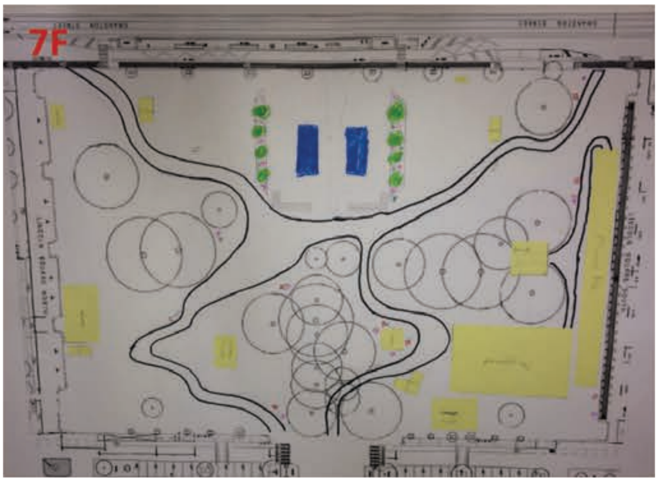
"Our paths, they look pretty small here but they're going to be 2.5 metres wide, so that's more accessible. Yes, it's pretty steep but we have added a wheelchair lift, so they can be lifted up there."



"We've got longer paths that are flatter so wheelchairs can use it, and ramps near the stairs."



"A playground with a flying fox, so it's going to be two levels, it's going to be wheelchair accessible with an elevated walkway so you get to walk through the tree branches, like a second level... And a winding ramp, so there's more space for wheelchairs to gradually go up the steep slope. "



"Wiggly line paths so it's not as steep to get to the street for people with disabilities and they don't fall. We've also got a huge flying fox, making use of the hill in the park."

"A nice wide winding path, it's inspired by mountain roads to ease the gradient on a steep hill, for wheelchairs, it winds up making it more accessible, then the ramps carry on all the way up to the tram stop at the top."

9A2 responded that "*if you ramp it left to right, make it less steep, you could make more progress that way*" with lack of detail about the precise site slope ultimately stalling the discussion. In the next session, 9A2 remarked that "*This path's a bit too steep for a wheelchair anyway*" with 9A4 deciding that "*I think we should have a wheelchair lift so don't have to have all the ramps everywhere*". Consequently, 9A's final design (Figure 1) featured a long wheelchair lift along the main east-west path and no ramps. Group 9B spent much time discussing how to reduce the gradient in the park so that they could install ramps for people in wheelchairs, revisiting the topic repeatedly. After 9B3 found the ramp standards, 9B were concerned whether ramps would fit in their proposed space. 9B2 suggested they "*do a zigzag thing [shows with hands above the small site map], like go around the trees*", but 9B3 commented "*That would take so long, imagine how long that would take [imitating pushing wheelchair wheels with hands]*". Later, 9B2 stated that "*We need to figure out how much steeper this is than this bit, to figure out if it's possible to make the ramp. I think if we make the zigzags far enough apart it will be possible to do it*". 9B4 argued that "*We'll just say there's a ramp like this, and no one will check to see if it actually works in real life. 'Cos this plan is 2D, no one can check if it works!*". The group agreed with this strategy, with their final design (Figure 1) incorporating a sinusoidal ramp for that path.

Unlike the other Year 9 groups, 9E worked at a conceptual level when designing their accessibility features. 9E started their brainstorming focusing on the accessibility parameter, with 9E1 musing that "*I don't know what we're going to do for the wheelchair cause it's so steep, it's too steep*". Then 9E2 suggested to "*Make it winding, then it's less steep. Like a mountain road*". Having decided to use a winding path as their main accessibility feature "*to ease the gradient*" the group moved on to other topics. During the design stage, 9E2 also suggested to "*have a ramp going up on either side to get up on the stage for disabled access . . . then they can access this whole area through here*" with 9E3 adding "*And then it can be a ramp like up to the street as well*". After 9E3 had sketched in the winding paths and the ramps to the stage area, 9E2 commented that "*And how winding they will be kind of depends on what the actual laws are*", with 9E3 adding "*Yeah, how much space we have, how steep it actually is, how much money we have!*" This was the only reference 9E made to the feasibility of implementing their winding path design (see Figure 1) at the site.

Another clear difference between the two cohorts was their consideration of slope beyond addressing accessibility, with Year 9 students demonstrating a greater awareness of the site slope than Year 7 students. There was no indication from their group discussions that the Year 7s had noticed the site slope during the field visit or thought about it how it might affect what they included in their designs. The sole exception to this was group 7F incorporating a flying fox that was "*making use of the hill in the park*". While Y7T used language conveying slope when addressing students, such as "*What was* <u>up</u> *here at Swanston Street*?", or "*It's about 100 metres from Swanston Street* <u>down to the bottom</u> *of the park, and along the bottom it's probably close to 150 metres*", the students did not use similar language themselves nor did they appear to react to those cues. Most Year 9 designs acknowledged the benefits of lack of slope by deliberately including flat paved spaces, for example "*a nice flat area where you can put food trucks and tents and stuff*" (9E1), however few of the Year 7 groups discussed the potential benefits of, or need for, flat spaces in their designs.

Although Year 9 students were more attune to the site slope than the Year 7 cohort, the extent that they considered slope varied amongst groups. Groups 9A and 9D remembered the slope when discussing one or two items. However, 9B, 9E and to a lesser extent 9C were conscious of the site slope throughout the design process. This was evident in their language, for example when 9E2 talked about positioning a stage "<u>Up</u> *around here, or maybe even* <u>down at the bottom</u>", and also in their use of gestures, such as 9B4 stating "*Food trucks.* <u>Up</u> *the top, where*" then using their hand to mime a flat surface. For 9C, realising that "*we have to prepare the ground as well!*" inspired them to redesign the whole park as an informally terraced space, as 9C4 described:

> Let's just make another set of stairs here, between all these trees here, so this area can be flat, Aboriginal art can be flat, and then more stairs going down, and then all of this playground area can be flat, so it's accessible for wheelchairs.

In contrast, groups 9E and 9B discussed the difficulties of landscaping to overcome slope and then actively sought ways to take advantage of the slope in their design. For instance, when 9E2 commented that "We *can't really change the downward slope of it*", 9E3 initially proposed "*putting in a lot of concrete to get rid of that*" but then realised that "*you're going to really have to build it up to get it flat and then it's going to be an issue for how wheelchairs are going to get up there, you'll have to have a really big winding ramp*". In a similar vein, 9B4 initially proposed building up areas with dirt to reduce the slope, however 9B1 was concerned about creating a "*big dirt wall*" and 9B2 argued that "*if there is a massive wall here, then there is going* *to be massive shadows over this road here and into those buildings*". For group 9E, the slope was a fundamental consideration in their stage design, focusing on the relative positioning of the audience and stage. When 9E3 argued that "*It's way too steep there for that, they'd be like*" and then mimed having head tilted back to look up, 9E2 responded that "*the stage would be at the bottom of the hill and the people watching would be at the top*". In group 9B, 9B2 noted that "*It's too sloped to have a soccer field on, or basketball court, or anything like that. It's not good for sport*". while 9B4 proposed multiple ideas to make use of the slope, including a long flying fox, installing water turbines to capture energy from water flowing downhill, and creating an elevated walkway ramp "*that goes through the tree branches*" as part of the playground.

Taken together, these verbal exchanges suggest that there is a progression in awareness and comprehension, with students in Year 9 demonstrating more advanced strategies for addressing slope. Timing of student exposure to supporting concepts in mathematics may contribute to these differences, as linear equations and gradient are taught from Year 8 in the Australian Curriculum.

Teacher actions to support student scale and slope understanding

During the sessions, the teachers acted in many ways to support their students' understanding of scale. This included the provision of physical resources such as rulers and tape measures; explicitly teaching the map scales and how to implement those scales in the designs; encouraging students to make scaled shapes of elements and manoeuvre them on the map to assess their appropriateness; reinforcing and modelling correct terminology when discussing dimensions and scale with students; hinting, prompting or correcting students when detecting obvious errors in the application of scale; describing relevant real-world examples that were familiar to students to support discussions around the possible style or sizing of design elements; and prompting students to estimate (Y7T) or measure (Y9T) items/distances in the classroom as a reference.

The teachers placed less emphasis on supporting understanding of slope over the day. Y9T noted afterwards that many of the students were "*very unprepared for the physical slope of the square . . . a lot of them had some quite bizarre ideas about how sloped it was . . . they both under and overestimated it quite dramatically*". Y7T discussed slope with each group solely in the context of designing accessible paths, using an anecdote from a recent school trip about winding mountain roads reducing the steepness for cars as a prompt so students would reconsider their proposed designs. For the Year 9 class, teacher discussions with students about slope were ad hoc based on what groups were discussing at the time of table visits. These discussions predominantly focused on designing accessible paths, with the content and depth of discussions varying depending on Y9T's perception of group needs. When 9A asked whether a path would be too steep to use as a ramp, Y9T initially suggested searching to find out more about the slope, "*I think that concept plan you found earlier had contour lines*" but after that proved fruitless, pivoted to support them in first mentally picturing the slope at the site, then suggesting they use the classroom height as a proxy and measure that. With group 9B, Y9T prompted them to think about other situations where they had observed ramps, stating "*You'll see out the front of a lot of public buildings, these giant long ramps that actually from the start to the end is not very far but [waved hand to show a zigzag]*" and then challenged them with "*Is there an alternative to the long ramp?*". Later, listening to 9B's discussions about using dirt to level out an area, Y9T responded "*Well there's two ways to make it level, you can dig out the high end, or you can add dirt to the low end*", which broadened their discussion. During Y9T's sole slope discussion with 9D, 9D3 explained to Y9T that they were "*minimising the gradient*" by using a particular ramp design. Y9T focused on the website where the design was sourced, exclaiming that "*It's actually a good website, it really shows you what the different gradients mean. It shows that 1:15 is not very steep, is it?! Like you've really got to have a mile long ramp to get over a small height*" but did not notice that 9D had adopted the general shape of the design whilst ignoring the length and slope specifications.

Both teachers indicated that with hindsight they would have conducted the field visit differently in order to better scaffold student comprehension of space and slope. Y9T suggested to

> do some sort of activity there to get them to . . . have a much better spatial appreciation of how big it is. . . . Maybe it's just taking a wheel . . . one of those measuring wheels down and saying . . . measure how many basketball courts could you fit end to end across this space.

Getting students to physically measure items they considered large or small while out in the field would assist their later estimations of sizes in the classroom. Y7T took a different focus, suggesting to

> get them to actually sketch where things were on the map, or take photographs of

things they liked, and . . . take photographs of the type of slope or the types of trees so that they could build a bit more of a portfolio to take in with them rather than sort of recalling from memory.

The teachers aimed to replicate the process with both cohorts, yet there were small differences in the resources provided, the types of exchanges that the teachers had with each group, and in the overall implementation of the classroom sessions. With hindsight, both teachers would ask students to undertake more activities during the fieldwork component. This concurs with Lim (2005), who argued that spatial intelligence and observation skills in adolescents are improved when students engage in fieldwork requiring them to record, share and co-construct their observations and understandings of local environments. Returning to the park midway through the task would have been ideal, but this is rarely practical with school fieldwork due to the prohibitive logistics, cost and disruption to other lessons.

Concluding discussion

There are many curriculum materials that offer a way to sequence understanding of a concept—for example skills books, worksheets and so forth—which may be paper-based or digital, and offline or online. Teachers often use exercises to teach about concepts and step-by-step or scaffolded approaches are often sequenced with examples that are hypothetical situations or unknown places. These approaches can and do enable learning. Yet there is a place to reduce scaffolding and enable students to experience the complexity of real-world design in which they must concurrently consider people, place and space, retrieving and applying knowledge to a novel situation. This project used a real-world task of park redesign requiring students to consider complex elements simultaneously whilst working collaboratively. These accounts of student dialogue can inform teachers of the thinking and reasoning of the students that they would otherwise miss.

This real-world design task generated data enabling the authors to interrogate students' use of the concepts of scale and slope. Golledge et al. (2008) classed these as complicated concepts to be taught in Years 7 to 10. We found that each table group of students varied in the ways that they grappled with scale and slope during the task. These variations included measuring, estimating, making scaled templates of items to add to the design map, checking for information using online resources, their peers and teacher. The excerpts of speech presented have informed our understanding that, on average, Year 9 students were able to grapple with scale and slope more thoroughly.

The teacher actions both preceding and during the task are influential. In a task of this type, interdisciplinary skill developments that have occurred in previous learning sequences are applied by students. The teachers designed or modified this project, offered instructional whole-class guidance related to the specific task and provided materials to support student deliberations. They systematically visited each group to offer in-the-moment monitoring, prompts and assistance during the sessions[1]. This was critical to fostering knowledge acquisition in response to the differing needs of each group. The combination of fieldwork, mapping dialogue and targeted teacher intervention made for stronger conceptual learning by both student cohorts.

Though no discipline can claim sole ownership of a concept, student understanding of scale and slope is predominantly developed in geography and mathematics. In teaching these across discipline areas through direct instruction, guided practice, and applying them to real-world tasks, this is an example of the need for a spiral curriculum in which concepts are incorporated into lessons repeatedly at more advanced level of complexity, leading to stronger long-term acquisition of concepts.

1 There is a detailed examination of the teacher interactions in this collaborative inquiry available. Kriewaldt, J., Robertson, L., Ziebell, N., Di Biase, R., & Clarke, D. (2021). Examining the nature of teacher interactions in a collaborative inquiry-based classroom setting using a Kikan-Shido lens. *International Journal of Educational Research,108.* https://doi.org/10.1016/j.ijer.2021.101776.

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