Using interactive physical models to improve pupil learning outcomes about rivers and coasts

Authors: Bridget Brady (JBA Trust), Kathryn Suter (Ermysted's Grammar School), Rob Lamb (JBA Trust and Lancaster University), Alex Scott (JBA Trust)

Abstract: Partnership between a school and an educational charity demonstrates how interactive physical demonstration models help to reinforce learning outcomes for spatial reasoning and processes in physical geography.

Introduction

This paper explores how the use of interactive physical demonstration models can help to reinforce geographical learning outcomes relating to rivers and coasts for secondary school pupils.

Ermysted's Grammar School in Skipton, North Yorkshire, and JBA Trust, an educational charity, have worked in partnership since 2019 to run three 'Interactive Geography Days' for Year 8 and 9 pupils. The aim was to provide pupils with an opportunity to increase their geographical learning about flood and coastal risk management in an exciting and engaging way using physical demonstration models. In addition, the sessions aimed to engage and inspire pupils, encouraging them to consider studying geography and to pursue related career pathways.

Ermysted's Grammar School is a voluntary aided grammar school for over 800 boys aged 11 to 18. Working in partnership with flood and coastal risk management specialists at the JBA Trust has given the school opportunities to increase geographical learning for pupils, beyond purely teaching geography as a subject. Additionally, it has enabled pupils to engage with professionals and with current geography university students, helping them to explore and consider ideas for their future studies and careers.

The use of physical demonstration models enables pupils to get hands-on experience of how water behaves in a river catchment and at the coast, as well as learning how a professional organisation uses theoretical ideas in geography to develop strategies to manage the water environment.

From the school's perspective, the benefits of the partnership have been summarised in a statement made during evaluation of the interactive geography days. "Our Year 8 and 9 geography pupils are so enthused by the interactive models that JBA Trust bring into school. They really bring to life the work we do as part of the geography curriculum and allow the boys to see the relevance of this in the real world. Each model provides a unique way of learning about how water moves in the environment. Their interactive and visual nature encourages pupils to consider the many varied and complex factors linking rivers, coasts, flooding and flood risk."

In this paper, we discuss how working in partnership has provided unique geographical learning opportunities for pupils, assisted the development of jointly-produced learning resources, and is helping the partnership to understand how the physical demonstration models support learning outcomes in geography.

JBA Trust is a charity that aims to help people create a resilient and sustainable future by supporting research, education and engagement. The Trust collaborates with partners to support pupils, schools, researchers, environmental charities and the public sector to improve understanding and management

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of environmental risks. All of the learning resources discussed in this paper, plans for physical models, and other JBA Trust outputs, are freely available to schools and charities.

Physical demonstration models

The JBA Trust has been using physical models and interactive visualisation since 2011 to demonstrate key principles of flood and coastal risk management. These tools help make complex 3D process and spatial information easier to understand and helps to engage with changes over time by demonstrating scenarios such as the impacts of climate change on flood risk.

The models allow pupils to interact with river and coastal processes in a physical way, which is particularly valuable for kinaesthetic learners. For example, pupils can modify a river catchment themselves in the interactive sandbox (see below) and see the immediate impact on the river system. Teachers have found that pupils remember the experience of experimenting with the models in future geography lessons, re-calling key geographical concepts.

The four physical demonstration models described below are used to support the teaching of geography. Details of how each model addresses different parts of the geography curriculum are presented in Table 1.

Hydraulic river flume – demonstrates principles of flood risk management and river infrastructure

The hydraulic river flume shows how the velocity, water level and flood risk in a watercourse can be affected by typical engineered structures, for example weirs, bridges and culverts.

Figure 1: Hydraulic river flume

Coastal wave tank – demonstrates principles of coastal flood risk and erosion management

The hand powered wave tank demonstrates how effective different types and combinations of coastal defences are at preventing wave overtopping and flood risk. Over-topping volumes are measured for each type of coastal defence, making the demonstration into an informal experiment, and encouraging an appreciation of coastal processes and cost benefit analysis for flood risk mitigation.

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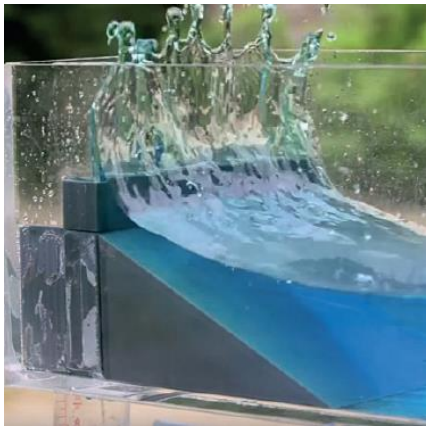

Figure 2: Coastal wave tank

Augmented Reality (AR) Sandbox – demonstrates topography, contours, river catchments, fluvial processes and natural flood management

The augmented reality sandbox shows how water moves through a catchment. Pupils shape the sand by hand to create river catchment landscapes which are then 'augmented' digitally in real time by a projector to show a coloured elevation map and contour lines. By adding virtual rain, pupils explore how topography, catchment management, river engineering and natural processes affect the flow of water and flood risk.

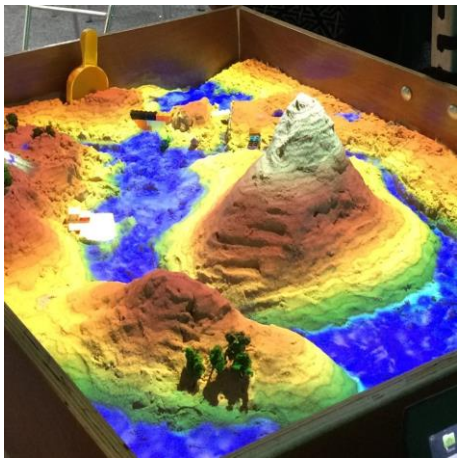

Figure 3: Augmented reality (AR) sandbox

Projection Augmented Relief Model (PARM) – demonstrates cartographic skills, extreme weather events and flood risk management

The PARM is a highly detailed, 3D-printed landscape based on remotely sensed aerial or satellite ground height data to create an accurate model that is then augmented with projected digital images, for example of areas at risk of flooding, historic land use or local landmarks. The 3D model aids the visualisation and understanding of spatial information.

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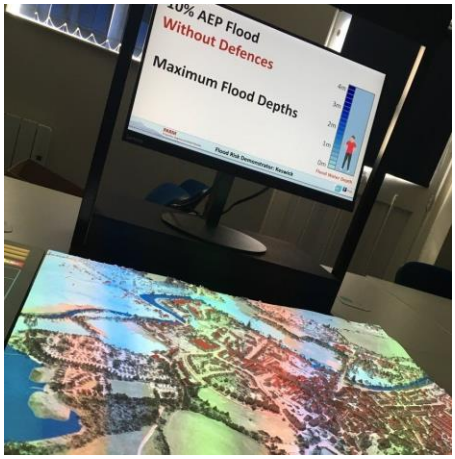

Figure 4: Projection Augmented Reality Relief Model (PARM)

Supporting the geography curriculum

The physical models help to illustrate many topics identified as keywords in the geography KS3/4 curriculum, as shown in Table 1.

Table 1: Table mapping JBA Trust physical demonstration models with geography KS3 and KS4 curriculum keywords.

Key stage	Curriculum keyword	Hydraulic river flumes	Coastal wave tank	Augmented Reality (AR) Sandbox	Projection Augmented Relief Model (PARM)
KS3	Natural hazards	X	X	X	X
	Extreme weather events	X	X	X	X
	Climate change (including mitigation & adaptation)	X	X	X	X
	Physical landscapes	X	X	X	X
	River landscapes	X		X	X
	River systems	X		X	X
	Fluvial processes	X		X	X
	Flood risk	X	X	X	X
	Flood risk management	X	X	X	X
	Hydrographs	X			X
	Coastal landscapes		X		
	Coastal processes		X		
	Wave types & characteristics		X		
	Coastal management		X		
	Cartographic skills				X
	Statistical skills				X
	Qualitative & quantitative data				X
KS4	Water & carbon cycle (including change over time, e.g. storm events, seasonal, human impact)	X	X	X	X
	River catchment	X		X	X

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	Storm hazards & impacts (including river & coastal flooding, high winds, storm surges)	X	X	X	x
	Coastal systems		X		
	Landscapes & processes		X	X	X
	Coastal landscape development		X		
	Coastal management		X		
	Drainage basins as open systems			X	X
	Water balance			X	
	Run off variation			X	
	Flood hydrograph	X			X
	Qualitative & quantitative skills				X
	Cartographic skills				X
	Statistical skills				X

Evaluation of benefits

Working as a partnership over three years, we have been able to refine the learning resources that accompany the physical models presented above, and to evaluate the geographical learning benefits of the physical demonstration model activities. By learning what works well (or less well) during the school sessions, we have been able to adapt and improve engagement activities for the benefit both of pupils at Ermysted's school, and anyone who accesses the Trust's resources. Here, we summarise the process of evaluating the learning benefits.

The interactive geography days involved question-led sessions that encouraged pupil involvement, incorporating opportunities to gauge pupil knowledge, to enable pupils to experiment and make predications and to discover the results of their investigations.

At the end of each session, pupils were asked to complete a feedback form to share their thoughts about the different activities. This enabled us to assess whether pupils had been inspired by their experience and to collate lessons learned to ensure continual improvement of engagement activities. Self-assessment gave an indication of how geographical learning had increased. The following data summarises the responses.

Sentiment analysis

The first stage of evaluation was to assess whether pupils were successfully engaged in the learning sessions. To do this, pupils were asked for three words that described how they felt during the sessions (2020/21 combined data, free text response). The most frequently cited words were "interested", "fun", "happy", and "excited", suggesting a positive experience conducive to engagement and learning. Other words suggesting a participatory and questioning experience included "enjoyable", "involved", "intrigued" and "informed".

These results are important in demonstrating that pupils were engaged and ready to learn in the sessions, therefore increasing the likelihood of improving their geographical learning about rivers and coasts.

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Preference analysis

Pupils were asked which activity they enjoyed the most and why. Figure 5 shows the responses, highlighting the popularity of the most interactive of the models, the AR sandbox. Reasons given by the pupils for expressing a preference included “most interactive”, “most fun”, “most interesting to observe”, “learnt the most from”, “learnt something new”, “most educational”, “most realistic”, and “most helpful”.

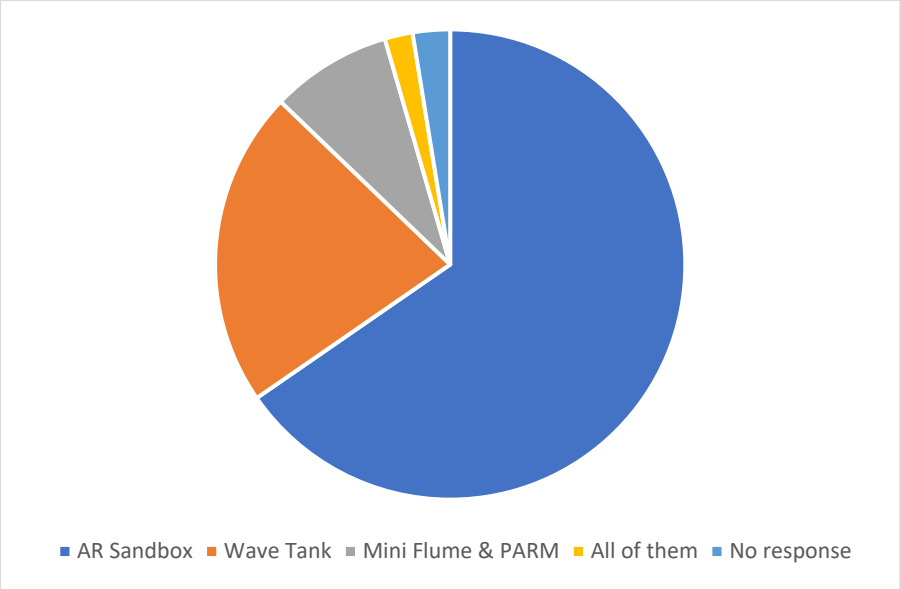

Figure 5: Pupil responses showing which activity they enjoyed the most (2020/21 combined data, free text response).

Statement agreement analysis

Pupils were asked to indicate their agreement to several statements about what they thought as a result of attending the interactive geography day, using a four-point scale, i.e. strongly agree, agree, disagree or strongly disagree. Figure 6 shows that more than two-thirds of pupils (and in some cases almost all pupils) agreed or strongly agreed with positive statements about understanding, learning or inspiration relating to flood risk.

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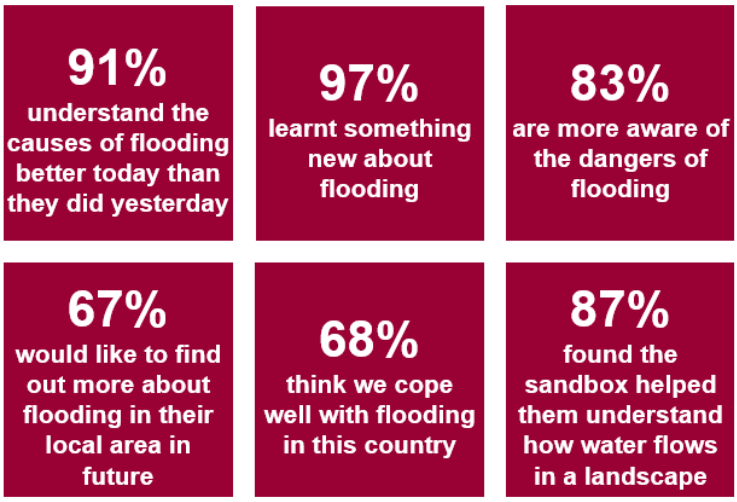

Figure 6: Pupil responses about knowledge gained during the physical model demonstrations (2020/21 combined data – average 141 responses per statement)

Experience description

Focusing on the most preferred model, the AR sandbox, pupils were asked to select up to three statements which best described their experience. The results plotted in Figure 7 show which statements were selected most often. Overall, pupils appear to have found the interactive sandbox session to be a positive and engaging experience, learning about rivers, coasts and flooding in a group environment, with relatively few negative statements being selected.

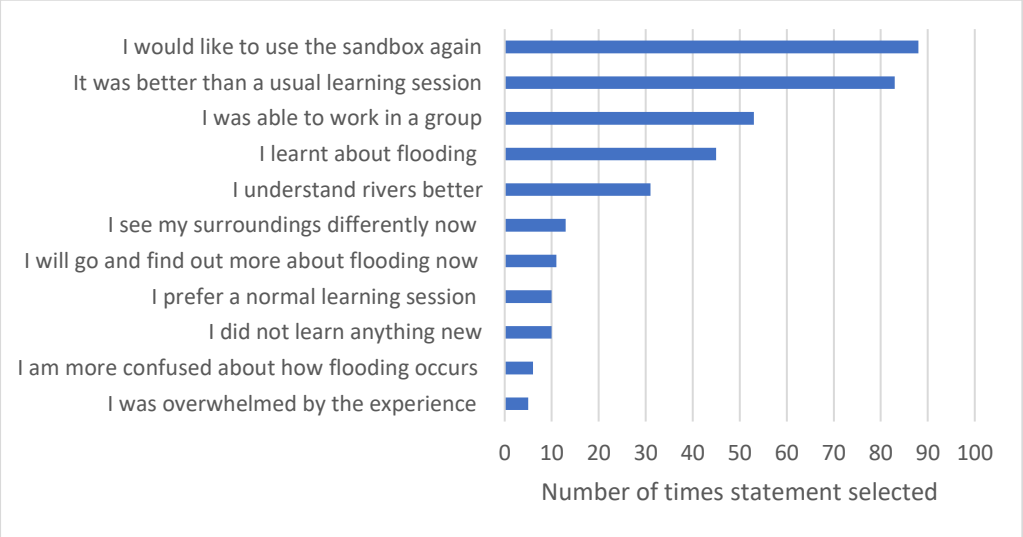

Figure 7: Pupil responses showing the number of times prepared experience statements were selected (2020/21 combined data)

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Outcomes and actions – implications for ongoing geography pathways

Pupils were asked to complete the following sentence, 'As a result of this session I will…' with responses shown in Table 2. The top four options suggest that the sessions encouraged pupils to consider continuing to study geography or to learn more about geographical topics.

Table 2: Phrases used by pupils to complete the following sentence 'As a result of this session I will…' and number of responses (2020/21 combined data, free text).

	Phrase	Numbers of responses
1.	Pick geography as a GCSE	21 – 25
2.	Learn more about flooding	16 – 20
3.	Study harder in geography	11 – 15
4.	Have more of an interest in flooding, rivers and coasts	6 – 10
5.	Be aware of risks surrounding water	6 – 10
6.	Be more aware of flooding and flood risk	0 – 5
7.	Be aware of the dangers of flooding	0 - 5
8.	Spread information and try to make a change	0 - 5
9.	Buy a sandbox	0 - 5
10.	Research flood defence	0 - 5
11.	Talk to a parent about their job	0 – 5
12.	See my surrounding differently	0 - 5
13.	Check flood risk in my area	0 - 5
14.	Clean rivers	0 – 5
15.	Make my own sandbox	0 – 5
16.	Be a water engineer	0 - 5

Narrative feedback

Pupils were also asked by their teachers to provide short statements about their experience after the events. Table 3 provides a summary of these responses. Notably, all but one of the quotes show that pupils directly identified the effects of changes (such as land management or different types of infrastructure) as a key feature of the demonstration, reinforcing our view that the interactive and experimental framing of geographical concepts using the models can deliver learning benefits.

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Table 3: Quotes from Year 8 pupils (2020 & 2021).

"The models are a different and more exciting way to learn than normal lessons. They are practical and fun, especially using the sandbox and wave machine."
"I enjoyed the AR Sandbox because you can find out how to slow down the river or stream and how to use the environment to stop unplanned floods."
"I enjoyed the wave tank because you could see the effectiveness of the different types of flood defence really clearly."
"The wave tank is a very good way to show how land can be affected by the sea and that there are many ways to help reduce coastal flooding."
"The wave tank was really interesting because I learnt that the public might not like some flood defences e.g. rocks."
"We were able to shape the sand in the sandbox to create different contours and topographical features, make virtual rain by holding our hands above the sand and then add trees and structures to see how trees can stop or slow the flow of water on a hillside and how run-off could flood towns."

Lessons we have learned

By working in partnership, we have discovered that:

- Physical models enable pupils to get hands-on experience of how water behaves in a river catchment and at the coast, with pupils re-calling the experience in future geography lessons.
- The interactive and visual nature of physical models encourages pupils to consider the many varied and complex factors linking rivers, coasts, flooding and flood risk through involvement and questioning.
- Collating pupil feedback helps to show how valuable physical models can be to increase understanding of flood and coastal risk management and as a result enhances geographical learning.
- Different physical models have the potential to support learning in different areas of the geography curriculum, as well as providing inspiration for other subjects in science, technology and engineering.
- Physical models are adaptable, allowing the development of associated resources for specific key stages and age groups.
- Working in partnership has enabled the development and provision of resources that are directly related to the curriculum and now widely accessible to many others. We also identified additional uses for the physical models, for example finding that the hydraulic flumes are a useful tool for demonstrating key water safety concepts.
- Multi-channel engagement, including in-person events and freely available online resources (including videos, worksheets and technical briefing material) offers a flexible and tailored package of geography related teaching resources to support continual learning.

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Challenges and future potential

Physical, interactive models provide a compelling focal point for learning about rivers, coasts, flooding and related topics in physical geography. Evaluation of feedback during our partnership shows that physical model demonstrations support geographical understanding and learning outcomes. It shows that pupils enjoyed the learning sessions, suggests that they understand the causes of flooding better and that some are considering pursuing geography career pathways as a result of the sessions.

Even so, a wider, more rigorous evaluation study would be helpful to measure the benefits of the model demonstrations for a larger population of pupils, in different contexts, in terms of learning outcomes and broader personal development such as knowledge of potential career pathways. The evaluation should assess learning about the primary geographical topics explored with the models, and the potential to connect other topics in science, technology, engineering and maths (STEM).

There are challenges regarding engagement with the teaching profession and how it can be achieved given time and resource constraints. Opportunities exist to provide teaching ideas, linking physical models to the curriculum, enabling a cross-curriculum approach to topics. We believe our partnership has been successful, but it remains a challenge to sustain the breadth and depth of partnerships needed to realise the full benefits of the models for cross-curriculum learning, and to share those benefits more widely.

Resources for teachers

The learning resources discussed in this paper are freely available as downloads from the JBA Trust website and YouTube channel. Detailed designs and plans for the physical models (flume, wave tank and AR sandbox) are available free of charge by request to info@jbatrust.org to enable others to replicate the models or create their own adaptations. The PARM is a customised installation that was developed in a research partnership between JBA Trust and the University of Nottingham. The AR sandbox uses free, open-source software published by the University of California.

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