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Research paper

Fostering Understanding of Water Resources Through an Interactive Sandbox: An Approach in Environmental Education

Promovendo a compreensão dos Recursos Hídricos por meio da Caixa de Areia Interativa: uma abordagem na Educação Ambiental

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***ABSTRACT**: The two-dimensional representation of three-dimensional relief forms is often challenging for children and adolescents and can hinder the learning process of topics related to water resources. This study proposed the design and implementation of an interactive sandbox as a valuable educational tool for teaching water resources in elementary and high schools. The project involves constructing a sandbox equipped with sensors capable of identifying surface alterations, allowing students to create and modify interactive landscapes through visualization, thereby facilitating the learning process. The methodology adopted comprised three stages: assembling the sandbox, installing technological devices (including a Kinect depth sensor and a computer), and applying the 3D sandbox as an educational resource. This tool enabled students to visualize relief forms, exemplify water systems, and simulate phenomena such as rainfall events and surface runoff. The presentation of the project in public schools elicited a highly positive response, as the visual appeal of the sandbox captivated and intrigued the students, regardless of age or level of education. Thus, the sandbox demonstrated its potential as a promising tool, capable of being applied at various levels of education, providing an immersive and engaging understanding of concepts, and encouraging exploration, analysis, and decision-making related to water resources management.*
***Keywords**: 3D sandbox; watershed; hydrological cycle; relief; teaching practices.*

RESUMO: A representação bidimensional de formas tridimensionais do relevo, muitas vezes é desafiadora para crianças e adolescentes e pode criar obstáculos no processo de aprendizado de tópicos relacionados a recursos hídricos. Este estudo propõe a concepção e implementação de uma caixa de areia interativa como uma valiosa ferramenta educacional para o ensino de recursos hídricos em escolas de ensino fundamental e médio. O trabalho consiste na construção de uma caixa de areia equipada com sensores capazes de identificar alterações na superfície, permitindo que os alunos criem e modifiquem paisagens interativas por meio da visualização, facilitando assim o processo de aprendizagem. A metodologia adotada compreendeu três etapas fundamentais: a montagem da caixa de areia, a instalação dos dispositivos tecnológicos (incluindo um sensor de profundidade Kinect e um computador) e a aplicação da caixa de areia 3D como recurso educacional. A manipulação dessa ferramenta proporcionou aos estudantes a oportunidade de visualizar formas de relevo, exemplificar sistemas hídricos e simular fenômenos como chuvas e o escoamento superficial. A apresentação do projeto em escolas públicas suscitou uma resposta altamente positiva, uma vez que o apelo visual da caixa de areia cativou e intrigou a audiência, independentemente de idade ou nível de educação. Dessa forma, a caixa de areia demonstrou seu potencial como uma ferramenta promissora, capaz de ser aplicada em diversos níveis de ensino, proporcionando uma compreensão imersiva e envolvente de conceitos, estimulando a exploração, análise e tomada de decisões relacionadas à gestão de recursos hídricos.
Palavras-chave caixa de areia 3D; bacia hidrográfica; ciclo hidrológico; relevo; práticas de ensino.

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INTRODUCTION

The ability to visualize and understand space is essential in education. Students can develop this skill using computational resources, which are instruments increasingly present in learning environments. Additionally, technologies that promote advancements in teaching methods can enhance the learning process and facilitate the dissemination of knowledge (Silva, 2009).

Certain concepts related to water resources, such as modeling rainfall and runoff, understanding water systems, and visualizing topographies, often prove challenging for students, especially at elementary and high school levels. Frequently, this knowledge is accessible only to a limited group of students and professionals specialized in the area at the undergraduate or graduate levels. Given this reality, it becomes imperative to seek tools and approaches that simplify understanding complex hydrological processes and encourage active participation in pedagogical activities in basic education.

Thus, the present study addressed the combination of augmented reality technology and interactive sandbox to boost teaching about water resources. This approach enables students to experience and interact with concepts practically and engagingly, culminating in a deeper understanding of water-related processes.

From this perspective, the objective of this study was to demonstrate the practical application of an augmented reality sandbox as an educational tool in the context of teaching about water resources. This method encourages students to experiment and interact with concepts in an immersive way, thus expanding their understanding of hydrological processes.

MATERIAL AND METHODS

ASSEMBLING THE SANDBOX

To assemble the sandbox, we used a multimedia projector, a motion sensor (Kinect), a computer, pool filter sand, and an MDF wooden box with 100cmx75cm×20cm (length x width x height), which makes up the field of view of the Kinect camera and the projection.

The augmented reality devices were installed after building the box. The depth sensor (Kinect) was placed 1 meter high, and the projector was positioned 1.5 meters high. The Kinect is responsible for capturing, through the depth camera, all the movement made in the sand by comparing overlapping images. The entire sandbox installation and calibration process was carried out on a computer with a Linux Operating System to install the SARndbox software (Kawamoto, 2016) and other software packages for its execution. Calibration means making the computer correctly recognize the dimensions of the image projected in the sandbox so that the user experience when using it is as close to the real thing as possible.

APPLICATION AS AN EDUCATIONAL TOOL

The sandbox's functionalities are demonstrated by exploring and connecting the concepts presented with the students' geographic context. The relationship between the plateau and the plain for the Pantanal was particularly highlighted, especially for people

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living in Poconé, located on the Pantanal plain (Mato Grosso). The hydrological processes that influence students' lives, considering their location in the basin and the environment they inhabit were discussed. During simulations guided by the teacher, students construct distinct scenarios of land use and occupation, simulate rainfall events of different intensities, and observe how the water spreads across the river basin and how springs, rivers, and lakes are formed. During these activities, flooding events in urban areas, dam bursts, and the effect of the shape of the basin on water flow are simulated.

The engagement in activities with the interactive sandbox was assessed considering the number of students willing to participate in the activity and the time spent in the sandbox was analyzed. Thus, after conceptualizing and demonstrating the topics covered, groups with five students were invited to interact with the sandbox, with no obligation to participate. Each group could stay in the box for up to 5 minutes. Subsequently, we counted how many students participated in the activity and how many remained until the end.

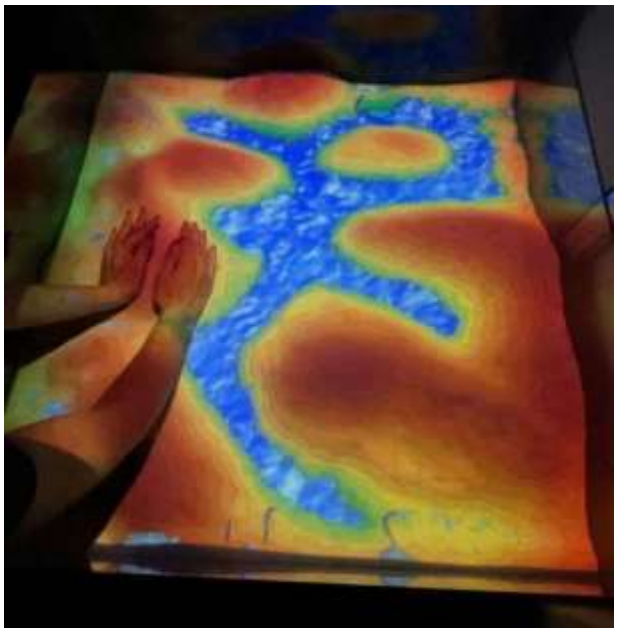
RESULTS AND DISCUSSIONS

This approach aimed to promote a deeper understanding of hydrological processes through sandbox manipulation.

PRACTICE 1 - REPRESENTATION OF RELIEF FORMS

In the sandbox, students engaged in free manipulation of the sand to create various landforms, including mountains, valleys, and plains. This interactive activity allowed them to observe the flow of water across different topographic surfaces. Through this process, they tested concepts related to river basins and identified how physical characteristics define essential elements such as watersheds, tributaries, riverbeds, floodplains, and river mouths (**Figure 1**).

Figure 1. Representation of different landforms made by students



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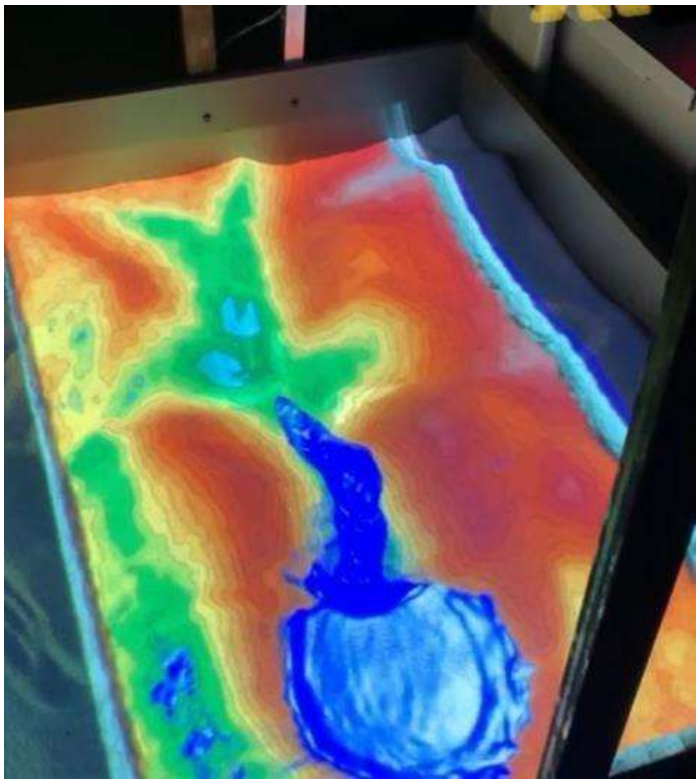
PRACTICE 2 - DEMONSTRATION OF WATER SYSTEMS

The water systems demonstration simulated the functioning of river basins and bodies of water such as rivers, lakes, and reservoirs, in an interactive sandbox. This approach combined augmented reality technology with principles of hydrology and geomorphology, providing an immersive educational experience. Students simulated events like rainfall or river springs by adding water to the sandbox. As they did so, they observed how water flowed and accumulated in different parts of the sandbox, forming lakes and other bodies of water. This activity was designed to deepen students' understanding of water-related processes and the influence of topography on water movement (**Figure 2**).

Figure 2. Demonstration of the dynamics of surface runoff in the river basin in a practical activity with students



PRACTICE 3 - SIMULATION OF THE HYDROLOGICAL CYCLE IN THE BASIN

During this activity, students simulated rainfall events using hand gestures, tracking the path of the water as it flowed across the terrain to reach rivers and observing how it accumulated in depressions and ponds (**Figure 3**). This approach, based on the principles of hydrology, provided students with a visual understanding of the interactions of water with different landscapes. After this simulation, students could observe how the water level progressively decreased as they pressed the key "1", which simulated the process of evaporation and infiltration, allowing students to visually understand how these phenomena affect the water level in a river basin. This practical experience helped students understand

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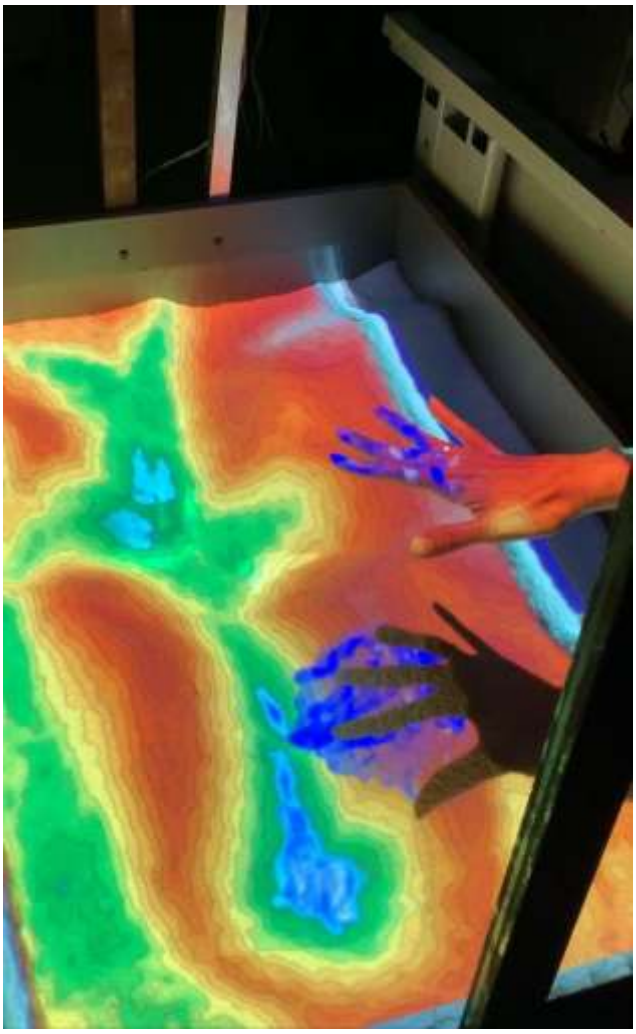
the importance of soil conservation and the effects of surface runoff, as well as the decrease in water levels due to evaporation and infiltration.

Figure 3. Representation of rainfall and surface runoff in the river basin in a practical activity with students



APPLICATION

Direct observations and group discussions were held to analyze students' responses. Satisfaction and effectiveness were confirmed based on the clarity of concepts demonstrated by students, improvements in learning, and active engagement in the activities since their visual aspect pleased and caught the attention of everyone, regardless of their age or education level (**Figure 4**).

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Figure 4. Elementary school students interacting with the experimental sandbox

During the presentation, the students heard explanations about the relationship between the formation of a river basin and water resources. Furthermore, basic notions of hydrology, topography, and environmental conservation were given, providing direct contact with these concepts. **Table 1** lists the evaluation of student engagement in the activity.

Table 1. Relationship between student engagement and interest

Schools	Total number of students	Engagement (%)	(%) Remaining after 5 minutes
State School Dom Ramon Sanches (full-time school)	40	100 (40)	95 (38)
State School Antônio Hortolani (rural school)	42	100 (42)	92 (39)
State School 29 de Novembro (youth and adult education)	19	89 (17)	73 (14)
Sesc Pantanal School (private school)	89	100 (89)	100

Some clear trends in data on student engagement and retention in schools were found by using the interactive sandbox as an educational tool. Firstly, the schools located in Tangará da Serra (state of Mato Grosso), that is, schools of the Full-time, Rural, and Youth and Adult Education modalities, had similar results in terms of engagement. Students from these schools showed a high level of engagement, with percentages between 89% and

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100%. This means that all students in these schools actively participated in the interactive sandbox activities, a positive indicator of student interest and engagement.

Using an interactive sandbox as an educational tool to teach water resources has aroused considerable interest and research in several academic works.

The study conducted by Kundu, Muhammad, and Sattar (2017) is a significant contribution to understanding the educational potential of an interactive sandbox, specifically in the context of advanced geoscience teaching. These authors made a detailed analysis, investigating the impacts of this innovative technology on students' understanding of more complex geological and hydrological concepts.

Our findings revealed the remarkable effectiveness of the interactive sandbox as a pedagogical tool, indicating substantial improvements in the assimilation of information by students. The three-dimensional and dynamic representation of geological and hydrological phenomena contributed significantly to an in-depth and more contextualized understanding of these concepts.

Accordingly, a similar study performed by Kundu, Muhammad, and Sattar (2017) in the context of water resources teaching, highlighted the significant benefits of implementing the interactive sandbox. The consistency between the results of the two studies evidences the robustness of the findings, suggesting that the effectiveness of the interactive sandbox may transcend the specific boundaries of educational disciplines and contexts.

Such contributions go beyond the mere confirmation of the effectiveness of the interactive sandbox. They provide a solid foundation for pedagogical reflections and practices, providing insights into the successful integration of this technology into higher education. The discussion on the educational and methodological implications of these results encourages further research and ongoing refinement of teaching approaches that incorporate the interactive sandbox.

Likewise, Rautenbach and Kruger (2012) dedicated their efforts to investigating the practical application of an interactive sandbox in teaching and learning geospatial concepts.

The capacity of this tool to make abstract elements visually tangible and provide an interactive experience contributed substantially to the effectiveness of the learning process. Analysis of the collected data revealed not only measurable improvements in the assimilation of these concepts but also indicated the engaging and accessible nature of the approach, promoting more meaningful learning.

This study also aims to employ the interactive sandbox as an innovative pedagogical tool to make concepts related to water resources more understandable and engaging for students, as also evidenced by Rautenbach and Kruger (2012). The proposal is based on the idea that the three-dimensional and interactive visualization provided by the sandbox can boost a deeper and more lasting understanding of these complex concepts.

Moreover, it is crucial to consider the broader implications of these findings. The effectiveness of the interactive sandbox, as corroborated by the results of Rautenbach and Kruger (2012), surpasses the scope of geospatial concepts, pointing to the promising flexibility of this technology in various educational fields. The discussion about these implications encourages critical reflection on the potential transformations in the paradigm at different levels, particularly in the teaching strategies adopted for water-related content.

Billinghurst and Duenser (2012) examined the adoption of augmented reality (AR) in the educational context. They emphasized the intrinsic advantages of interactivity and immersion provided by AR in the learning process. Although not directly related to an

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interactive sandbox, these benefits share notable similarities with the features offered by the latter, which also provide an immersive and interactive experience for students.

Research by Billinghurst and Duenser (2012) shed light on the growing importance of augmented reality as a novel tool in education. The emphasis on interactivity and immersion highlights how these elements can significantly enrich students' learning experiences. Although these authors did not specifically focus on interactive sandboxes, they deliver a valuable perspective on the fundamentals that support interactive technologies in the educational context, contributing to a broader understanding of the potential applications of these tools.

The benefits of interactivity and immersion, as reported by Billinghurst and Duenser (2012). are particularly relevant to the context of the interactive sandbox, which embodies these fundamental characteristics. By offering a three-dimensional and dynamic experience, the interactive sandbox aligns with the principles outlined in this study, providing students with a more engaging and hands-on approach to learning. An analysis of these benefits can also be extended to support the effectiveness of the interactive sandbox specifically in the area of water resources education.

The combination of advantages provided by augmented reality and the interactive sandbox underscores the relevance of these innovative approaches in the modern educational setting. Therefore, integrating such approaches not only keeps up with contemporary educational trends but also effectively addresses the demands and expectations of students and educators in the digital age. The discussion surrounding the principles underlying augmented reality strengthens the theoretical foundation of the interactive sandbox proposal, enhancing our understanding of the educational potential of these emerging technologies.

These reviewed studies align with the proposal outlined in this study, which aims to integrate the interactive sandbox as an engaging and practical tool for teaching water resources. The consonance between the results obtained in the reviewed studies and the approach proposed here highlights the coherence and robustness of the accumulated evidence in favor of the interactive sandbox's effectiveness as a promising pedagogical resource.

The collective assessment of the reviewed studies points to several conclusions, mainly the role of interactive sandboxes in promoting a deeper and long-term understanding of complex concepts related to water resources. By providing a visual and interactive representation of water phenomena, the innovative approach emerges as a significant booster of the learning process.

The consistency of the results and the convergence of conclusions offer a solid foundation for the continuity of initiatives that aim to integrate this innovative technology into pedagogical practices, thus aligning with the growing demands for more dynamic and engaging teaching methods.

CONCLUSIONS

The sandbox has proven to be a promising educational resource in the context of water resources. It facilitated the visualization and understanding of concepts and processes related to water, offering a practical and engaging approach. Students not only observed but also tangibly interacted with complex concepts. This also improved their understanding

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of hydrological processes.

Some improvements can be taken into account to enhance the educational approach. One of them involves implementing a continuous assessment system, with clear criteria and regular feedback from students, so that they better understand their progress. Furthermore, developing questionnaires to help assess the theoretical knowledge acquired and practical work, which allows the application of knowledge in real scenarios, focused on the students' reality, and mixed with the content of each grade, and adapt teaching strategies to meet the specific requirements of different groups of students, aiming for greater effectiveness when using this educational approach.

REFERENCES

BILLINGHURST, M.; DUENSER, A. Augmented reality in the classroom. **Computer**, v. 45, n. 7, p. 56-63, 2012.

KAWAMOTO, A. L. S. *et al***. Manual de instalação, configuração e uso da caixa de areia de realidade aumentada (SARndbox).** Campo Mourão: UTFPR, 2016.

KUNDU, S. N.; MUHAMMAD, N.; SATTAR, F. Enhancing Advanced Geoscience Education through Interactive Sandboxes. **Journal of Geoscience Education**, v. 20, n. 4, p. 321-335, 2017.

PINTO, A. B. C. **Geodiversidade e patrimônio geológico de Salvador: uma diretriz para a geoconservação e a educação em geociências**. 2015. Tese de Doutorado – Universidade do Minho (Portugal).

RAUTENBACH, V.; KRUGER, M. Interactive Sandboxes in Geospatial Education: A Comprehensive Study. **Geospatial Education Journal**, v. 15, n. 1, p. 45-60, 2012.

SILVA, A. F. da. **RoboEduc: Uma metodologia de aprendizado com Robótica Educacional**. 2009.

TORI, R.; KIRNER, C.; SISCOUTTO. **Fundamentos e Tecnologia de Realidade Virtual e Aumentada**. CBC, 2006.

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