10th International Conference on Higher Education Advances (HEAd'24)
Universitat Politècnica de València, València, 2024
DOI: https://doi.org/10.4995/HEAd24.2024.17770

Applying the Photovoice methodology to the resolution of numerical modeling problems

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How to cite: Bayon, A.; Ortega-Reig M. 2024. Applying the Photovoice methodology to the resolution of numerical modeling problems. In: 10th International Conference on Higher Education Advances (HEAd'24). Valencia, 18-21 June 2024. https://doi.org/10.4995/HEAd24.2024.17770

Abstract

The use of mathematical/numerical models poses a crucial challenge in the learning process: determining which simplifications to adopt depending on the specific case. This decision can compromise the reliability of the model or make it impractical due to excessive computational power requirements. In this work, an innovative methodological proposal is presented that applies Photovoice, a technique commonly used in action research, to numerical modeling subjects.

The main goal of the proposal is to encourage individual and group reflection, both in groups of 2-4 students and in the entire class, including the professor. This is achieved by providing an appropriate context through the creation of photo-narratives as a guide for problem analysis. The results suggest an improvement through more active participation, as well as the development of skills such as effective communication and critical thinking.

Keywords: *Photovoice, numerical modeling, critical thinking, motivation, effective communication, experiential learning.*

1. Introduction

Mathematical modeling is a broad umbrella that encompasses a wide range of tools to address issues in technical and social disciplines. The quantity and diversity of existing models are immeasurable, ranging from more deterministic ones—based on the implementation and resolution of well-established laws and principles—to more statistical/stochastic ones, such as neural networks or artificial intelligence (AI). The subjects covering these numerous tools, in turn, encompass very diverse application areas and a varied range of application scenarios.

This combination of factors places students in a situation that, in the authors' experience, often poses a greater challenge than understanding the models from a theoretical standpoint: the need to learn how to determine which model to use and with what simplifications. After all, a model is nothing more than a simplification of reality that facilitates its understanding and analysis. This decision, which may seem trivial at first, becomes particularly critical, as failing to adapt the appropriate model to case study requirements can often result in a significant loss of precision and/or the use of high computational resources that render the model impractical.

This paper proposes a methodology designed to address this challenge in numerical modeling education. Our proposal is inspired by the Photovoice technique, a participatory methodology. It usually involves participants taking photographs connected to their environment and subsequently writing narratives based on them. This process enables them to subjectively identify and represent topics of importance. However, despite its use in Participatory Action Research (PAR) and community development, the use of Photovoice as a teaching tool is limited. There are documented experiences with teenage students (Leivas, 2020) and in higher education (Musanti & Steren dos Santos, 2020; Pierce & Longo, 2020). Although, as highlighted by Ortega-Reig et al. (2023), the use of this technique has traditionally been excluded from STEM disciplines—Science, Technology, Engineering, and Math. According to the authors' most up-to-date knowledge, there is no case of educational application of Photovoice in these fields or, in the teaching process of numerical modeling applications.

Our case study employs Photovoice in a numerical modeling course with Computational Fluid Dynamics (CFD) applied to environmental engineering. In this field, the modeling scenarios are diverse, ranging from estimating wind resources or wind loads on buildings, sediment transport, operation of hydraulic structures, wave action and dispersion of pollutants in fluids.

For this reason, our proposal aims to fill this gap, exploring Photovoice as a methodology for active learning in this field. We also explore its contribution to mitigate some issues identified by Ortega-Reig et al. (2023) in STEM teaching: lack of motivation and involvement, limited communication and reasoning skills, surface learning, and lack educational environments where students can engage in discourse beyond traditional academic subjects and materials.

In this context, the main goal of the present work is to foster modeling students' debate and reasoning skills, to be able to converge, and propose sound numerical fluid modeling solutions for environmental engineering problems. To achieve this, the following specific objectives are:

- **SO1:** Apply the fundamental and theoretical concepts covered earlier.
- **SO2:** Address a variety of practical problems related to numerical modeling.
- **SO3:** Engage in the expression of ideas, comparison, exchange of feedback, and improvement through discussions with peers.

2. Innovation development

Apart from taking Photovoice out of its traditional application scope, our methodological proposal introduces a difference from the classical approach of the technique. The traditional approach involves participants taking photos and creating collective narratives about them (Leivas, 2020). In our case, students do not take the photos; instead, they are exposed to them, with the methodology somewhat related to Photo-elicitation.

Therefore, neither students nor professors need any materials to carry out the methodology beyond a device for viewing the photos and/or consulting supporting documentation (e.g., course notes, literature, etc.), as well as writing materials for notetaking.

The proposed activity follows four successive phases, ideally carried out in a single session of approximately three and a half hours. In each stage, participants work individually, in small groups, or even as a whole class. The methodological development and expected outcomes for each phase are elaborated in the following subsections and summarized in Figure 1.

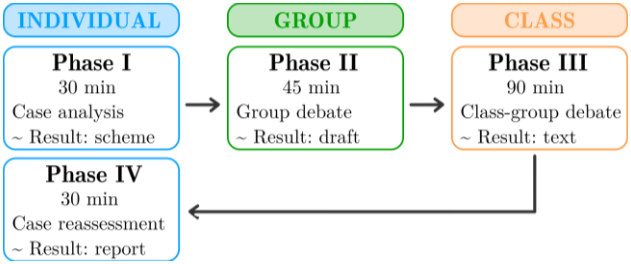

Figure 1. Workflow of the activity.

2.1. Phase I (estimated duration: ~30 minutes)

Initially, the professor explains the methodology for 15 minutes, and each group of 2-4 students is assigned a collection of pictures related to a realistic practical case that could benefit from the use of a numerical model. This process is carried out individually, and students do not know who else shares the same practical case. Figure 2 shows example photographs from practical cases of CFD numerical modeling in environmental fluid mechanics. Note that the pictures may include specific textual explanations to provide context.

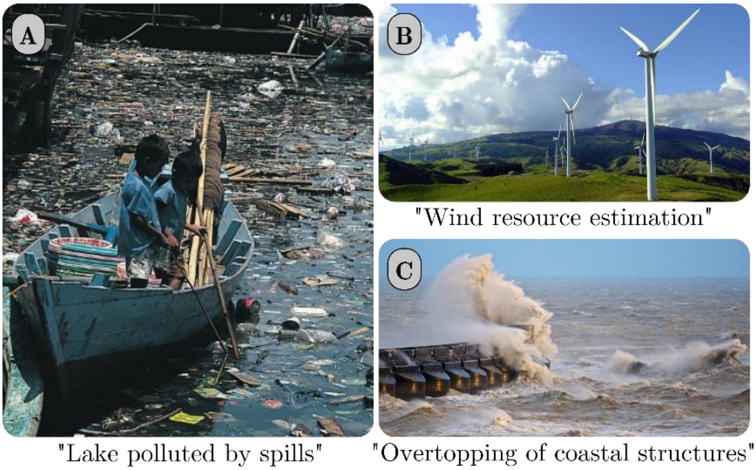

Figure 2. A. Myanmata Bay, Japan (Cordington, 2005). B. Wind Park in Apiti, New Zealand (Jondaar, 2012). C. Brighton Breakwater (U.K.) (Thomas, 2014). Reproduced under Creative Commons license.

During the next 15-minute period, students reflect individually and outline a scheme (result of Phase I) with the key ideas of the model they would propose to address the phenomena observed in the pictures, based on the knowledge acquired throughout the course. This situation is one that students commonly face in their future professional lives.

2.2. Phase II (estimated duration: ~45 minutes)

In the second phase, students will meet with others having the same case study. Once in a group, they will share individual schemes developed in Phase I. Over a 30-minute period, students are expected to debate and assess the strengths and weaknesses of their respective approaches. The professor should encourage each student to provide and receive feedback. During the last 15 minutes, it is essential to emphasize the need to reach a consensus and draft a photo-narrative about the most suitable modeling approach (result of Phase II).

2.3. Phase III (estimated duration: ~90 minutes)

In the third phase, the following procedure will be followed for each group with a shared case:

a) The professor will briefly present group's case to the rest of the class (2-3 minutes).
b) Each group, through a spokesperson or collectively, will present its consensus draft from Phase II to the rest of the class (4-6 minutes).
c) The class, including the professor, will reflect on the approach presented by the group, discussing and providing constructive feedback (5-7 minutes).

Once the strengths and weaknesses of their respective approaches have been assessed, based on the feedback received, groups must reach a consensus on a final text (result of Phase III).

2.4. Phase IV (estimated duration: ∼30 minutes)

In the fourth phase, students will again work individually. The aim is to reflect individually on their experience and the evolution of their Phase I proposal and prepare a report with a firm modeling strategy to adopt for the practical case (result of Phase IV).

If the activity is part of the evaluation process, it is recommended to assess the evolution of each proposal throughout the phases, the ability to provide feedback and integrate received critiques, and participation during the activity. The evaluation can also include peer-evaluation.

Additionally, the work (or a selection or best-rated photo-narratives) could be presented to a more general audience, as was done after the case study experience.

2.5. Methodology and Teaching Context

The activity involved 12 students, the entire class of Atmospheric Aerodynamics in the Master's program in Computational Fluid Mechanics at the Universitat Politècnica de València (Spain), for the academic year 2022-23. The students formed 6 groups and worked on cases related to the modeling problems mentioned in Section 1. The assess the acquisition of modeling skills, the individual initial scheme (Phase I result) was used as pre-test, while the final narrative (Phase IV) was used as post-test. In evaluating the intervention, both the improvements in the adequacy of the approach and in the model setup were compared qualitatively.

To assess student's satisfaction with the use of Photovoice as a teaching tool and obtain information for improvement, students responded to the SEEQ questionnaire (Students' Evaluation of Educational Quality), using a 5-point Likert-scale. SEEQ is a formative evaluation instrument that analyzes the efficiency of teaching (Andrade-Abarca et al., 2018). It is a robust, internationally verified, and recognized survey with high psychometric characteristics (reliability, validity, internal consistency, etc.) (Marsh, 1982). SEEQ provides information on different categories, the ones assessed in this work are: learning, group interaction, and overall assessment. A last category of open-ended questions also gave space for other non-covered aspects.

3. Results

Acknowledging the limitations of the reduced sample, preliminary results show the proposed activity is suitable for developing the skills necessary to translate fundamental and theoretical concepts from the course into the practice of numerical environmental modeling. The creation and improvement of a narrative serve as a tool for deepening and critically reflecting on the more qualitative aspects of modeling. The approach resembles the strategy to address such problems in a professional environment. The activity encourages the exchange between groups addressing different examples of numerical modeling.

3.1 Professors' valuation

After Photovoice activity, the professors observed a qualitative leap in the students' ability to tackle numerical modeling CFD problems in environmental fluid mechanics. This is evidenced by comparing the initial individual narratives (Phase I) with the final reports (Phase IV). The main aspects indicating qualitative improvement are: a) a better problem-solving and reasoning approach, b) a more accurate selection of model setup (achieving higher precision with lower computational cost), and c) a better overall understanding of the process, focusing on even the smallest details of the proposed models. These aspects seem to contribute to a deeper learning (although being the first year the course is taught makes not possible to use former years as control group). Professor's perception as well as open-question student's responses show that students valued positively feedback processes and working in a less traditional atmosphere.

3.2 Students' valuation

As observed in Figure 3–C, students highly value the methodology: 100% agree or strongly agree with the fact that it is a good methodology and would recommend using it in other courses.

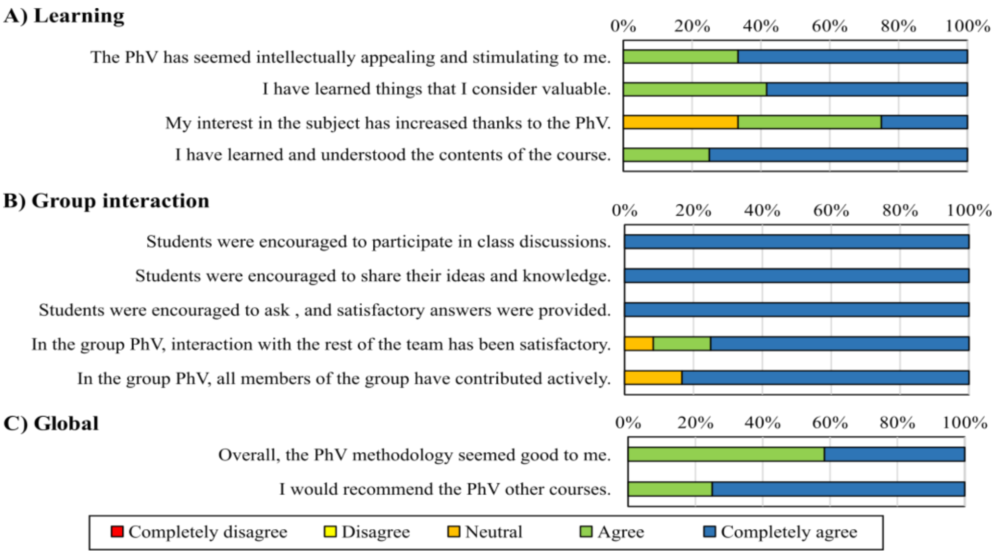

Figure 3. Overall assessment of Photovoice (PhV) by students.

Figure 3–A also shows students' responses regarding aspects related to their satisfaction with the methodology and how it has contributed to improving their interest in the subject. It is noteworthy that all students perceived this tool as "intellectually appealing and stimulating" and indicated that it helped them understand the course content and learn valuable things.

Regarding the improvement of motivation, Figure 3–A shows that 25% strongly agree on Photovoice increasing their interest in the subject, while 42% agree, and 33% remain neutral.

Results of the assessment of group interaction (Figure 3–B) show, overall, that students perceive they have been able to actively participate in discussions, share their knowledge, and receive satisfactory feedback (100% of students strongly agree with these aspects). The evaluation of group interaction and participation indicates the effective performance of the activity.

4. Conclusions

Starting from common principles inherent to the Photovoice tool, this technique has been adapted and implemented to the specific teaching context of a numerical modeling course. This adaptation has led to addressing modeling problems as a "divergent” question, allowing for multiple responses and fostering creativity. This has allowed students to apply their knowledge in a more flexible way and in different contexts. On one hand, photographs have been useful to narrow down environmental fluid mechanics modeling cases and frame them in a real context. On the other hand, the creation of narratives has been used to work on the reflection process around a case study related to specific aspects of the course, fostering critical thinking and effective communication (oral and written). This implies mobilizing abilities such as analyzing, evaluating, and creating, usually requiring higher-order thinking skills (in Bloom's taxonomy). Delving into this type of analysis provides future modelers with a crucial skill, which is knowing which model and what simplifications to apply when and where, perhaps the most challenging aspect for those facing these disciplines.

The potential use of individual and collective narratives as a tool for critical reflection on numerical problems presents a potential application to STEM disciplines. Compared to a more traditional 'practical' application format (such as problems solving), this methodology offers the potential to develop a higher level of analytical skills, through initial individual reflection, followed by justification and comparison in small groups, as well as discussion with the class and providing/receiving feedback.

In a context where the use of artificial intelligence (AI) in higher education is of increasing importance due to notable opportunities and implications for teaching and learning processes (Domenech, 2023), with one of its applications being the support for rapid text generation, the creation of narratives in a face-to-face, 'analog,' and 'non-automated' way offers a learning opportunity where students face this task without support. Furthermore, their revision and rewriting ensure students perform this activity and exercise their communication skills.

Moreover, in line with recommendations to adapt teaching and assessment to the advent of AI, Photovoice allows for a change in the educational approach and offers an additional alternative –in line with "Reflective Reports on Learning" (Sweeney, 2023)– to the writing of critical essays or practice reports (the latter being common in STEM disciplines), placing greater emphasis on judging critical thinking and conceptual understanding, rather than simply measuring data retention or the mechanical application of algorithms or models to solve problems. Additionally, the proposal includes the evaluation of in-person work and its oral presentation; both are robust ways to assess the degree of knowledge and skills acquisition by students, avoiding possible dishonest practices, such as plagiarism or unauthorized use of generative AI.

Acknowledgements

Project funded by the PIME A+D "Photovoice: using participatory photography for the development of transversal competencies" from the Universitat Politècnica de València. The authors express their gratitude to J.L. Mocholí for the post-processing and visualization support.

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