Lessons learned: creating tutorials teaching Agent-Based Modelling for Archaeologists

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1 Introduction

While Agent-Based Modelling is a predictive tool that is in high demand from archaeologists, there are significant sectoral problems with access to vocational training for this skill. A survey of practitioners (Davies and Romanowska 2018) found significant deficiencies in the provision of ABM training; 76% of modellers were primarily self-taught with some degree of secondary support i.e. 27% relied on peer support, only 7% had any sort of formal training at a workshop or summer school while only 14% received training as part of a degree.

A consortium of Landward Research Teoranta, Aarhus Universitet, Universiteit Leiden and Saxion University of Applied Sciences recognised this need, and sought to address and overcome this training deficiency through

the development and delivery of a project to create and make available open learning materials that could be integrated into a wide range of training programmes, such as face-to-face training, employer-focussed continuing professional development seminars, webinars, MOOCs (Massive Open Online Courses) and self-directed learning.

This project, Agent-Based Modelling for Archaeologists (https://erasmus-plus.ec.europa.eu/nl/projects/search/details/2021-2-IE01-KA220-VET-000049054), was delivered with the support of the Erasmus+ programme of the European Union.

The project sought to create Open (Open Access and Open Source) Educational Resources (OERs) for training in Agent-Based Modelling for Archaeologists. These OERs were to be HTML and JavaScript based so they could be used on any device with a browser, even if it is not connected to the internet. These are hands-on practical exercises, taking learners through the process of creating the digital models, and modular so they can be independent or incorporated into other teaching tools like learning management systems. They are deliberately 'method agnostic' so they can be incorporated into any tools from self-teaching to MOOCs, and are supported by the creation of support materials to encourage use of the OERs.

The activities the project implemented were:

- Development of a hands-on vocational training programme, aligned with the recently published *Agent-Based Modelling for Archaeology: Simulating the Complexity of Societies* (Romanowska, Wren and Crabtree 2021).
- Conversion of the training programme into modular learning resources that are interactive, based on HTML and JavaScript standards.
- Creation of support materials to encourage use of the OERs.
- Creation of how-to guides to help trainers incorporate OERs into their teaching
- Creation of a code and learning materials repository that will allow the project to continue sustainability after the European Union support has ended and to facilitate the creation of an open-source community to manage and improve the OERs in the future.
- Promotion through a series of multiplier events.

The expected results and outcomes, for the target audience of professional archaeologists, were:

1. increased level of digital competence, specifically in advanced computer modelling skills that are highly transferable to other industries (computer programming and simulation development);
2. improved transnational mobility through matching of the skills being delivered with European and Sectoral Frameworks, leading to individual workers being better enabled to demonstrate their skills to employers across Europe;
3. increased opportunities for professional development by having access to professional training that can be incorporated into formal or non-formal/informal learning.

For the secondary target audience of vocational training providers in archaeology e.g. employers, colleges and not-for-profit organisations, the expected results and outcomes were:

1. increased quality of education and training in the areas of ABM that are free and open;
2. access to teaching materials for skills that are in high demand and aligned with employers' needs.

We were able to draw on previous experiences with a small private online course (SPOC) on 'Modelling and Simulation in Archaeology' that some of us designed for graduate teaching at the Faculty of Archaeology, Leiden University, where we taught this course in 2016/17 and again in 2018/19 (Scherjon, Romanowska and Lambers 2019). For this course we developed new online teaching materials comprising pre-recorded lectures, practical exercises, reading assignments and exams. While we greatly benefited from that experience, the target group of the SPOC was graduate students with prior experience in digital archaeology, whereas the ERASMUS+ project was aimed at a much broader target group of archaeology students and professionals with only basic digital skills.

2 Method

During the project we developed online tutorials. The tutorials were first designed using storyboards which were later converted into tutorials using NetLOGO Web (https://www.netlogoweb.org/launch) and Javascript (). The tutorials were developed as a team and we worked together using GitHub (https://github.com/ABMArchaeologists/ABMA_tutorials). During the project, initial testing was done by all authors and issues in GitHub were used to tackle bugs.

The learning and teaching material for ABM for archaeologists assumes that the users have completed secondary education. It is suitable for archaeologists with at least some background in archaeology, preferably after the first year of a Bachelor study in Archaeology (above EQF levels 4 or 5). In addition, the tutorials are aimed at professionals working in archaeology who have some experience with computer applications. We also assume that learners are proficient in English and have at least the Reading B1 level, but Reading B2 is recommended (Council of Europe 2020). The tutorials are developed aiming to develop learners' skills in the following competence area's: 1. Information and data literacy, 2. Communication and collaboration, 3. Digital content creation and, 5. Problem solving (European Commission, Joint Research Centre et al. 2022).

After initial debugging by the project team, the tutorials were tested 'in the wild' during various online and in-person conferences. The in-person conferences were attended by several people from the project team. During the online events we were always present with several people and enabled participants to go to break-out rooms if they needed any help or wanted to discuss things. In addition, we also had students working with the tutorials at Saxion University of Applied Sciences and Leiden University. We We obtained structured feedback from the participants and used it to improve the tutorials prior to the next test. The feedback was obtained from two surveys using Qualtrics. The participants of the events were asked to answer questions of the first survey before participating. We used the answers to understand what the background of the participants was and to get an estimate of their level of knowledge in relation to ABM (see appendix ... for the questions). At the end of the event the participants were asked to answer a second survey. Questions of this survey were aimed at measuring the effectiveness of the tutorials and getting feedback on the workshop and tutorials (see appendix ... for the questions). For some events participants had to register beforehand and we were able to send the pre-workshop survey by email. At other events no registration was possible or necessary and the pre-workshop survey was given at the start of the event. The post-workshop survey was distributed using QR-codes or links at the end of the workshop during the event. After each event we improved the tutorials based on the received feedback.

Table 1: Conferences, events and situations were workshops were held at which the tutorials were tested.

Conference or event	Period	Online, in person or hybrid	Number of participants	Number of registrations
CAA Amsterdam	April 2023	In person	36	53
EAA Belfast	August 2023	In person	21	No registration
CAA-DE/NL-Fl Online workshop	October 2023	Online	40	76

Conference or event	Period	Online, in person or hybrid	Number of participants	Number of registrations
Reuvensdagen	November 2023	In person	13	No registration
CAA-UK	November 2023	Hybrid	53	
Leiden (course)	December 2023	In person	11	No registration
Aarhus	January/February 2024	Online	176	>500
Saxion	March 2023-January 2024	In person	18	No registration
Total			**368**	**>628**

The surveys were analysed using R (R Core Team 2023). The following packages were used for analyses: ggplot2 (Wickham 2016), dplyr (Wickham et al. 2023), tidyr (Wickham, Vaughan and Girlich 2023), forcats(Wickham 2023a), lubridate (Grolemund and Wickham 2011) and stringr (Wickham 2023b). The date and the code is available at https://github.com/ABMArchaeologists/ABMA_paper and (... insert Zenodo reference...)

Over the course of the project three groups of students worked on the project during the Smart Solutions Semester at Saxion University of Applied Sciences. This is an interdisciplinary semester in which students of at least three different study-programmes or disciplines work together on a complex problem/project (https://www.saxion.edu/business-and-research/collaborate-with-saxion/smart-solutions). The backgrounds of the various students were diverse: Applied Computer Science, Archaeology, Business Management Studies, Creative Business, Creative Media & Game Technologies, and ICT. The diverse groups of students contributed new ideas, developing educational material, testing the tutorials and developing a style for the website and other materials.

3 Results

3.1 Workhops and tutorials

3.2 Final tutorials

The set of developed tutorials consists of the following tutorials:

- Tutorial 1: Introduction to ABM
- Tutorial 2: Beginning with NetLogo
- Tutorial 3: Expanded ABM skills
- Tutorial 4: Intermediate ABM
- Tutorial 5: How to Model

Each tutorials consists of a different number of lessons that guide the learner in a self-pace manner through the lessons.

In the first tutorial the user will learn what simulations and agent-based models are and how they can help in archaeological research. This tutorial consists of 4 lessons. The first two lessons introduce the learner to simulation in general and Agent-Based Modelling in specific. Various concepts related to ABM are introduced and the first concepts within NetLogo are explained. The third lesson aims to explain how ABMs are used in archaeological research. The final lesson introduces the learner to the NetLogo Interface and the difference

between the Interactive and Authoring mode. This tutorial build a foundation for working in NetLogo and with ABM. All activity stays within the intermediate level, although higher levels might be touched upon.

In tutorial 2 the user will learn the basics of NetLogo by making your their simulation on the Out of Africal dispersal of homo sapiens. The learner will work with basic NetLogo syntax and learn how to set up a simulation and visualize its outcomes. This tutorial consists of 9 lessons. This tutorial intends to guide the learner from the intermediate to the advanced level of proficiency. The learning curve is relatively gentle. This is achieved by learning to work with the NetLogo web interface. The primitives are introduced and initialization phase of a simple ABM is gone through. The world within NetLogo's world (including dimensions, coordinates, origin) and how to alter it are explained and experience in a hands-on approach. The learners learn about simple simulation loops and how to use primitives. The advanced level is achieved with the custom procedures and variables. In addition, if-statements are introduced and more complex versions thereof. Exporting information using plots is also explained.

In the third tutorial, the learner will build a simple trade model, picking up more advanced NetLogo coding along the way, such as loops, lists and reporters. The learner will be introduced to some techniques like modular code development and debugging which will become important with this increased coding complexity. This tutorial consists of 7 lessons. This tutorial intends to guide the learner from the intermediate to the advanced and highly specialised level of proficiency. This is achieved by improving development through using modular code, pseudocode and annotating the code. In addition, custom agent breeds are introduced. Visualization with labels and reporters, plots and monitors are learned. The use of loops is further explained. Debugging is learned in lesson 7. This can be very advanced, since it involves knowledge of the NetLogo-language combined with problem solving of unexpected behaviour.

In tutorial 4 the learner will work with Sugarscape simulations to further expand their ABM and NetLogo skills. The learner will learn how to set up more complex interactions between agents and the environment. Furthermore, the basics of setting up good experiments and validating models will be explained. This tutorial consists of 8 lessons. This tutorial intends to guide the learner from the (intermediate and) advanced level to the highly specialised level of proficiency. In this tutorial more complex agent-environment interaction is further learned, including ways to visualize the environment and how to give more agency to patches. Creating toy landscapes is central to lesson 5. The learner also learns the basics of setting up experiments in NetLogo and how to use monitors and flexible plots to understand the results. The validation of agent-based models is an important concept of designing a good experiment. The finale step, is to compare simulation results with the archaeological record. The last lesson is aimed at learning syntax to make lists more dynamic and how to refactor code.

In the final and fifth tutorial the learner will learn more about how to actually incorporate agent-based modelling in research. This tutorial focusses less on programming in NetLogo and more on the model development process. The learner will learn about the different phases in modelling and how to export data from models. This tutorial consists of 5 lessons. This tutorial touches upon various levels, but mainly between the intermediate and highly specialised level of proficiency. This tutorial approaches more theoretical aspects in a practical environment. The learner leans about the model development process starting with the conceptual phase of the model development. Good and bad research questions for modelling are explained and the difference between them. The learner needs to understand how to pick the right modelling technique. The learner should understand the importance of properly conceptualizing a model before starting the technical phase of the model development. In this phase parametrisation, designing experiments and the analysis and interpretation of the models are important. Learning about the dissemination phase of the model development is aimed at understanding (the importance of) publishing models and replication. In addition, learning how to export results from NetLogo using basic export primitives is explained. The BehaviorSpace is explained to enable the learners to analyse the output of models.

3.3 Before the workshops

A large proportion of the participants of the workshops gave us information using the survey before the workshops (172 of 368 participants). The respondents came from many different countries all over the world

(see Figure 1. The number of female respondents slightly outnumbers the male ones and a small group did not share their gender, while two identified as non-binary (see Figure 2). The ages of the respondents ranged from below 20 to over 70, reaching people in different age classes, although the majority was aged between 20 and 40. It seems that the different events also had a slightly different distribution of both gender and age. For example, more older people attended the workshop at the CAA conference in April 2023 and more male people were present during the workshop at the Reuvensdagen in November 2023.

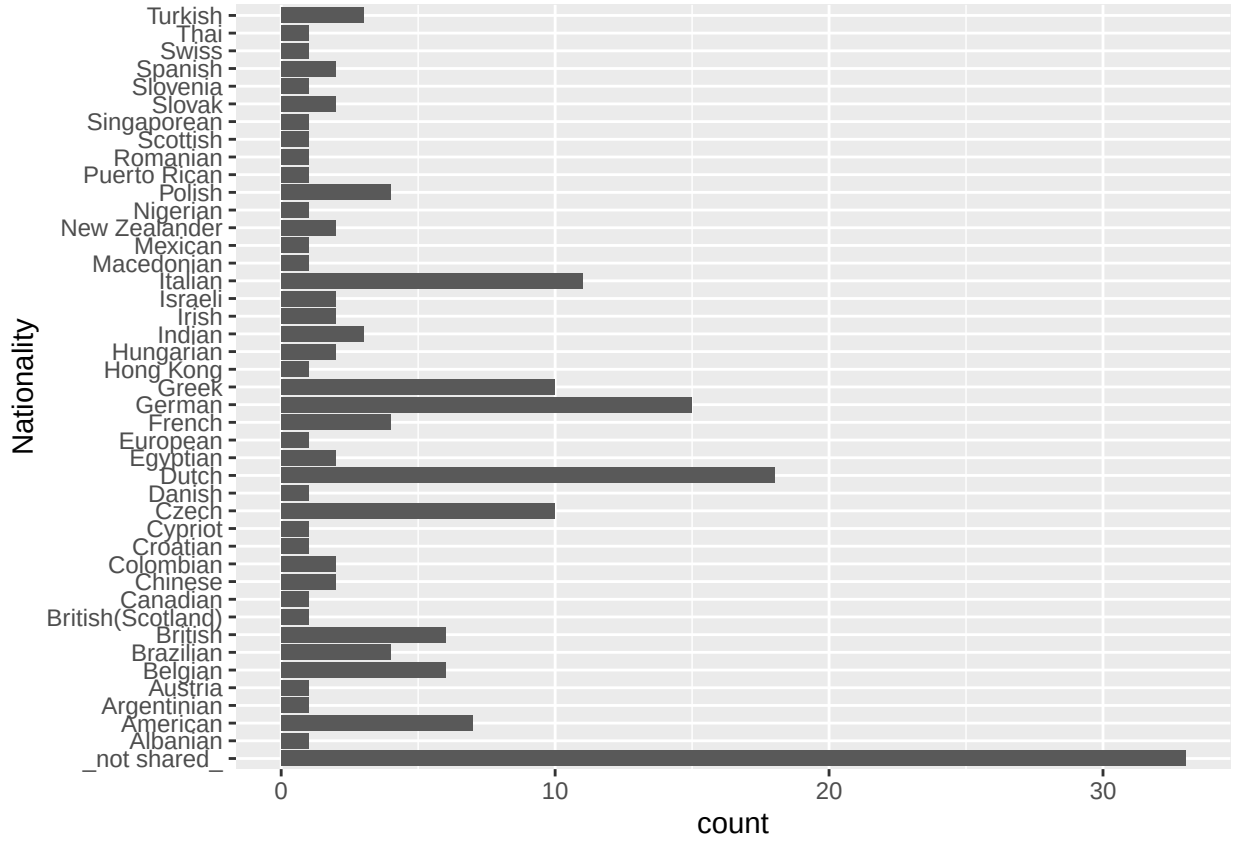

Figure 1: The nationality of the participants that filled in the survey.

Most of the respondents had several skills with computer applications in archaeology (see Figure 3), and many of them did have some knowledge of ABM, although a large group was completely new to the subject. The majority had never applied ABM before participating in the workshops with 14 having applied ABM. It is interesting to note that many respondents did know what kind of software was available for ABM (see Figure 4).

As shown above, the respondents had some knowledge on ABM in general, but did not know how to apply it or had never applied it before. The respondents were also asked how they rated the available knowledge on ABM (Figure 5). While the largest group of them had no opinion on the subject, a very large proportion of the responded answered that they rated the available theory on ABM as limited and a smaller group as sufficient. A minority rated the available theory on ABM as more than sufficient. This clearly shows the need for better educational material.

3.4 During the workshop

During the workshops the participants worked in a self-paced manner, often on their own, but sometimes working together and discussing the tutorials. Some particpants engaged in discussion with the teachers

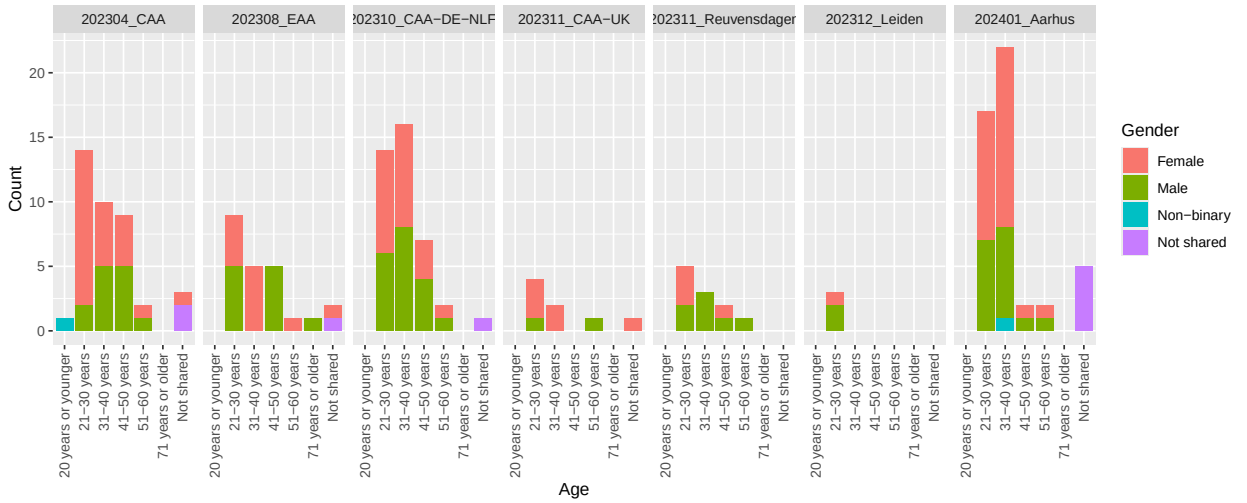

Figure 2: The gender and age distribution of the respondents for each workshop

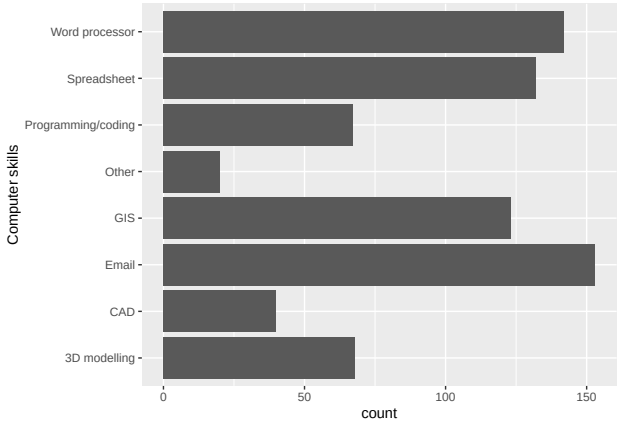

Figure 3: The computer skills of the respondents.

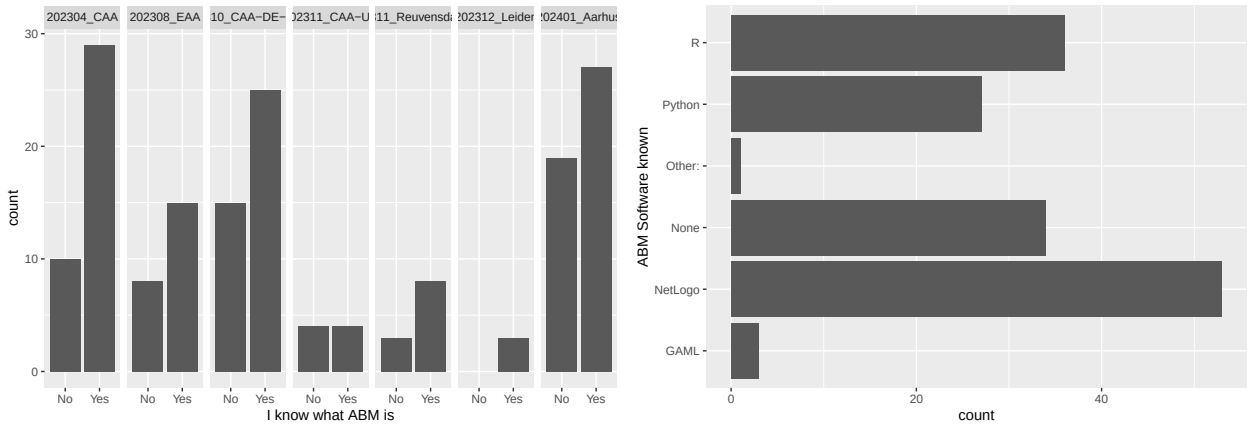

Figure 4: Respondents knowledge and experience with ABM.

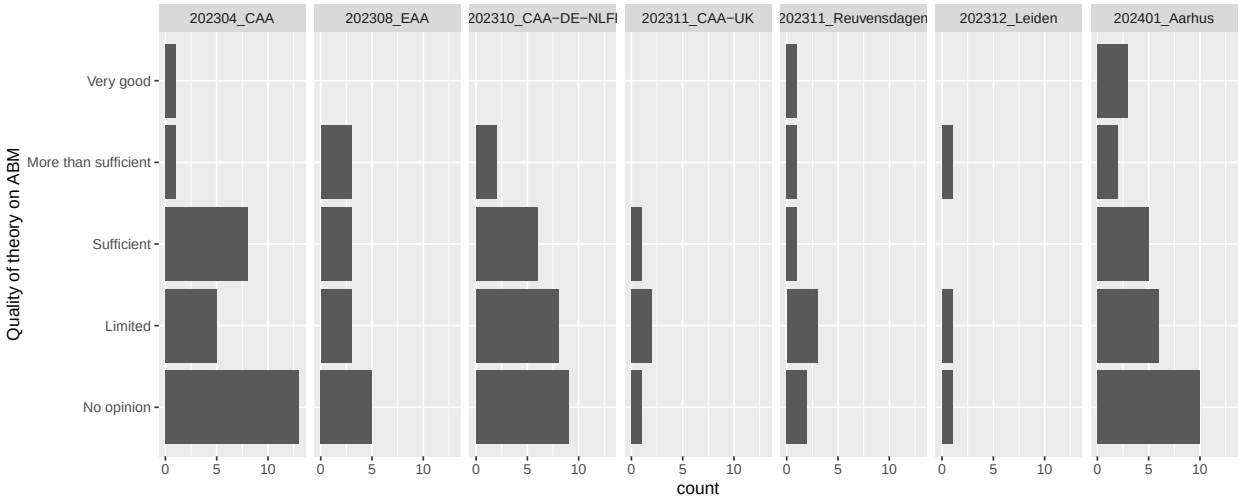

Figure 5: Respondents optionion on the quality of theory on ABM faceted out by event.

to learn how they could apply ABM in their research of discuss possibilities for the application of ABM in general. Individual progress varied depending on skills and preferences of the participants. While bugs were still a problem in earlier workshops, participant-teacher interaction was more focused on content-related learning problems in later instalments.

3.5 After the workshop

A large proportion of the participants of the workshops gave us information using the survey after the workshops (171 of 368 participants), a similar proportion as those responding to the survey before the workshop.

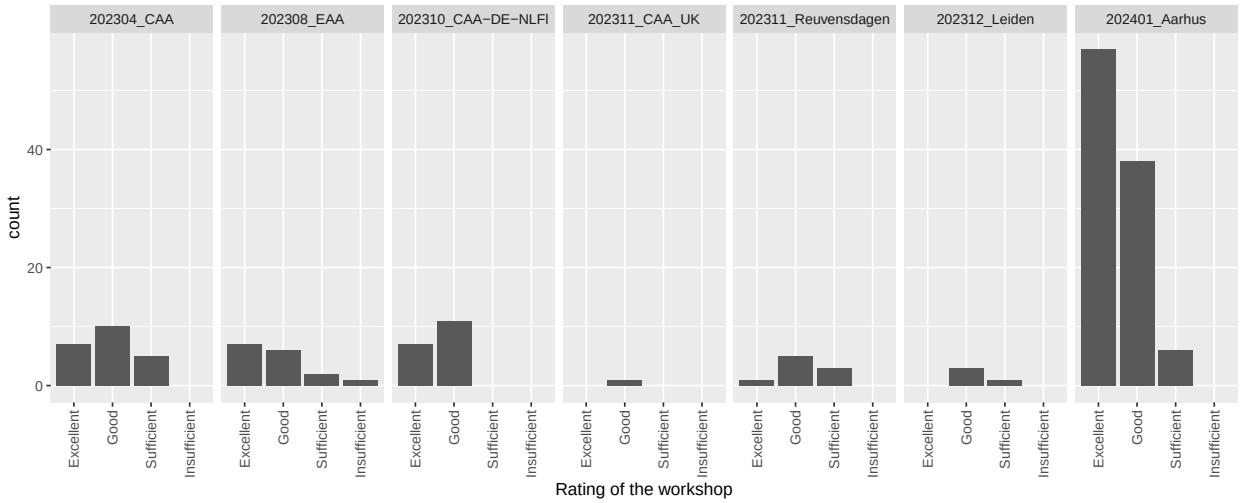

Figure 6: Respondents rating of the workshop in general faceted for each event.

The majority of the respondents were enthusiastic about the teaching material, with the majority rating it as excellent or good. The teachers were even rated better than the teaching material, with more respondents rating them as excellent (see Figure 7).

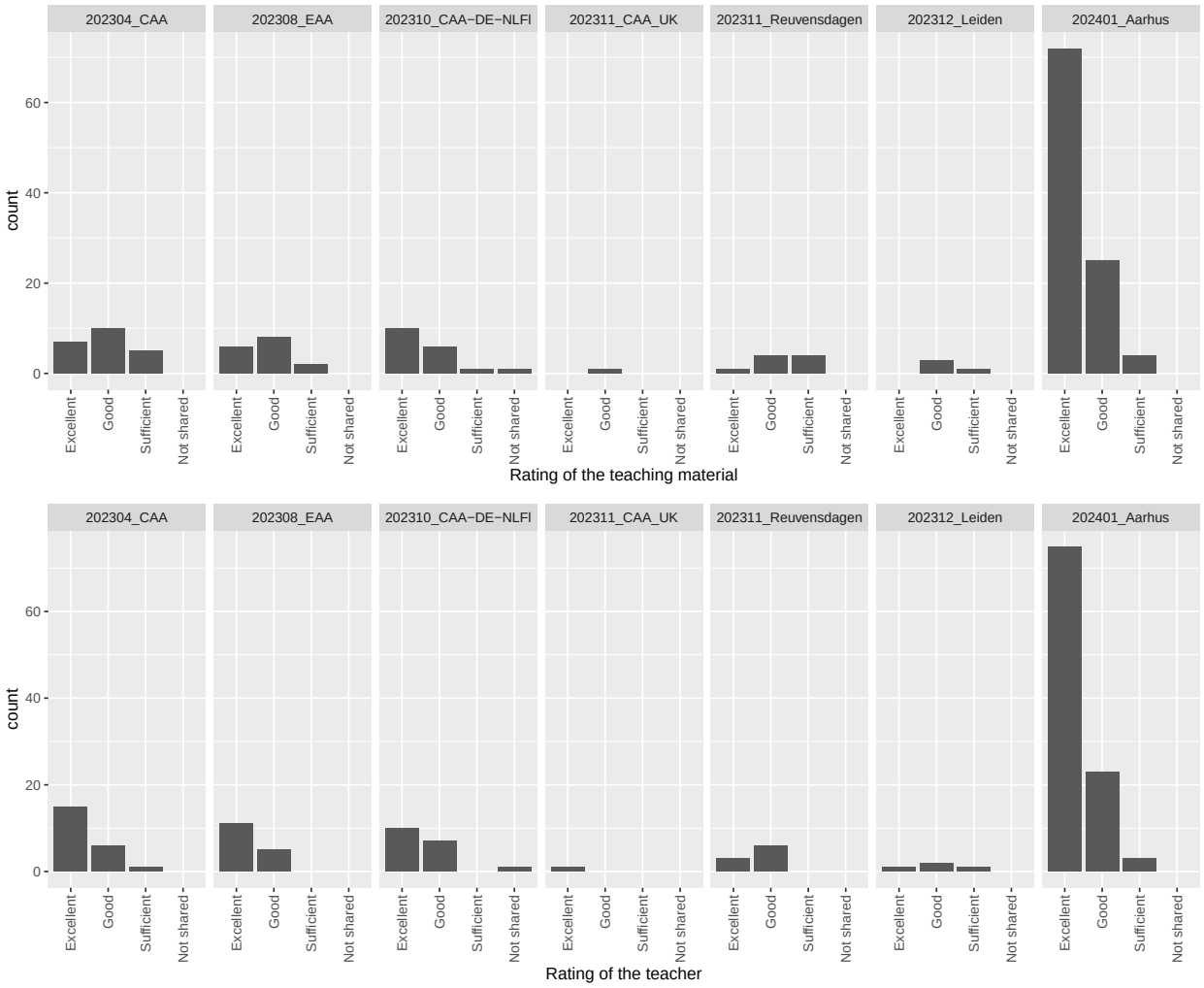

Figure 7: Respondents rating of the teaching material in general faceted for each event.

Two more open questions were asked to the respondents. The first was aimed at learning what aspects the participants liked in the tutorials, and the other was aimed at getting feedback to improve the tutorials.

The respondents generally liked the interactive step-by-step way of going through the tutorials, but also valued the interaction with the teachers very much. The easy and intuitive introduction into ABM and NetLOGO were also mentioned quite often. This was also observed during the workshops by us, most participants were working in the own pace and did not need much help. From a didactic point of view, the self-paced going through the tutorials is very efficient for teachers.

We also received feedback on possible improvements. For the first workshops we mostly received feedback on the number of bugs. During the CAA-conference in Amsterdam we did the first test of the tutorials and we also instructed the participants that this was work in progress. The number of references to bugs reduced to zero by the end and people started providing other feedback, for example the wish to see more examples or expanding the tutorials more. Some wanted more cooperation, which is possible, but harder for some online events, although we provided break-out rooms. It is also interesting to note that over time more and more people did not see any room for improvement.

The majority of the respondents wanted to apply ABM in the future for research (144 of the 164 that answered this question, see Figure 8). Some of the respondents were already using ABM. A large group was not sure yet how to apply ABM and wanted to read more on the subject or play a bit with the possibilities. Many respondents also shared the context to which they were thinking to apply ABM. Various participants mentioned movement of people or goods over land or water, sometimes in relation to trade or other distribution mechanisms. Others thought of demography, social networks, migration or settlement distributions patterns. The natural environment and the interaction with humans in the past was also mentioned by some, and often in relation to GIS or how to replace GIS with ABM. The archaeological periods that the participants were interested in were very diverse, ranging from the Paleolithic to the Medieval period.

3.6 The Digital Competence Framework for Citizens (2.2)

As mentioned above, the following competence area's were identified as relevant for the tutorials: 1. Information and data literacy, 2. Communication and collaboration, 3. Digital content creation and, 5. Problem solving (European Commission, Joint Research Centre et al. 2022). In these competence area's various competences are developed towards an advanced or even specialised level.

For competence area 1. Information and data literacy: the tutorials mainly address 1.2 Evaluating Data, Information And Digital Content and 1.3 Managing Data, Information And Digital Content. The users learn about working with data, being critical of their digital content and how to model and manage the data in the context of an ABM. For tutorial 2 the user is expected to be able to find information using the NetLogo(Web) dictionary (http://ccl.northwestern.edu/netlogo/bind/ or http://ccl.northwestern.edu/netlogo/docs/dictionary.html).

For Competence Area 2. Communication and collaboration the tutorials mainly address 2.1 Interacting Through Digital Technologies, because the users are constantly interacting with digital technologies, but communication is not relevant for the tutorials. However, during the workshops given in the course of the project, participants interacted with each other and the teachers.

Competence Area 3. Digital content creation is one of the main competence areas for the ABM-teaching material. In the process of learning ABM the users are constantly 3.1 Developing Digital Content and 3.2 Integrating And Re-Elaborating Digital Content. The material does not touch upon 3.3 Copyright And Licences, but we assume that users have a general understanding. A very important aspect of learning ABM is 3.4 Programming. The users are exploring the possibilities and chances of programming an ABM. The users are expected to learn both syntax and more general concepts such as modular code development, loops, lists and commenting and documenting code.

Competence Area 5. Problem solving is very important and is closely tied to 3.4 Programming, since programming involves a lot of problem solving. In addition, the creation of a highly complex ABM consists of problem solving all the time, including debugging. All competencies are addressed: 5.1 Solving Technical

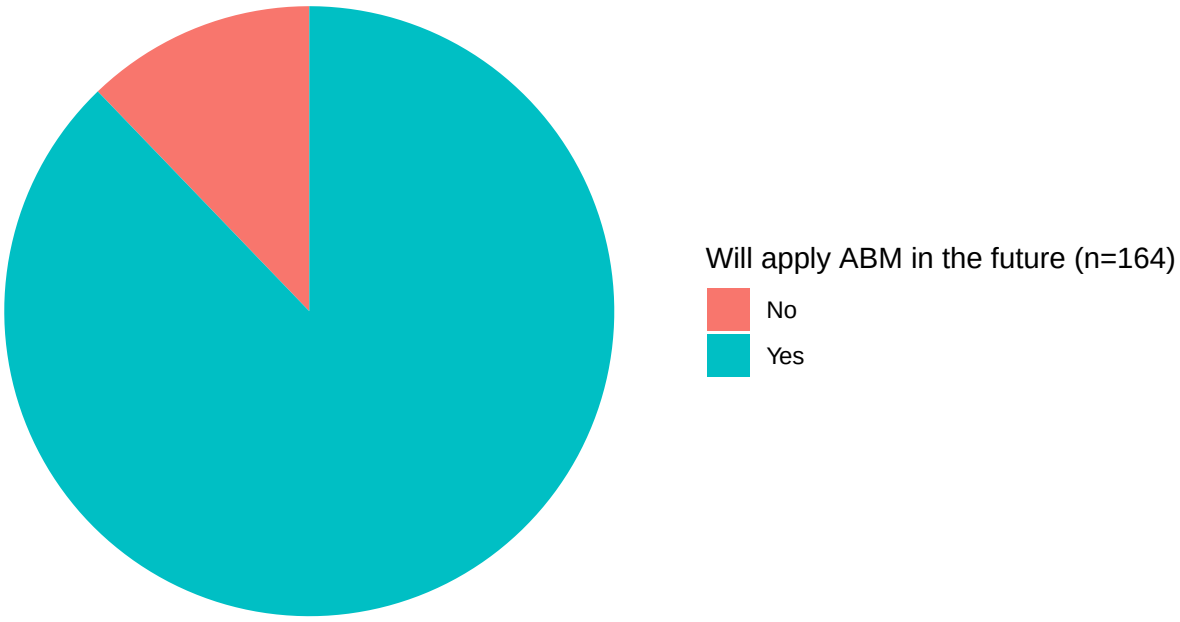

Figure 8: The respondents reaction to the question if they thing that they will apply ABM in the future.

Problems, is common when writing code, learning about coding, error handling and going from pseudocode to real code. The competence 5.2 Identifying Needs And Technological Responses, is a central issue of the course, while 5.3 Creatively Using Digital Technology is an important aspect of learning to think in models and develop models themselves. In tutorial 2 various aspects of 5.4 Identifying Digital Competence Gaps, are relevant, since this tutorial will force the user to remember code and commands and to assess their knowledge and skills.

3.7 Digital Skills Passport

3.8 Dissemination of tutorials

The tutorials are publicly hosted on GitHub (https://github.com/ABMArchaeologists/ABMA_tutorials/). Anyone interested can download the tutorials and their source code. To increase the accessibility and visibility of the tutorials, a website has been launced (https://ABMArchaeologists.github.io/ABMA_Website). On this website, the tutorials can be followed without the need to download any software.

Besides, the tutorial, the website provides: a link that can be used for feedback, basic explanations of agent-based modelling, an introductory presentation from one of the workshops, videos from an online course at Leiden University (Scherjon, Romanowska and Lambers 2019) and external resources people can use to learn agent-based modelling. The website was mainly developed by one of the student groups from Saxion University of Applied Sciences, see the acknowledgements.

4 Conclusion

Things to address

- demand for tutorials exceeded expectations
- tutorials helpful in understanding ABM
- international cooperation
- Digital competency framework / Skills passport
- OER: open learning
- Future aspects:
  - application in educational programmes
  - community driven updates (?)

5 Acknowledgements

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