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Title: Post-pandemic education for the students of the future
Abstract (maximum of 150 words):
The Covid-19 pandemic has had a major impact on the field of education, with the forced move of many activities to online environments. This has led to the adoption of a series of changes that focus on students' intelligence, resilience, and emotional intelligence. This new model of education will combine classic face-to-face learning with online learning, since it has been shown that students can learn more efficiently online. In this paper, we discuss the distributed classroom paradigm that takes advantage of novel methods such as Massive Open Online Courses, Research-Based Learning and Digital and Virtual Labs. The paper also analyses responses from a related questionnaire and proposes a distributed classroom implementation for Education 4.0 using eduGAIN, CKAN, and JupyterHub.
Key words (up to five): eLearning, MOOC, virtual lab, distributed classroom, Education 4.0
Text of paper (maximum of 3000 words, excluding references):

Introduction

The COVID-19 pandemic has had a major impact on the field of education, with the forced move of many activities to online environments. Although this was meant to be temporary, a series of changes appear to be permanent, or at least to represent the basis of a revolution of sorts in education. Sine long ago, education was viewed as transmitting information to students, which would then be memorized and reproduced in a standard way (Krishnan, 2022). However, experts believe that future education should be a combination of classical intelligence, resilience, and emotional intelligence (Krishnan, 2022). Furthermore, this new model of education would be aided by combining classic face-to-face learning with online learning, since it has been shown that students can learn more efficiently online, with an increased retaining rate of 25-60% for online study versus 8-10% in a physical environment (Gutierrez, 2022). The advantage of online study is that it allows students to maintain their own pace throughout the study process.

Although a debate between traditional and online learning (or **eLearning**) has existed for at least the past ten years, it has certainly increased since the pandemic, mostly because many people (ranging from kindergarteners to full-grown adults) have been forced to use alternative methods to study online. It is estimated that, in 2020, approximately 70% of the world's students were affected by the pandemic (Ciccarelli, 2022), which has made the online learning market grow exponentially. This has manifested itself as a need for the existence of various kinds of eLearning tools able to cater to many types of students and/or courses. One area of this domain, which actually existed and was popular pre-pandemic, is represented by **Massive Open Online Courses** (MOOCs), offered by online platforms such as Coursera, edX, or Udacity, which allow the use of the Internet for sharing of free online courses. However, in and of themselves, MOOCs are not able to fully disrupt the traditional learning methods at this moment in time, because they are costly to develop and thus only available to rich institutions (Attis et al., 2012), and there is still the problem of the vast number of students starting but never finishing a course.

On top of simple MOOC platforms, we have observed the increased popularity of a novel learning method entitled **Research-Based Learning (RBL)**, which, as its name states, attempts to combine classroom teaching with research methodologies. In other words, students are encouraged to find their own way towards a conclusion, in order to help them develop qualities such as critical thinking, analysis, argumentation, and the ability to sift through sources and extract or deduce the information that they require (Parra, 2022). This way, students can construct the solution to a problem themselves, instead of applying pre-determined patterns of solving it (e.g., a certain algorithm to solve a mathematical problem). The aim of RBL is to allow students the freedom of choice, while at the same time helping them with important skills such as finding, processing, organizing, and evaluating information. Last but not least, RBL helps students learn how to collaborate and communicate. One can see how RBL has become more popular during the pandemic, since it reduces the need of a step-by-step guidance of the student by the teacher.

One important tool introduced recently is the **Digital Lab**. A proper RBL process should start with the actual research, or with the data being input or resulting from it. Students should be asked questions such as: *How would you answer a research question like X if provided with the right data?* And they should be provided with the data and scientific conditions to run their own experiments. This can be done with the help of Digital Labs, which are interactive tools (often accessible through an online platform) which allow students to recreate experiments in various areas (Leininger and Morhell, 2022). This includes collecting the data, processing and analysing them, and drawing conclusions about the results, all done through advanced simulations.

Finally, Digital Labs evolve into **Virtual Labs** (Krontiris, 2021), which offer advanced virtualization of laboratories that can be accessed remotely. These Virtual Labs are thus the closest thing students can have to being physically present in a lab, without actually being there. This can of course be useful by offering access to students that do not have such labs at their universities, or that cannot physically be present in the lab due to various reasons (such as the COVID-19 pandemic). Furthermore, it is sometimes better to allow students to get familiar with the lab environment and equipment virtually, prior to using it in real-life (e.g., in chemistry labs, it is safer for the students to experiment various reactions virtually, especially as some of them can be dangerous, and it is hard for a teacher to keep an eye on many students in such a scenario). Furthermore, Virtual Labs can be combined with other online learning tools such as web resources, animated demonstrations, etc., for a more immersive experience (Krontiris, 2021).

In this paper, we discuss the distributed classroom paradigm that takes advantage of all the methods mentioned above, we motivate the necessity of using it by analysing the responses from a questionnaire we developed, and we propose a distributed classroom implementation.

The Distributed Classroom

If we combine eLearning with MOOCs and extend this with Digital and Virtual Labs, we move towards a novel paradigm entitled **the distributed classroom** (Gazi and Baker, 2021). It is called as such because it entails a distribution of the entire education experience in both space (i.e., the students and the teacher can be located in different places) and time (i.e., teaching can be both synchronous – traditional face-to-face teaching or online webinars or calls – and asynchronous – courses are recorded and students play them back whenever they wish).

What sets a distributed classroom apart from normal asynchronous online learning (like what we have seen for the past two years) is that the time and space distribution can happen simultaneously. In other words, a teacher might be physically co-located in a classroom with a group of students and present them the lesson, while at the same time the presentation is transmitted to a different group of students located in a separate classroom in a different location, live streamed to other students that may each be in their home, and also recorded for asynchronous viewing (which would be helpful for participants that might be located in a distant country where the course takes place at night, for example). Furthermore, each separate group of students can have a teacher or an assistant with them that could aid them and facilitate online teaching. Interactions with the teacher can thus take place directly (face-to-face or through online tools such as Google Classroom or Microsoft Teams), or indirectly through forums, e-mails, etc. In addition, wherever students may be located, they will have access to the laboratories pertaining to the course they are attending. This might be either physically, or remotely through Virtual and Digital Labs as mentioned before. For remote attendees, they can either be guided by the teaching assistants, or the Digital Lab can come together with videos, presentations, or other materials.

These synchronous and asynchronous interactions are meant to improve the students' experience by adding the social component of learning, which brings additional motivation and involvement (and was found to be missing at regular MOOCs). Thus, the main goal of the distributed class can be reformulated as follows: *"Distribute not just learning across time and space, but the actual classroom experience – including synchronous interaction – even while removing the requirement to attend at a certain time and in a certain place"* (Joyner, 2021).

Education 4.0

Based on the distributed classroom paradigm described above, we present our view regarding the future of education (i.e., Education 4.0) in Figure 1. In our vision, Education 4.0 is a mix between learning, where online lectures are complemented with self-paced online practice activities, and science, where students are co-designers and co-creators of new knowledge. Laboratories are main generators of both education and innovation capabilities. By digitally enabling laboratories and connecting education and research institutions, we believe that the tide of innovation and future education capabilities can be turned. However, the big challenge here is dealing with the vast amounts of data that come from experiments in a variety of scientific areas. Although large amounts of data are being generated daily, there is still a collective inability to benefit from them truly and completely (Krishnan, 2022). Therefore, we believe that the solution is to connect and corroborate data from disparate sources. In other words, we consider that connected data is key to transformation.

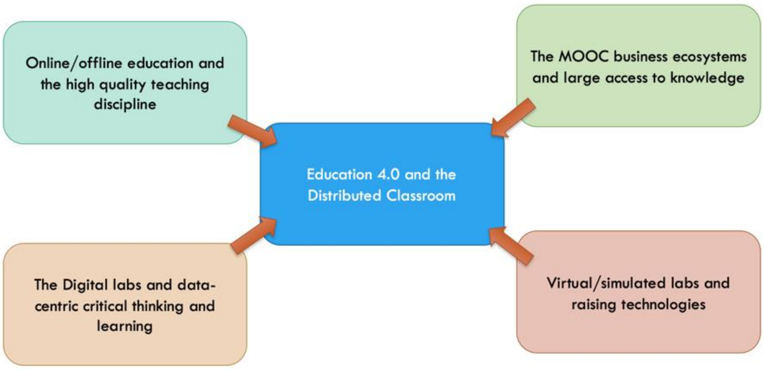

Figure 1. The Education 4.0 and Distributed Classroom vision.

According to the vision of the European Commission, the EU's digital decade will be focused on data, technology, and infrastructure-based digitalization. Thus, the focus of universities and other education or research institutions should be on transforming the way they utilize the data that they generate, with the aim of obtaining “digitally-transformed labs” (Krishnan, 2022), with the help of technologies such as IoT, AI, or ML. We believe that the development of international networks of interconnected smart labs can provide students from Master and PhD levels from different parts of Europe with flexible digital study options. The aim is to ensure a more accessible higher education by providing the right conditions for students of different backgrounds to succeed, but also by using a delivery technology that is accessible all around the world. Such a network of smart labs can thus provide digital readiness to universities, but also resilience of educational services in the face of unexpected events, like the COVID-19 pandemic. This aspect can thus refine the user experience and content so that new online platforms can contribute to better digital capacities for universities.

Our vision combines aspects of all four previously discussed directions in an online environment. At the core, it is about the adaptation of the learning methods (Education 4.0) and supporting infrastructure (distributed classroom) to make use of Active Learning and Research-Based Learning over online distributed virtual labs. We thus envision universities working together to create a training environment where students learn the use of digital technologies through experimentation at their own pace, by actively working with data and applications over smart remote laboratories.

Motivation

To verify that our vision is correct, we devised a questionnaire which we then used to collect data from five universities located in different European countries (Romania, Portugal, Italy, Israel, Spain), for a total of 12 responses. Among other things, the responses showed that all institutions already currently combine online and offline learning activities, since most students have access to an electronic device such as a laptop, smartphone, or tablet.

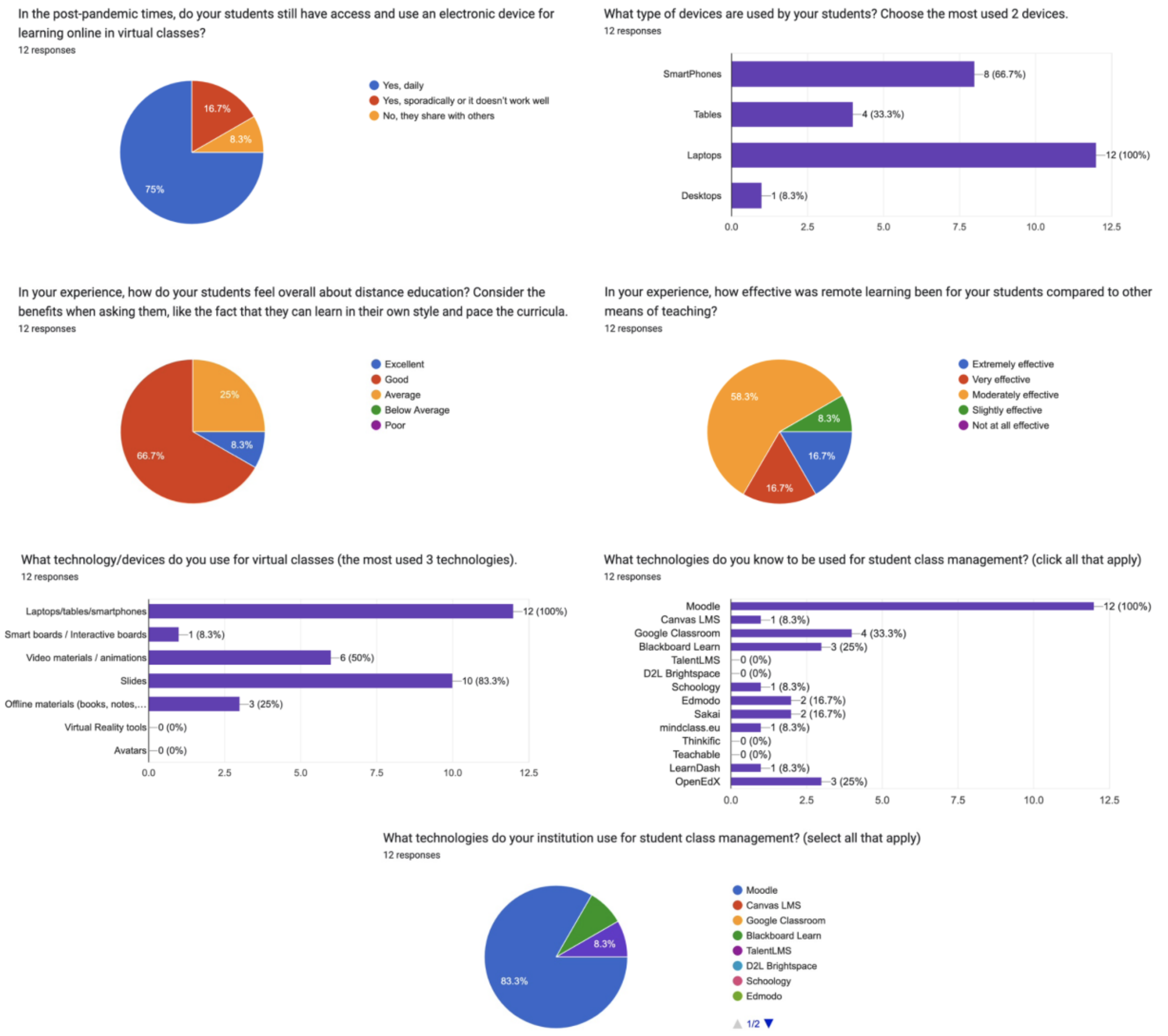

Figure 2. Answers to the questionnaire.

When asked what the most engaging activities that happen in an online-based class are, responders mentioned: activities that involve students in solving a problem (e.g., laboratories / seminars / projects development); the fact that students can see live coding, can share a screen or an editor (of documents or even of code) and that the overall experience seems more hands-on, real-time, and shared use of software tools for example to show how a piece of code works; webinars; practice exercises, demos, short tests, short evaluation questionaries.

Another question asked the participants what is one thing they believe would make online teaching more engaging for students in an online-based class, and the answers included: students must be actively involved in order to stimulate them (e.g., quiz, live demonstration with students' involvement); encourage dialog; give students the possibility to interact remotely with physical objects such as instruments or sensors; mutual collaboration; offer the possibility of using laboratories in real time for making measurements and experiments; collaboration, dialog, self-evaluation. Several other answers to the questionnaire can be found in Figure 2.

<u>Implementation</u>

By looking at the answers, several aspects can be identified. First, all responders use, in a form or another, the Moodle open-source platform as an LMS (learning management system). By looking at different other universities in Europe and beyond, Moodle seems to be one of the most preferred LMS platforms to support online teaching activities. However, the main issue with Moodle is locality. The platform is usually installed within the premises of a university and integrated with only the Identity Provider service of that institution. However, such an approach only works for people located within the premises of that university – for a remote user it is harder to verify the online identity alone, not to mention it is simply not working for partnerships.

Furthermore, only placing resources in a Moodle instance is not enough. In our vision, we discussed about developing Digital Labs and properly adapting the teaching methods to online characteristics. One idea is that students should have access in their classes, as much as possible, to Data. For example, in the Big Data class being taught at the University Politehnica of Bucharest (UPB), students are presented with challenges based on sets of data: "please present your conclusions from an analysis of the data pertaining to this particular phenomenon". To present students with such challenges encourages them to critically think about their solutions. They need to show how they reach a particular conclusion, what are the rationales behind their steps in the analysis, how they motivate their work methodology in particular (so the result is not necessarily important on its own, but rather important is how it is obtained).

For this particular purpose, universities should be able to also give access to data. If a student from an external university enrols in the Big Data class at UPB, she will need access to the datasets to complete the learning challenge. The solution we propose consists of an integration with eduGAIN (Michael and Anna, 2019), a service that connects identity providers, simplifying access to content, services, and resources. Since each university has an institutional data repository – usually based on technologies like CKAN (Wang et al., 2020), Dataverse (King, 2007), Invenio (Katoch et al., 2019) – or a generic data repository such as Zenodo (Peters et al. 2017), it can easily be registered in eduGAIN as a service provider, which means that, like with Moodle, a student could be correctly recognized in the data repository at UPB with her credentials from an external institution. And, of course, the same logic could apply to a bunch of different other digital tools classes rely on. Any digital tool can be registered in eduGAIN as a Service Provider, and then we can integrate the recognition of remote Identity Providers as part of the credentials correctly accepted for authentication and service provisioning. Figure 3 gives an example of such a situation.

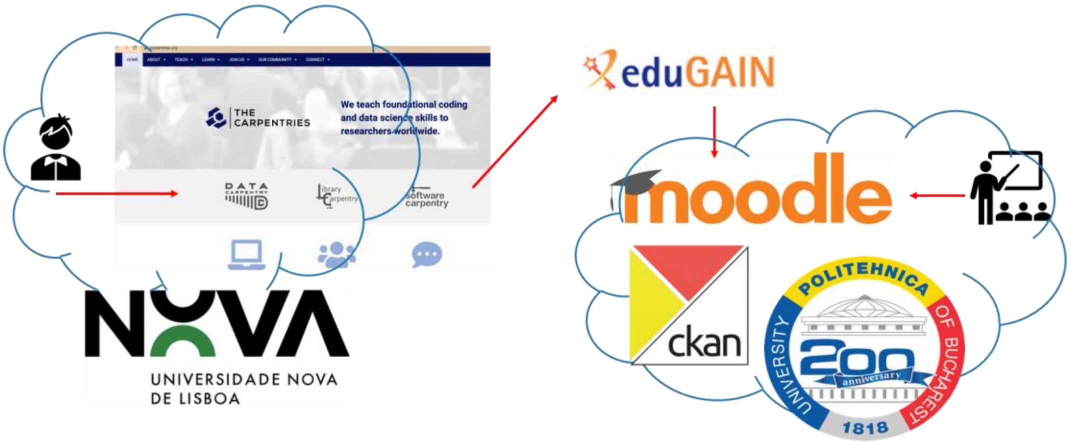

Figure 3. Integrating eduGAIN with Moodle for collaboration between education institutions.

One important such tool is Jupyter Notebooks (Kluyver et al., 2016), which is a framework for interactively implementing, documenting, and sharing data science projects as *notebooks*. These notebooks are documents composed of code (e.g., Julia, Python, R, etc.) and visual elements (text formatting, figures, URLs, etc.), as well as experiment results (figures, tables, etc.). At the same time, a notebook can be executed to replicate an original data analysis. The Jupyter Notebook has grown in popularity in recent years, and it has quickly become the preferred environment for data science. Furthermore, recent years have seen it grow in popularity in education because it allows teachers to develop and share interactive lessons. The Jupyter Notebook app is a web-based application that supports the execution of Jupyter Notebooks, which can be run locally or on a remote server. And, more importantly according to our responses in the questionnaire as shown in Figure 2, many universities provide classes based on applications on top of Jupyter Notebook app.

On top of Jupyter Notebook, a plethora of tools were developed in recent years, such as JupyterHub, which offers a full Jupyter deployment that can be set up in a private datacentre or in a remote cloud. And then, a tool like Binder (Ragan-Kelley et al., 2018) can be used, which creates custom Jupyter Notebook instances automatically from a repository, and allows them to be shared with, for example, the students participating in a course. It also helps create reproducible research (useful in RBL) and it can work with various Data Repositories like the ones mentioned above. Binder is widely used for teaching and training since it allows the sharing of links to interactive environments (Ragan-Kelley et al., 2018).

So, in our vision, all these digital tools could easily be part of the educational system, part of activities in classes belonging to the IoT or BigData domains, and even more importantly, be integrated with eduGAIN to allow for remote access to educational resources for students from all over the world. Completely out-of-the-box, such tools can give students access to resources without having to install and maintain anything. Students would simply connect, each to their own copy of the environment, and develop content as directed, often writing short segments of code. Such an approach has the potential to be used as a teaching tool for both specific course content and programming languages. It allows for flexibility for instructors and students, or for accessible coding environment. Additionally, it is highly relevant for investigations in applied academic research. Thus, we believe that Jupyter Notebooks need to become part of the remote Classroom we envision. In Figure 4, we can see a depiction of our proposed vision.

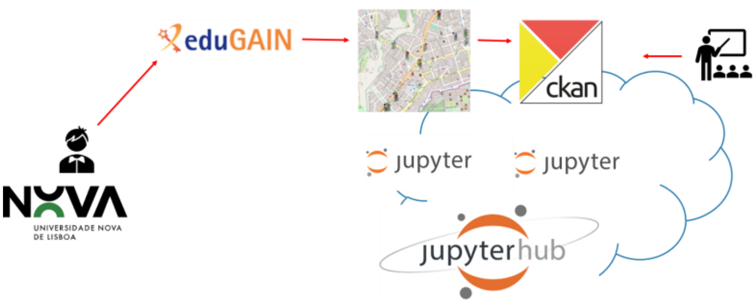

Figure 4. Integrating Jupyter Notebooks with eduGAIN.

Conclusions

In this paper, we discussed the distributed classroom paradigm in Educaion 4.0, which is based on Massive Open Online Courses, Research-Based Learning, and Digital and Virtual Labs. We motivated its necessity by analysing the responses from a questionnaire we developed, and we proposed a distributed classroom implementation using eduGAIN, CKAN, and JupyterHub.

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References[1]:

Attis, D., Koproske, C. and Miller, C., 2012. Understanding the MOOC trend: The adoption and impact of massive open online courses. *Washington, DC: The University Leadership Council, The Advisory Board Company*.

Ciccarelli, D., 2022. *Elearning vs. Traditional Learning: Considerations for Educators*. [online] Voices. Available at: <https://www.voices.com/blog/elearning-vs-traditional-learning/> [Accessed 7 October 2022].

Gazi, Y. and Baker, N., 2021. Moving Horizontally: The New Dimensions of At-Scale Learning at the Time of COVID-19.

Gutierrez, K., 2022. *Facts and Stats That Reveal The Power Of eLearning [Infographic]*. [online] Shiftelearning.com. Available at: <https://www.shiftelearning.com/blog/bid/301248/15-facts-and-stats-that-reveal-the-power-of-elearning> [Accessed 7 October 2022].

Joyner, D.A., 2021. Mechanisms for Supporting Emergency Remote Classes: Towards a Distributed Classroom. Georgia Institute of Technology.

Katoch, S., Thopalli, K., Thiagarajan, J.J., Turaga, P. and Spanias, A., 2019. Invenio: Discovering hidden relationships between tasks/domains using structured meta learning. *arXiv preprint arXiv:1911.10600*.

King, G., 2007. An introduction to the dataverse network as an infrastructure for data sharing. *Sociological Methods & Research*, *36*(2), pp.173-199.

Kluyver, T., Ragan-Kelley, B., Pérez, F., Granger, B.E., Bussonnier, M., Frederic, J., Kelley, K., Hamrick, J.B., Grout, J., Corlay, S. and Ivanov, P., 2016. *Jupyter Notebooks-a publishing format for reproducible computational workflows* (Vol. 2016, pp. 87-90).

Krishnan, K., 2022. *Our education system is losing relevance. Here's how to update it*. [online] World Economic Forum. Available at: <https://www.weforum.org/agenda/2020/04/our-education-system-is-losing-relevance-heres-how-to-update-it/> [Accessed 7 October 2022].

Krontiris, A., 2021, June. Virtual labs–challenges, opportunities and practical lessons learned. In *2021 9th International Conference on Modern Power Systems (MPS)* (pp. 1-4). IEEE.

Leininger, C. and Morhell, N., 2022. *[Panel Webinar] Transforming R&D and data control with cloud-based informatics*. [online] Pharma IQ. Available at: <https://www.pharma-iq.com/informatics/webinars/transforming-r&d-data-control-with-cloud-based-informatics> [Accessed 7 October 2022].

[1] Please apply the Harvard style system (UK spelling) for text and bibliography.

Michael, S. and Anna, Z.J., 2019, April. An identity provider as a service platform for the edugain research and education community. In *2019 IFIP/IEEE Symposium on Integrated Network and Service Management (IM)* (pp. 739-740). IEEE.

Parra, J., 2022. *What is Research-Based Learning (RBL)? — Observatory | Institute for the Future of Education*. [online] Observatory | Institute for the Future of Education. Available at: <https://observatory.tec.mx/edu-bits-2/research-based-learning> [Accessed 7 October 2022].

Peters, I., Kraker, P., Lex, E., Gumpenberger, C. and Gorraiz, J.I., 2017. Zenodo in the spotlight of traditional and new metrics. *Frontiers in Research Metrics and Analytics*, *2*, p.13.

Ragan-Kelley, B., Willing, C., Akici, F., Lippa, D., Niederhut, D. and Pacer, M., 2018. Binder 2.0-Reproducible, interactive, sharable environments for science at scale. In *Proceedings of the 17th python in science conference* (pp. 113-120). F. Akici, D. Lippa, D. Niederhut, and M. Pacer, eds.

Wang, Z., Lin, G., Tan, H., Chen, Q. and Liu, X., 2020, July. CKAN: collaborative knowledge-aware attentive network for recommender systems. In *Proceedings of the 43rd International ACM SIGIR conference on research and development in Information Retrieval* (pp. 219-228).