Promises of AI in Education

Discussing the impact of AI systems in educational practices

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1 Introduction

Bringing innovative technologies into the classroom is always experimental and requires some awareness of what the needs are of the teacher and students. Artificial intelligence (AI) has begun finding its own way into classrooms, schools, and the ways in which we bring school home via homework or extracurricular activities. This has led to new conversations that may have been foreign to students, teachers, and administrative staff alike twenty years ago. Conversations about learning analytics, AI in education, digital literacy, privacy, and questions of data sovereignty. This report delves into the use of AI in educational practices on a micro, meso, and macro scale. This is not only a question for educational IT departments, as the application of AI in Education (AIED) also directly impacts the educational practices of teachers and support services by educational experts.

1.1 Discovering AI in Education by way of collecting examples

The main goal of this publication is to give educational professionals a starting point from which to discover the possible applications of AI in education. For this the basis does not lie in theories of AI in education, but the practical application within the classroom or educational institution.

In the appendix you will find a collection of different applications of AI in education. This list can function as an inspiration and a guide for discovery. Are you interested in the improvement of reading and writing skills for students? Have a look at FeedbackFruits or Perusall. More interested in applications that lower administrative workload? Check out chatbots such as Ada and Jill Watson, or perhaps smart interactive apps like Deakin's Genie. This collection is not complete, but might serve as a guidepost in the discovery of these new applications.

1.2 How do we get from AI to AI in education?

To understand AI in education we need to better understand AI as a technological development and its application within the domain of education. In chapter 2 we discuss the differing definitions of AI and how this translates to the educational domain. This is followed by an analysis in chapter 3 where four specific applications of AI in education (Perusall, Jill Watson, PhotoMath and GPT-3) are viewed through the lenses of the micro-, macro-, and meso contexts of their application.

How does the use of an AI-enabled social learning application like Perusall impact the classroom and its learners and teachers (micro)? What additional questions and responsibilities arise for support and administrative staff in using chatbot systems like Jill Watson on an institutional level (meso)? And, how do we deal with new technology when students or staff members bring them in from the outside world; such as PhotoMath or GPT-3 (macro)? The introduced applications show the breadth of AI within education and the changing contexts of its application.

1.3 AI in education and changing contexts

When we further discover the possible future role of AI systems in education, new and challenging questions for stakeholders within institutions come up. This 'system technology' will have a pervasive and systematic impact on society as a whole, including education.[1] As a result of its increased use, the questions surrounding AI application become more urgent. In the European context, there is increasing awareness of the promises and risks of the use of AI, which has led to Ethics Guidelines for Trustworthy AI[2] and a proposed regulatory framework[3]. These developments show the dynamic context of the use of AI in education and mean this publication should be seen in relation to these surroundings as a guidepost more than a complete overview.

[1] https://www.wrr.nl/binaries/wrr/documenten/rapporten/2021/11/11/opgave-ai-de-nieuwe-systeemtechnologie/Summary+WRRreport_Mission+AI_The+New+System+Technology_R105.pdf

[2] https://digital-strategy.ec.europa.eu/en/policies/expert-group-ai

[3] https://digital-strategy.ec.europa.eu/en/policies/regulatory-framework-ai

2 What is AI (Artificial Intelligence)?

Developments in AI have begun streaming into many aspects of society. Increasingly AI is applied in varies domains, such as healthcare, banking, and IT services. We also see an increase in application of AI in the educational sector. There are now AI systems that work with students for second language learning, math skills, braille teaching and even social skill developments, to name a few. In general, AI can be seen as a technological development that will be applied in a domain. This chapter aims to grasp what artificial intelligence is as a technology or method and what it means applied to the domain of education. This report reviews multiple definitions of AI to show how it is not easy to understand AI methods and systems in isolation. After a definition is given of AI and its related field of Machine Learning, the context of education is brought in. What is AI in Education turns to understanding the use of AI in educational applications with an educational perspective in mind.

2.1 Understanding definitions of Artificial Intelligence (AI)

Defining 'artificial intelligence' is a complex activity, as its systematic impact results in lots of different people having different perspectives on the technology. When it comes to AI, there is a strong history of speculating about the nature of intelligence and attempting to build parts of it. Often AI is defined as the research that develops technologies that have a capability to do things that would require intelligence if done by humans. As a consequence, our perception on what AI is continuously shifts as we often see AI as the "cool things that computers can't do" and humans can. It is important to realise that AI is more of a discipline than a 'thing', which means it is not 'an AI' but 'an application of AI' or 'an AI method' that we are talking about[4]. Two often used definitions are those by Nilsson and by Russell and Norvig.

> "*AI, broadly (and somewhat circularly) defined, is concerned with intelligent behaviour in artifacts. Intelligent behaviour involves perception, reasoning, learning, communication and acting in complex environments*."[5]

And

> *"In computer science, artificial intelligence (AI), sometimes called machine intelligence, is intelligence demonstrated by machines, in contrast to the natural intelligence displayed by humans. Colloquially, the term "artificial intelligence" is often used to describe machines (or computers) that mimic "cognitive" functions that humans associate with the human mind, such as "learning" and "problem solving"."*[6]

Both share the placing of intelligent capability within artefacts or systems and an outwards oriented element where the system seems to demonstrate intelligent behaviour. This behaviour might be learning, communicating, or acting; but at least has a proactive element where a system is 'doing' something. A more general definition can be found in the Dutch National AI

[4] "A Free Online Introduction to Artificial Intelligence for Non-Experts," Elements of AI, accessed January 19, 2022, https://course.elementsofai.com/.

[5] Nilsson, N. J., & Nilsson, N. J. (1998). *Artificial intelligence: a new synthesis*. Morgan Kaufmann. https://doi.org/10.1016/B978-0-08-049945-1.50005-8

[6] Russell, Stuart, and Peter Norvig. "Artificial intelligence: a modern approach." (2002). http://aima.cs.berkeley.edu/

Course, which defines AI as "*Intelligent systems that can perform tasks independently in complex environments and improve their own performance by learning from experience*"[7].
Another definition of artificial intelligence comes from a recent report by the OECD, which refers to AI as, "*the capacity for computers to perform tasks traditionally thought to involve human intelligence or, more recently, tasks beyond the ability of human intelligence*."[8]
The key word in the OECD definition is 'traditionally', as AI methods and applications have begun to challenge what people should be doing versus what machines should be doing in task-oriented work. As we shall see, the same challenges about what tasks should be done by computer applications and what tasks should be done by people has also begun to ring through the halls of educational institutions.

These definitions might be broad, somewhat circular, and open to interpretation. In legal and policy discussions, AI is often defined more strictly. In the current draft version of the European Union AI Act, the definition specifically refers to an annex list of technologies and approaches that fall under 'AI'.

"Artificial intelligence system' (AI system) means software that is developed with one or more of the techniques and approaches listed in Annex I and can, for a given set of human-defined objectives, generate outputs such as content, predictions, recommendations, or decisions influencing the environments it interacts with"[9]

This annex includes technologies based in machine learning, logic- and knowledge based, but also statistical and probabilistic approaches. Policy definitions such as this are oriented on the effect of the technology on people, as can also be seen with the mention of 'content, predictions; where recommendations, or decisions' central to AI have a severe impact on peoples' lives and wellbeing. In the current draft of the AI Act, AI systems used in education are seen as high-risk where AI systems determine access to education or evaluate persons on tests, as they can significantly determine a person's future.

2.1.1 Many different definitions for many different domains

These definitions help with getting a grip on the term artificial intelligence. They show how shared elements of a system are capable of demonstrating some kind of intelligent behaviour. In many cases it is more important to try and understand each other's definitions than it is to come to a shared definition. All these methods or technologies become relevant in the application to a specific problem or a specific domain and for each domain a different definition might prove more fitting. The contextual knowledge of a specific domain, often called domain-knowledge, is necessary for any successful application of AI. This means that not all AIs used in all educational applications are the same, and defining artificial intelligence overall may not be the only way (or best way) to understand its significance in a classroom. AI in education does not mean applying one artificial intelligent system to all of education, but many uses of AI in various applications.

[7] "Gratis Online Cursus Kunstmatige Intelligentie," accessed April 25, 2022, https://app.ai-cursus.nl/.

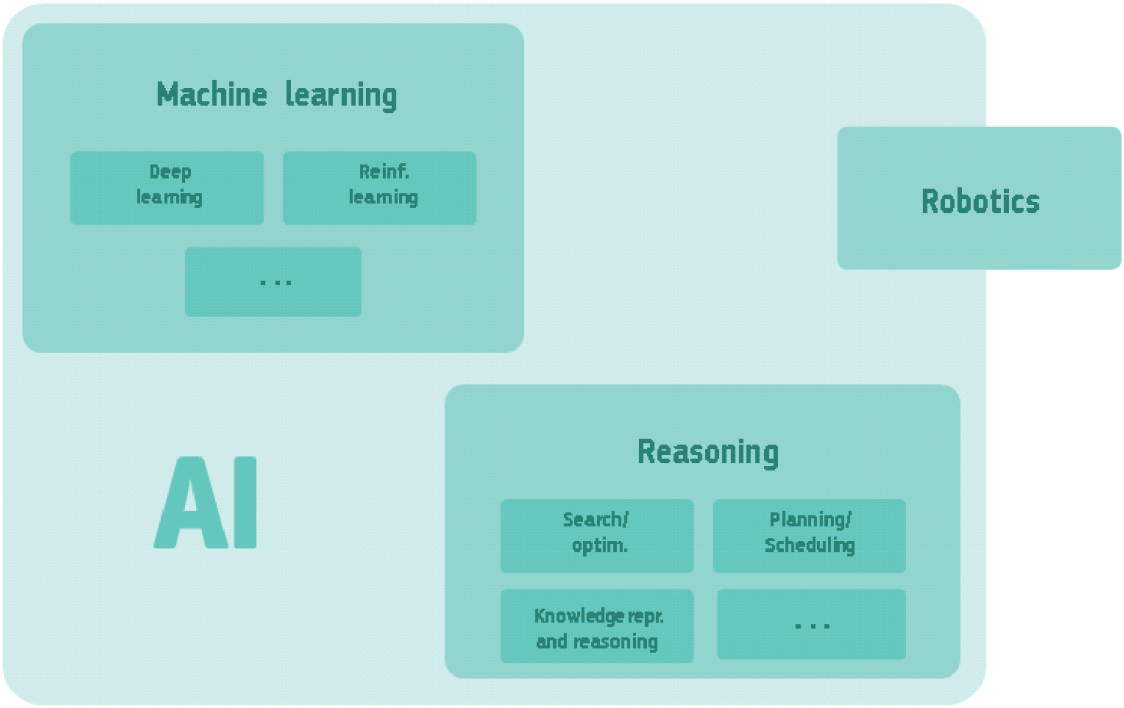
[8] OECD, *OECD Digital Education Outlook 2021: Pushing the Frontiers with Artificial Intelligence, Blockchain and Robots*, OECD Digital Education Outlook (OECD, 2021), https://doi.org/10.1787/589b283f-en.

[9] EC. (2021). Proposal for a Regulation of the European Parliament and of the Council laying down harmonised rules on artificial intelligence (Artificial Intelligence Act) and amending certain union legislative acts (2021/0106 (COD).

Later, this report goes into different examples that can be considered as using AI methods to substitute, augment, modify and or redefine educational practices[10]. First, we will discuss one of the driving technologies behind the current rise to success of AI applications.

2.1.2 Artificial Intelligence: a collection of methods

Over time, the field of AI has developed the following different ideas of which method would work best in creating intelligence. Many of the current and impressive achievements accredited to AI come from developments in the field of machine learning (ML), which is based on the concept of learning from data. However, the other paradigm based on reasoning and decision-making also has a strong history within the AI in education field.



A simplified overview of Artificial Intelligence by the EC High-Level Expert Group on AI[11]

One clarifying definition is that machine learning "*is when a system discovers patterns from data – becoming more effective at doing so when more data is available (and even more so, when more comprehensive or representative data is available).*"[12] Machine learning is a part of, or subfield of, AI. Machine learning is often used for improving performance of systems in a specific given task. A machine learning system is normally trained before implementation, meaning the 'learning' part stops at implementation, but can also keep learning when deployed. The training of machine learning can be supervised or unsupervised, or a little bit of both.

[10] According to the SAMR-model, these are the four manners in which educational technologies can enhance or transform educational practices. http://www.hippasus.com/rrpweblog/archives/2013/04/16/SAMRGettingToTransformation.pdf

[11] HLEG AI (2018), *A definition of AI: Main capabilities and scientific disciplines* https://ec.europa.eu/futurium/en/system/files/ged/ai_hleg_definition_of_ai_18_december_1.pdf

[12] OECD, *OECD Digital Education Outlook 2021: Pushing the Frontiers with Artificial Intelligence, Blockchain and Robots*, OECD Digital Education Outlook (OECD, 2021), https://doi.org/10.1787/589b283f-en.

Supervised training of Machine Learning systems requires that data in a dataset is already labelled. Think of a dataset with pictures of dogs and cats, which are each marked with a label 'dog' or 'cat'. Often this is done by people. An example of this are ReCAPTCHAs, which are used to show you are a real human being attempting to log-in, where in selecting all cars you are essentially labelling a dataset. During training, the algorithm progressively determines the relationship between the characteristics and their respective labels. The supervisory part of this means that you are telling the system that for every output, there is a specific 'right' answer that you will give it and it should start to see.

Unsupervised training then consists of an algorithm finding meaningful or significant patterns in data which are not labelled beforehand. ML systems then cluster data or label it in ways that can give insights into the data. Think of how recommender systems as used by entertainment platforms have a dataset of all the movies you have seen and based on that data can infer which other movies fit the pattern (and you might like).

As you can see, the availability of data for systems to train on is crucial. AI as a technology has a long history, but has recently become more able and relevant, partly due to increases in available data and compute power. AI systems can be found in many different applications in our everyday life that were not possible 10 years ago. In the next section we will discuss how AI can be applied to the domain of educational technologies.

2.2 What is AI in Education?

From virtual tutors to classroom chat bots, the application of AI in the educational world has come a long way. Since the early 1980s, AI work has been applied to try to capture the most efficient ways of teaching or training students in specific fields of knowledge such as maths and engineering.[13] Because of the well-defined problems in maths and engineering, it was possible to completely encode the learning activity and shown to the learner what they got right or wrong along the way. One example of an older AI learning system was used to teach individuals how to shut down a boiler system properly, effectively training users without much prior knowledge of the system.[14] Increasingly AI is becoming more pervasive in education. Nowadays teachers and students are often using AI without being consciously aware of it. AI can be found in search engines, social media, games and other general applications. We also see AI-based language learning tools such as Duolingo used all around the world.

In the case of AI applications in education, a distinction is often made between student-facing, teacher-facing, or system-facing applications[15]. There are adaptive learning environments, intelligent tutoring systems, and AI systems aimed at assessment. As AI is a technology applied within the domain of education, any part of education could possibly be confronted with the new possibilities of this technology. In the context of AI in teaching and learning, that is often referred to as AIED, AI in Education. Within this report, we follow a relatively broad perspective on AI in education, encompassing also the system-facing applications of AI. In the appendix, a

[13] Woolf, Beverly Park, H. Chad Lane, Vinay K. Chaudhri, and Janet L. Kolodner. "AI grand challenges for education." *AI magazine* 34, no. 4 (2013): 66-84.
[14] Woolf, B. (1991). *AI in Education*. University of Massachusetts at Amherst, Department of Computer and Information Science.
[15] Wayne Holmes, Maya Bialik, and Charles Fadel, *Artificial Intelligence In Education: Promises and Implications for Teaching and Learning* (Boston, MA: Center for Curriculum Redesign, 2019), http://udaeducation.com/wp-content/uploads/2019/05/Artificial-Intelligence-in-Education.-Promise-and-Implications-for-Teaching-and-Learning.pdf.

collection of different examples of AI in education is gathered, a selection of which will be analysed in the next chapter on educational practices.

The use of AI in education is dependent on the necessary educational data. Educational institutions gather data from systems and technologies used within the institution. The analysis of this data is often called learning analytics. This is not necessarily an application of AI in education, but can be enhanced by new AI-based technologies. In essence, learning analytics is the collection of data about learners and their contexts; the data is gathered with purpose and used to measure student performance, understand the effectiveness of teaching practices, and inform institutional decisions and strategies.[16]

One could say that once educational data is analysed it is categorised as learning analytics; once that analysis also generates an output (whether it be a decision or an action), it can be seen as AI in education. That output can be seen in language learning applications such as DuoLingo, where a system decides which assignment to present to the student next, as well as feedback applications such as FeedbackFruits, which gives feedback to students on whether they have met an expectation or norm.

Successful applications of AI in education can only occur when the technology is applied with a deep understanding of the education domain. For FeedbackFruits and DuoLingo this means that to be successful in their product they need the technological capabilities just as much as the pedagogical knowledge of teaching writing skills and memorisation of words.

2.3 Conclusion

AI has been around for a long time. In consideration of the proliferation of definitions of AI that have popped up over that time, this report recognises several of these definitions. This is both to help new learners of AI see how the technology is described in a variety of ways, as well as show that the technology continues to impact new domains. AI takes advantage of many methods of algorithmic processes that, when coupled together, create a powerful system of decision-capable applications. Machine learning, a subfield of AI, is also recognised here as an important part of AI. When trained well, ML systems can label and categorise many data points without being supervised by humans. This leads to new predictive capabilities by ML in huge datasets that humans can often take advantage of.

Increasingly we see examples of AI technologies used in education. In this report we present a selection of examples from a broader collection in the appendix. Precisely defining when an educational technology will be AI in education is difficult, which is why it is important to understand that AI is always a method or technology applied in a particular domain. For legal purposes, a strict definition of AI is very important. For the practical purpose of the use of AIED, it is more important to discuss and make sure you understand each other's definitions.

In the next chapter we will look at the impact AIED applications have on students, teachers, and educational institutions and their educational practices.

[16] Northeastern University Graduate Programs. "What Is Learning Analytics & How Can It Be Used?," February 18, 2020. https://www.northeastern.edu/graduate/blog/learning-analytics/.

3 Applying AI in Educational Contexts

While AI might have promising applications in education, its use has ripple effects across the schools and institutions in which they are implemented. A clarifying way to model what this impact looks like in schools is through profiles, or sections dedicated to the school community members. The following sections will discuss use cases from examples found in our research (see appendix for more) in relation to the micro, meso, and macro contexts of education. To reflect on how relevant persons will be impacted by the use of AI systems in education, we discuss its impact in the classroom (micro), the educational institution (meso), and on broader society (macro). Different use cases from the AI in Education table will be used as helpful examples to guide readers through understanding AI impact and changes within their own role and perhaps their colleague's role.

3.1 In the Classroom (micro-level)

In this section we will discuss the application of AI to technologies used on the micro-level, the classroom. By in the classroom, we mean in a physical interaction and not mediated by video conference technologies. This classroom perspective helps us to break down examples from the broader context of teaching. Educational technologies using AI will impact the educational experience of teachers and students by substituting, augmenting, modifying, or redefining current educational practices.[17]

As an example, we will investigate the use of Perusall as a tool to augment the practice of teaching students how to read academic literature. There are many other examples in the appendix table that were also found and considered for this section, including IguideMe, Braille AI Tutor and MATHai. Perusall was chosen for both the amount of research available on the tool as well as for its popularity in the Netherlands. It is a unique platform that is designed to prepare students for the class, where the student is asynchronously active in a group. From this, Perusall is therefore classified as a social annotation platform.

3.1.1 Example: Perusall

What is it?

Perusall is an application used by teachers to support and motivate students in preparing class readings. By using insights from behavioural science and the application of AI methods, Perusall improves students' reading and annotation skills by stimulating peer feedback, offering informative questions, and helping students by addressing questions or confusions. [18]

How does Perusall work?

Perusall has a goal of creating more readiness in students for courses through pre-reading compliance. To achieve this, educators develop online courses through Perusall by uploading materials which vary from: PDFs, videos, podcasts, e-books, and Word or Excel documents. Encouraging students to read means engaging in a learning cycle focused on core teaching practices such as explaining or modelling content in a way that is digestible for students.[19] Perusall's value on collaborative work means that teachers, mentors, student teachers and students can contribute to the conversations asynchronously through feedback, comments, or

[17] Holmes, Wayne, Maya Bialik, and Charles Fadel. "Artificial intelligence in education." *Boston: Center for Curriculum Redesign* 2019 (2019): 1-35.

[18] Perusall, "Perusall - Research," accessed February 10, 2022, https://perusall.com/research.

[19] Carisma Nel and Elma Marais, "Addressing the Wicked Problem of Feedback during the Teaching Practicum," *Perspectives in Education* 39, no. 1 (March 12, 2021): 410–26, https://doi.org/10.18820/2519593X/pie.v39.i1.25.

questions. The AI used in Perusall is deployed as a behavioural change agent that curates both comments and nudges for students to give feedback in clever ways.[20] Perusall relies on intrinsic social motivations of students as well as extrinsic motivations of automatic grading of comments or annotations, assuming students want to receive good grading and are motivated. Moreover, other features include 'student confusion reports', participation analytics, and word clouds based on feedback from documents students annotate. Ultimately, these tools intend to both help teachers learn more about how their students engage with text, while also pulling students towards being "on the same page" and in the same direction of content comprehension and reading engagement.[21]

3.1.2 Teachers

The instructors of the classroom will look towards Perusall for many ways of teaching and working with students. Perusall, once set up with the correct documents and accounts for students to log into, can aid teachers in several ways that not only shape new routines and habits in the classroom, but also the way in which learning material is taught.
With Perusall, what is often first noticed is how classroom discussions begin to change. Classroom discussions have been described as less of a 'monologue' by teachers, and more of a two-way conversation between students and lecturer.[22] This may be explained partially by how Perusall as a platform measures performance of students based on quality of annotations made in assigned reading before class. Moreover, considerations for student involvement in answering other student questions online may play a part as well. In this, dialogues about the text have already happened before the students return to class; or have come back to the online lecture. From these students' annotations, teachers can also learn more about what 'makes sense' as an answer to their students[23]. From the reflections about grading and what students annotate in text, there is an opportunity for critical considerations about what is to be considered a 'satisfactory answer' for students; ultimately shaping the curriculum that reflects this new approach to answers.

Generating more engaging feedback for classroom discussions has become increasingly important considering the increase in online classes. Perusall's clarification, support, and feedback features may provide a new tool that many teachers can take advantage of. Bringing this technology into a classroom may also raise new critical questions. These will be discussed after first considering how Perusall affects students' experiences as well.

3.1.3 Students

Perusall co-shapes new ways of annotating for students, as well as how they receive feedback from mentors or teachers. The platform supposedly develops (and grades) "annotating thoughtfully" which is defined as: deeply engaging points in the readings, stimulating responses by classmates, offering informative questions or comments, and helping others by addressing their questions.[24] Through both the intrinsic and extrinsic motivations discussed in the earlier section, student engagement is partially supported by trying to achieve these thoughtful valuations. Moreover, the AI grades the students' comments based on 3 relevant criteria:

[20] Perusall, *Introduction to Perusall*, 2021, https://www.youtube.com/watch?v=_PfAc0D2erk.
[21] Carisma Nel and Elma Marais, "Addressing the Wicked Problem of Feedback during the Teaching Practicum," *Perspectives in Education* 39, no. 1 (March 12, 2021): 420-421, https://doi.org/10.18820/2519593X/pie.v39.i1.25.
[22] Perusall, *Introduction to Perusall*, 2021, https://www.youtube.com/watch?v=_PfAc0D2erk.
[23] Carisma Nel and Elma Marais, "Addressing the Wicked Problem of Feedback during the Teaching Practicum," *Perspectives in Education* 39, no. 1 (March 12, 2021): 421-422, https://doi.org/10.18820/2519593X/pie.v39.i1.25.
[24] Brian Lukoff, "What Is 'Perusall'?," https://crlt.umich.edu/sites/default/files/NFO19_Concurrent_Session_Materials/Perusall-FutureFaculty.pdf.

Complexity of structure, distribution of comments throughout the reading, and interaction between comments.[25] This creates a general way of understanding how the AI may give one student with one word answers a lower grade than one student with long, 'thoughtful' comments that spark new questions from others. Moreover, students are advised to read further into the assigned piece before commenting, because the AI grades them based on distribution of comments as well. In other words, putting a few complex comments in the first few lines of text does not lead to better scores.

By simplifying Persuall's grading system, we find that students are held accountable for their annotations and comments in the virtual text. The technology tries to mimic a sort of 'social media platform'-like discussion on the text and adds it as part of the reading process. In turn, creating new relationships to reading online and the practice of annotations as collaborative through digitise engagement. The hope, of course, is that this engagement flows over into classroom discussions.

3.1.4 Discussion: Perusall and the Classroom

The benefits of a technology like Perusall when effectively implemented in a classroom show promise. Looking both from the teacher and student perspective, the next section considers new critical questions and analysis about Perusall and tech like it in the classroom.

Teacher-Student: Analysis

Moving forward with a technology like Perusall is both an exciting and curious endeavour for teachers and the way they work in the classroom. One change would be understanding a shift in pedagogical practices. New pedagogies form for teachers as AI use in the classroom finds a way to digitise student accounts, profiles, and dashboards – ultimately producing information about seemingly countless data points.[26] The sheer amount of information that Perusall will give to teachers is astonishing. For example, Perusall monitors continuously, and can even send students a private nudge with help and directions, as well as alerting you to 'at-risk' students. For features like this to work effectively, they need consistent monitoring of a student's behaviour with the texts they read.

Further, Perusall allows teachers to see information about many features of the student that were not available before and the way in which students see annotations of each other. For example, teachers can choose instantaneous grading of annotations, make student annotations anonymous to all other students, or break the class into a manually determined set of sub-groups.[27] Pedagogies in the classroom begin to change through a consistent flow of digital information relating to every student's reading performance, where it used to be impossible to 'watch' every student in the classroom before. What teachers do with this information and how they make use of it is still up to them.

One good thing to remember is that AI applications are trained on data sets to make qualitative interpretations of the words we write. They are often trained on data from specific communities. These communities are never 'perfect' or free from faults, but they continue to change over

[25] Brian Lukoff, "What Is 'Perusall'?," https://crlt.umich.edu/sites/default/files/NFO19_Concurrent_Session_Materials/Perusall-FutureFaculty.pdf.

[26] OECD, *OECD Digital Education Outlook 2021: Pushing the Frontiers with Artificial Intelligence, Blockchain and Robots*, OECD Digital Education Outlook (OECD, 2021): 47-48, https://doi.org/10.1787/589b283f-en.

[27] Andrew J. Clarke, "Perusall: Social Learning Platform for Reading and Annotating (Perusall LLC, Perusall.Com)," *Journal of Political Science Education* 17, no. 1 (January 2, 2021): 149–54, https://doi.org/10.1080/15512169.2019.1649151.

time. For Perusall, the automatic grading system supplied grades similar to those expected by the teacher, even in a study with non-native English-speaking students.[28] It is possible that due to the students' language skills, because Perusall is trained in English and other languages, that this training may influence the automated scores compared to the teacher's expected scores. In other words, it may be more difficult for students with less overall English vocabulary and skill to do well on the automated grading review if the system is not set up for the (dominant) language of the classroom. Still, students perceive the automatic grading in this study as fair and consistent with teacher expectations.[29] What insights like these can lead to is the general discussion around educational technologies and AI, where historically, under-served and underrepresented populations, including ethnic/racial minorities and linguistic minorities are not well represented by these technologies' training data.[30]

Teachers implementing AI systems in their classrooms and lectures therefore have questions they should ask, such as:

Teacher: Questions

- Do all my students have access to a device and Internet connection to do their classwork?
  And also at home to do their homework?
- Who can I go to for support with a new system like Perusall?
- Do I agree with the grades this system is automatically giving? What do I do if I disagree?
  What changes in curriculum will have to happen to work with this platform?
- How do I communicate to my students that an algorithm will grade their work?
  What if students do not know the AI is grading their work?
- Will there be students that don't 'fit in' to the AI framework of grading?
  Can we resolve this consideration, or will it constantly be a problem?
- Is this AI-driven system shaping or producing the kind of learning practices I want my students to perform and pursue later?
- Will I give students an opportunity to opt out of automatic grading by the platform?

While teachers begin to co-create new educational practices with AI-powered technologies like Perusall, students must meet the standards set and experiment with the technology to finish their assignments. For automatic grading, feedback and annotation work, students will need to meet certain expectations that may not be clear. The earlier sections reviewed how grading and functionality of Perusall is curated by the teachers implementing the platform. This can lead to a situation of unclear grading practices. Where a teacher does not have experience with the Perusall system or does not communicate well the rather unclear grading requirements of Perusall, then students are forced to learn through experimentation. Experimenting with what the system believes an 'excellent' quality answer is until they fit the parameters sufficiently. In turn, some research has shown that students do want to have student-teacher evaluations included in their work, or more teacher discussions on their feedback. In other words, "Students state that, although the automated assessment process can make it efficient and impartial, they personally prefer a human "opinion"."[31] Leading back to new conversations about the role of the teacher in student engagement and evaluation with AI as a supposedly impartial first reader.

[28] Cecchinato, Graziano, and Laura Carlotta Foschi. "Perusall: University learning-teaching innovation employing social annotation and machine learning." *Qwerty-Open and Interdisciplinary Journal of Technology, Culture and Education*15, no. 2 (2020): 45-67.
[29] Ibid.
[30] OECD, *OECD Digital Education Outlook 2021: Pushing the Frontiers with Artificial Intelligence, Blockchain and Robots*, OECD Digital Education Outlook (OECD, 2021): 48-50, https://doi.org/10.1787/589b283f-en.
[31] Cecchinato, Graziano, and Laura Carlotta Foschi. "Perusall: University learning-teaching innovation employing social annotation and machine learning." *Qwerty-Open and Interdisciplinary Journal of Technology, Culture and Education*15, no. 2 (2020): 57-58.

While grading and assessment are important to understand with any AI-generated feedback, monitoring is also a unique feature of a platform based almost solely on reading annotations. Perusall needs this monitoring in order to provide its 'confusion reports' which are reports that are often generated before class which supply questions and comments that students needed to have answered in the text. Confusion reports automatically summarise the most important areas considered by AI where either reading or video analysis caused confusion or was not clear to students.[32] Perusall, effectively, "automatically mines questions that students are asking about a particular reading assignment and, using a topic-modelling algorithm, groups questions into three to four conceptual areas of confusion".[33] Reports like these require data about where students spend time on a page, what they answer for annotations, and whether they are getting through the text effectively. Interestingly, students in some reports are not keen on or do not care much about AI monitoring their behaviour.[34]

A student's perspective on AI continues to change as technologies come and go from their years in education. This may allow students to have special insights on how AI methods develop them as learners. For students then, it is good to question whether the technologies they use are affecting them for the better and voice their opinions about their educational experiences with them.

Students: Questions

- Am I learning skills that don't require this specific technology? Do I have to have Perusall to give valuable feedback in future courses?
- Who can I go to for help when I don't agree with an algorithm's evaluation of my annotations or work?
- Where does my assessment data as a student go after I leave the educational institution? Can I ask for it to be deleted?
- Does my teacher understand how the AI methods in this technology are implemented? Can they explain them to me?
- Can I opt out of being monitored by an AI system in my school? What are my rights as a student involved in a private company harvesting my data?

3.1.5 Key Takeaways

The use of AI-powered educational technologies co-shapes 'the classroom' in a variety of ways, impacting both students and teachers. Perusall shows us that through analysing collaborative commenting, an AI system can inform teachers about students' reading skills and engagement with assignments. Students, too, are faced with these uses of AI in their education. Students may be helped by more automated feedback but are also confronted with the pervasive observing AI whilst trying to meet their teachers' expectations of numerous annotations. Educational technologies using AI raise questions for both students and teachers regarding their educational experiences. Discussions need to be had on how an AI system generates a grade, what kind of learning routines it can assist with, and if students should be able to opt out of automatic grading. Teachers should recognise that AI is not perfect, and many parameters may need to be adjusted for their classroom situation that they are still responsible for.

[32] Andrew J. Clarke, "Perusall: Social Learning Platform for Reading and Annotating (Perusall LLC, Perusall.Com)," *Journal of Political Science Education* 17, no. 1 (January 2, 2021): 149–54, https://doi.org/10.1080/15512169.2019.1649151.
[33] Carisma Nel and Elma Marais, "Addressing the Wicked Problem of Feedback during the Teaching Practicum," *Perspectives in Education* 39, no. 1 (March 12, 2021): 415-416, https://doi.org/10.18820/2519593X/pie.v39.i1.25.
[34] Cecchinato, Graziano, and Laura Carlotta Foschi. "Perusall: University learning-teaching innovation employing social annotation and machine learning." *Qwerty-Open and Interdisciplinary Journal of Technology, Culture and Education* 15, no. 2 (2020): 57-58.

3.2 In the educational institution (meso)

In this section we will discuss the application of AI to technologies used on the meso level, the educational institution. Other AI-driven applications that impact the meso level were also considered in this section from the table found in the appendix, including TurnitIn and Comproved. Jill Watson was selected for its rising popularity and possibilities of scale. In this way, a question is raised regarding: What does the use of an AI application mean for the responsibilities and challenges of running an educational institution? This larger institutional perspective helps us to break down the impact on educational administration and support. To grasp the role and question(s) that are raised by new AI-powered technologies in the educational institution, we will investigate an example of a virtual conversational agent, Jill Watson.

3.2.1 Example: Jill Watson

What is it?

The Jill Watson AI Agent is a virtual teaching assistant that has many functions and capabilities.[35] One of the most discussed features of the assistant is its ability to answer questions that users ask it. Jill Watson is a "Conversational Agent", which is integrated into classrooms to answer frequently asked questions and interact with students in various ways.[36]

How does Jill Watson work?

Jill Watson uses three machine learning models that are each trained with the same data. Users ask questions that are then passed through these models; the final output is then constructed as a greeting and then the relevant information from the syllabus.[37] The virtual agent uses semantic information processing technology to reply to human-typed questions.[38] Importantly, Jill Watson does not and cannot learn from student responses or feedback in their interactions with (outside) users.[39] Virtual agents like Jill Watson are an answer to the increasingly large and popular Massive Open Online Courses (MOOCs), where thousands of students may be asking questions and requiring some form of learning assistance all at once.[40] It is good to remember that there is not one Jill Watson, but rather many instances of Jill Watson that are trained on different domain-specific knowledge bases.

3.2.2 Support Staff

For this report, the group of support staff consists of education support staff that supports educators and educational administration. These are people that are needed for various responsibilities, such as where teachers go for technical services, who can help recommend new training for teachers, and where students go for emotional and administrative help. Conversational agents or virtual teaching assistants such as Jill Watson can greatly impact the work and responsibilities of support staff.

[35] "Jill Watson: A Suite of Online Learning Tools – Design & Intelligence Lab," accessed March 9, 2022, https://dilab.gatech.edu/a-suite-of-online-learning-tools/.
[36] Qiaosi Wang et al., "Towards Mutual Theory of Mind in Human-AI Interaction: How Language Reflects What Students Perceive About a Virtual Teaching Assistant," in *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (CHI '21: CHI Conference on Human Factors in Computing Systems, Yokohama Japan: ACM, 2021), 1–14, https://doi.org/10.1145/3411764.3445645.
[37] Wang et al.
[38] "Jill Watson."
[39] Wang et al., "Towards Mutual Theory of Mind in Human-AI Interaction."
[40] Ashok K. Goel and Lalith Polepeddi, "Jill Watson: A Virtual Teaching Assistant for Online Education," Technical Report (Georgia Institute of Technology, 2016), https://smartech.gatech.edu/handle/1853/59104.

Support staff can look to Jill Watson for various ways of relieving both repetitive questions and answering, as well as new ways of engaging students in the near future. Jill Watson allows for many new ways of supporting learning at scale by quickly and automatically answering frequently asked questions. The conversational agent allows students around the world to ask questions about courses at any time, always there to support students trying to get assignments turned in, even at the last minute. With Jill Watson, many different courses can be supported by this technology once it is trained on their specific domain's course content, which enables scalability and diverse uses.

Image 1, an overview of the different AI systems that build a Jill Watson.[41]

This direct form of engagement with students can not only save time for administration and teachers, but could also be used for building community. Students often expect conversational agents like Jill Watson to be "smart", creating a new interaction expectation through expectation of the virtual agent's capabilities for true intelligence.[42] Virtual social agents, like the Jill Watson Social Agent (SA) application, are designed to address social barriers that arise between students in online courses. The SA version of Jill Watson intends to support students' understanding of course requirements and foster a community where students can build their own support structures.[43]

[41] "Jill Watson: A Suite of Online Learning Tools – Design & Intelligence Lab," accessed March 9, 2022, https://dilab.gatech.edu/a-suite-of-online-learning-tools/.
[26] Qiaosi Wang et al., "Towards Mutual Theory of Mind in Human-AI Interaction: How Language Reflects What Students Perceive About a Virtual Teaching Assistant," in *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (CHI '21: CHI Conference on Human Factors in Computing Systems, Yokohama Japan: ACM, 2021), 1–14, https://doi.org/10.1145/3411764.3445645.
[43] "EmPRIZE: AI Assistance for Online Learning," accessed March 9, 2022, https://emprize.gatech.edu/#front-page-4.

The flexibility and applicability of a conversational agent like Jill Watson has many advantages and disadvantages for support staff. And the introduction of these kinds of applications raises questions that, when answered, may reveal some insight into how educational support can relate to these kinds of technologies in the future. These questions and advantages will be discussed after first looking at educational administration.

3.2.3 Administration in Education

Working in administration within an educational institution generally refers to the work and positions within an education system that are not directly involved in the education of students. These administrators often work within the institution but are not teachers or lecturers. Their responsibilities can vary from budget analysis, data management, ensuring that students achieve certain goals and expectations or even meeting regional or national government accreditation.[44] The administrative employee may also benefit from or see their role impacted by conversational agents like Jill Watson.

While not often directly tied to the work being done in the offices of administrators, implementing a conversational agent does impact organisational or strategic decisions. Conversational agents cost time and money to develop and implement, requiring long-term thinking and consideration by administrators before they can be seen as a valuable addition to an institution's digital strategy. Technologies like Jill Watson can be argued to be part of sustainable education practices, offering long-lasting solutions for active learning in social, economic and environmental issues.[45] Moreover, lifelong learning course structure and development benefits from this as a way to engage people who work and learn at their own pace. This follows as well with consideration for current student engagement, something Jill Watson may be able to help with by personalising learning through just sparking conversations from students.[46]

[44] "Wat Is Onderwijsadministratie?," accessed March 9, 2022, https://www.netinbag.com/nl/education/what-is-education-administration.html.
[45] Constanta-Nicoleta Bodea, Maria-Iuliana Dascalu, and Alexandru Hang, "Chatbot-Based Training for Project Management: Another Way of Corporate Training or a Must-Have Tool for Sustainable Education?," in *Research on Project, Programme and Portfolio Management*, ed. Roxana Cuevas, Constanta-Nicoleta Bodea, and Pablo Torres-Lima, Lecture Notes in Management and Industrial Engineering (Cham: Springer International Publishing, 2021), 249–59, https://doi.org/10.1007/978-3-030-60139-3_17.
[46] "Meet Jill Watson: Georgia Tech's First AI Teaching Assistant," Georgia Tech Professional Education, November 10, 2016, https://pe.gatech.edu/blog/meet-jill-watson-georgia-techs-first-ai-teaching-assistant.

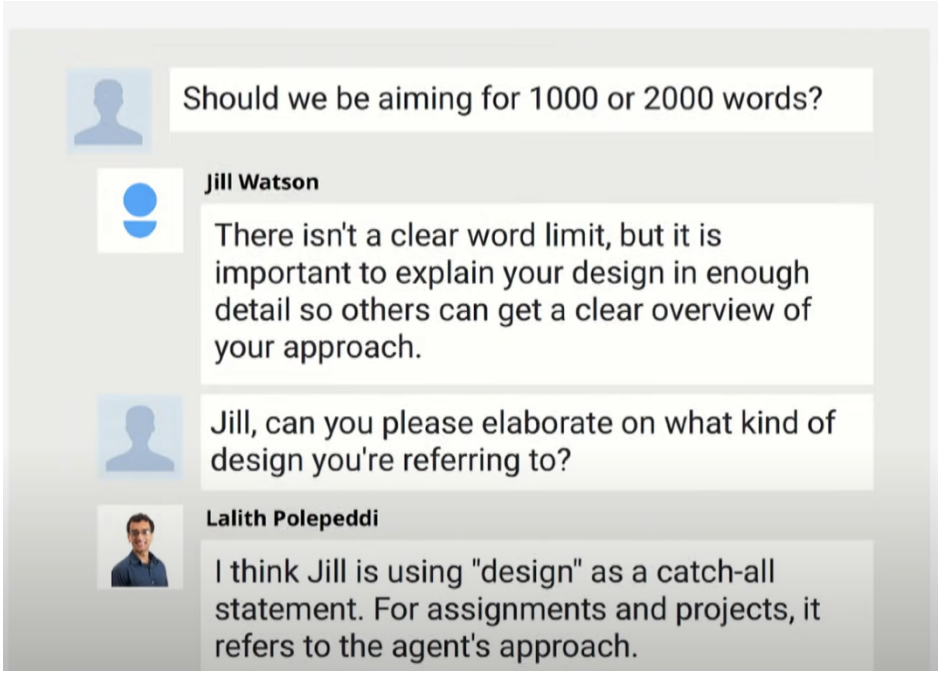


Image 2, Correcting Jill Watson

3.2.4 Discussion: Jill Watson & the Educational Institution

Jill Watson's possibilities are inspiring and show the new ways conversational agents can be used in education. Looking both from the support staff and educational administrator perspective, the next section analyses the impact of Jill Watson and similar technologies on the educational institution.

3.2.4.1 Support staff - Administrator: Analysis

When innovative technologies enter educational institutions, support staff and administration are expected to be aware and knowledgeable of these technologies and where to find advice or support. Jill Watson as a virtual agent can be considered a new technology that manages relationships between students and teachers or students and their institution. To be successful, Jill Watson will need to be up to date on all things involved with the curriculum and syllabus work within a course and possibly additional institutional policies. This has multiple implications, as all this information should be linked, available, and extractable for Jill to use. And depending on how this is approached by an institution, it raises a question of responsibility as to what certainties a student can expect from Jill Watson. What if Jill Watson sends a student to the wrong building for their exam, what manners of recourse does a student have when negatively affected by Jill Watson's inaccuracies? This can lead to an increase in AI-related workload for support staff such as study advisors, who may need to be (re-)trained for this new aspect/role. In other words, the scaling of Jill Watson beyond more than one or two courses leads to new concerns as to how to manage and keep up to date the answers Jill Watson will give to students. Professors and lecturers may come to support staff departments with questions regarding last-minute changes to their syllabus that are not automatically or incorrectly picked up by the conversational agent, leading to new and more technical skills for arguably anyone in a supporting position.

The successful scaled application of Jill Watson will require managed workflows and integration with existing systems and applications. To formulate answers, it needs access to 'good' quality data. Standardising and reviewing all syllabus course work materials is extremely time-consuming, often only being done by the lecturer themselves. Still, support staff may find it helpful to have an intelligent conversational 'helper' that can remember the finer details of coursework and scheduling. With support staff playing such a significant role in educational institutions, it is crucial that they consider various questions for themselves:

3.2.4.2 Support Staff: Questions

- How will we know that the conversational agent is correctly answering the students' questions?
- Where will the answers be stored for last-minute edits? Who has access to them?
- What training do I need to change answers or give input to the database of answers?
- Are students aware that the conversational agent is not a human? Will the students' chat logs be logged or saved somewhere for later review?
- What will we do with incorrect answers by the conversational agents that might have had severe consequences for the student, such as missing a deadline?
- What will we do as an organisation if Jill Watson gives an insensitive or offensive answer that may harm a student? Is this a possibility we can account for?

3.2.4.3 Director and administrative: analysis

It's clear that conversational agents need to use up-to-date syllabus information for discussion points and chat terms to be reliable. Yet support staff alone cannot make decisions about the significant impact that these technologies can have on an institution. It also requires leadership, direction and policies that can both protect and advise future decisions in educational institutions. Continuing, this section pivots the analysis towards administrative and director-focused considerations. Regarding conversational agents, it means understanding how the relationships between learners, educators and the institution at large are mediated by a conversational agent. These conversational agents provoke emotions, new interactions and even trust-building over long-term human-agent relationships.[47]

The interactions between students and their peers and between staff and students are often considered as more sensitive and complicated challenges in educational institutions.[48] Administrators often develop many plans and processes for how to navigate problematic behaviour for all stakeholders in the school; this is work that is best done before a crisis or situation arises. Teachers are expected to have a professional demeanour, even when faced with inappropriate behaviour by a student. Teachers and support staff often have clear processes ready for when the unexpected happens or students feel unsafe or unwelcome. Perhaps these processes should also be available for conversational agents that we put in between institutions and learners? Therefore, challenges in social engagement might also impact the use of Jill Watson. The Jill Watson agent will be asked many questions, including ones that are not relevant to course material, i.e. 'what is the meaning of life?' or 'what is your favourite character from Game of Thrones?'.[49] Students often try to test what will happen with conversations with conversational agents, such as intentionally asking the same question multiple times to see if it will answer differently.[50]

[47] Wang et al., "Towards Mutual Theory of Mind in Human-AI Interaction."
[48] Robert Jones and Liz Thomas, "Promoting Social Engagement" (University of Birmingham, 2012), https://www.birmingham.ac.uk/Documents/college-eps/college/stem/promoting-social-engagement-he-stem-transition.pdf.
[49] Wang et al., "Towards Mutual Theory of Mind in Human-AI Interaction."
[50] Wang et al.

The boring answer is that Jill will not answer differently because, as was discussed before, Jill Watson is not learning from the conversation.

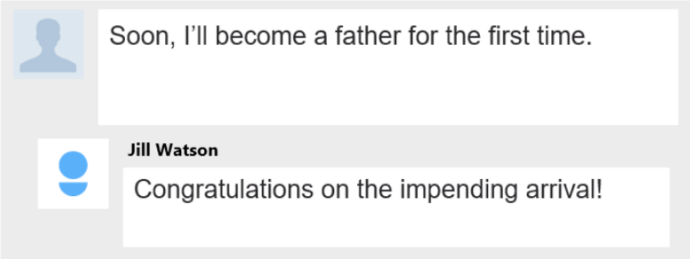


Image 3, Example of Jill Watson commenting

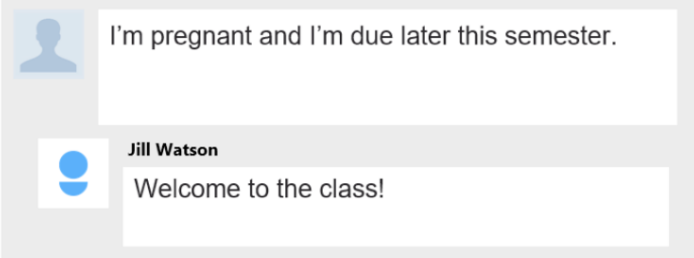


Image 4, Jill not specifically commenting

While this may be fun in many cases, it can have unintended side effects. The answers that Jill Watson gives can sometimes be a bit off or incorrect, which also affects students on a social level during their course. An interesting example of this came from a computer science course, where Jill Watson was implemented as a conversational agent and had as a function making personal introductory remarks to students. Jill Watson was trained on data available for the course and was oddly able to respond to questions such as "will be father for the first time" with "congratulations on the impending arrival!", yet not able to give a corresponding response to "I'm pregnant".[51]

While the researchers in this study try to identify a reason for a response like this from Jill Watson by hinting at their training data, there are larger discussions that cases like this expose. The data that a conversational agent can train on will always be limited. This is a given for any AI that has been discussed throughout this report, but what is important for Jill Watson is the context in which the conversational bot is often applied. Jill Watson is given both a responsibility to facilitate the lecturers' expectations as well as represent the university or organisation at large as a conversational agent. This requires the application to be specific and sensitive to the smaller-scale course context as well as setting general expectations on an institutional level. It means gathering and systematising enough information that enables an independent and reliable Jill Watson, while being prepared for situations that can arise when misinformation or uninterpretable messages are sent out at a large scale.

[51] Bobbie Eicher, Lalith Polepeddi, and Ashok Goel, "Jill Watson Doesn't Care If You're Pregnant: Grounding AI Ethics in Empirical Studies," in *Proceedings of the 2018 AAAI/ACM Conference on AI, Ethics, and Society* (AIES '18: AAAI/ACM Conference on AI, Ethics, and Society, New Orleans LA USA: ACM, 2018), 88–94, https://doi.org/10.1145/3278721.3278760.

It is not clear how situations like these, where a conversational agent misinterprets an interaction, impact students.[52] Yet, these pregnancy comments do raise important concerns about how the application of these technologies impacts on the social wellbeing and participation of students.

This leads to more general concerns for directors and administrators regarding conversational agents in various aspects of an educational institution.

3.2.4.4 Director and Administrative: Questions

- How can we learn from students' interactions with our conversational agents so that we can improve our use of the technology? Who is not being accounted for in the datasets we provide or train our conversational agent on?
- What policies do we need to account for unexpected behaviours of these conversational agents, impacting our organisational interests?
- What kind of standardisation of curriculum and educational material formatting will we need to develop in order for our organisation to scale a conversational agent to more courses? Who can maintain this and how will it be applied in new domains such as marketing and communications? How will this shape the pedagogical standards of curriculum developers?
- Does the conversational agent speak on behalf of the institution? Are the answers this technology communicates in line with our mission and vision? Who will ensure this is the case for the future?
- What (private) data should be allowed for our conversational agent to be trained on? Is this standard practice amongst other institutions that use this technology? Who owns the data generated using this system?
- What kind of contractual agreements do we have with the supplier of the technology?

3.2.5 Key Takeaway:

There is no AI capable of answering every question. Training data for a Jill Watson or conversational agent may be limited to what course it is tasked with supporting and depending on the quality of the training data, you may get interesting results. For support staff, the advantages and disadvantages vary, both in supporting these innovative technologies, but also in having the ability to always have a 24/7 conversational aid for students. To scale and promote a conversational agent at the organisational level, executive administrators need to consider how technologies like these may impact social engagement in courses as well as what kind of data management or regulation may be needed to effectively expand the reach of the conversational agent. In turn, both social and educational conflicts could be addressed when planning, approving and deploying a conversational agent in an institution.

3.3 Out in the real world (macro)

This report has so far tried to relate technologies that take advantage of artificial intelligence to the work and support of educational professionals. From the micro lens, the first section developed questions about changes in pedagogical and teaching practices with the introduction of AI in the classroom. In the meso, or organisational perspective, the second section considers the impact of AI applications on support staff and executive directors by example of conversational agents like Jill Watson. However, AI-powered technologies are also increasingly prevalent in our society. Students and teachers are using AI-powered applications daily and

[52] Eicher, Polepeddi, and Goel.

these technologies might transfer to the classroom. This outside-in perspective is what we consider in this section as being the macro, or societal, use of AI in education.

While navigating conversations from the macro perspective, we see a shift in who is in control of the application. Where Perusall and Jill Watson are applications incorporated into the educational practice by teachers or institutions, the AI applications with the most impact on education might be brought in by students. Students, as independent agents, will experiment with and use a variety of tools to help them in their coursework. Experiments like using the Internet as an information resource or using spelling check add-ons to become better writers has happened in the past with curious students. This will happen with AI-driven applications as well. In this section we discuss two examples, PhotoMath and GPT-3, and their possible impact on the educational classroom and institution. Other examples were also considered for this section's level, including Scholarcy, Writing Pal and Grammarly, which all in some way assist students outside the classroom.

3.3.1 Example: PhotoMath

What is PhotoMath?
PhotoMath is a mobile application that utilises a smartphone's camera to scan and recognise mathematical equations; the app then displays step-by-step explanations onscreen. It is available for free on both Android and iOS.

How does PhotoMath work?
This application covers several topics in mathematics, including basic math, pre-algebra, algebra, geometry, trigonometry, precalculus, calculus and even statistics. By using the camera of a smartphone, the application scans the photo taken of a math problem and makes it computer readable. It then produces a solution with steps to solve it.

PhotoMath enables students to get through normally very challenging work, more easily. The application allows for instant answers to most math problems that can be captured by a mobile phone's camera. Newer versions of the app now can recognise handwriting as well. PhotoMath also shows the user how to solve the problem, aiding users in problem solving even when a teacher or instructor is not available to explain 'why' a solution is correct. Remarkably, if a user is willing to pay for the 'premium' version of the application (currently ~4.50 euro/month), the application will offer more tips for solving problems, detailed explanations from textbooks and even show animated tutorials to visualise problem solving.[53]

From the macro perspective, PhotoMath comes from 'outside' the educational system and enters through the mobile phones of students or curious instructors. Technologies like PhotoMath often raise concerns among educators. The most obvious reaction will be to standards and norms in cheating. What if students use this application on their homework assignments? These are valid questions and specifically difficult to answer as this largely happens outside of the control of an institution.

The design and usability of the app has been studied and complimented in human-computer interaction research.[54] PhotoMath was given marks of 'high' or good in effectiveness, efficiency, and satisfaction by students, parents and teachers in the recent 2021 study. Parents found the app to be a "trustworthy companion" for their children and use it to aid their children with their

[53] "Photomath Plus," Photomath, accessed March 16, 2022, https://photomath.com/en/photomath-plus/.
[54] Mariam Zakariashvili, "Challenges in Human-Computer Interaction on the Example of Photomath Mobile Application," *Middle European Scientific Bulletin* 16 (September 18, 2021), https://cejsr.academicjournal.io/index.php/journal/article/view/721.

homework in math skills they themselves do not possess. In this way, PhotoMath creates a space for both parents and students to bond over homework and, on the other hand, students can receive help at home even when they do not have access to a teacher.

Mathematics is not the only discipline being changed by technologies outside the educational sphere – the same is happening with reading and writing. The next section will jump into GPT-3, followed by an analysis of how both these technologies raise similar questions for both educational professionals and students alike.

3.3.2 Example: Generative Pre-trained Transformer 3 (GPT-3)

What is GPT-3?
GPT-3 is the largest publicly disclosed language model ever. Trained on 570 gigabytes of text, GPT-3 displays a variety of abilities including learning and writing about novel tasks when given examples in context.[55] In short, GPT-3 is a computer system that is designed to read and write in more than 26 languages with abilities to analyse and respond to questions in natural language. It is a technology that can be understood as a text predictor, in so far as its output is a statistically plausible response given the input and, of course, grounded on the data it was trained with before, around 175 billion parameters.[56]

How does GPT-3 work?
While the examples of text that GPT-3 can produce (see below) seem almost too good to be true, the program is not magic. Each word is calculated and is based on how likely it is a word would appear in the text given the word that precedes it.[57] In more complex terms, GPT-3 uses a form of data compression to take on millions of pieces of sample text to convert these various words into vectors, i.e. numeric representations. These vectors are then rearranged into easier-to-read sentences for our brains. Since GPT-3 can generate a relevant response with only a few examples, it does not need to be exposed to a lot of text samples every time it is used.
One of the best ways to understand GPT-3 is to play with it. You can access it via OPENAI's beta playground here. This tool allows for a variety of uses, including summarising your notes, chatting, converting JavaScript to Python code, or converting writings from a first-person to third-person point of view. Originally, GPT-3 showed off its powers by writing news articles that were indistinguishable from real sources by human evaluators comparing them to articles written by humans.[58] Later research then showed that GPT-3 could also write original computer code, retrieve and structure data, and generate financial statements. <bit of antihype analysis here, as in what is the demystified analyses here> Impressive results that required an enormous effort in building and training the model of 175 billion parameters that requires the same amount of power used by 126 homes in Denmark per year or even driving to the Moon and back.[59]

Just like for PhotoMath, it is not difficult to imagine that this tool could be used for plagiarism/cheating by students. It can effectively generate essay texts or answer questions with

[55] Alex Tamkin et al., "Understanding the Capabilities, Limitations, and Societal Impact of Large Language Models," *ArXiv Preprint ArXiv:2102.02503*, 2021.
[56] Sciforce, "What Is GPT-3, How Does It Work, and What Does It Actually Do?," *Sciforce* (blog), September 17, 2021, https://medium.com/sciforce/what-is-gpt-3-how-does-it-work-and-what-does-it-actually-do-9f721d69e5c1.
[57] Sciforce, "What Is GPT-3, How Does It Work, and What Does It Actually Do?," *Sciforce* (blog), September 17, 2021, https://medium.com/sciforce/what-is-gpt-3-how-does-it-work-and-what-does-it-actually-do-9f721d69e5c1.
[58] N Dehouche, "Plagiarism in the Age of Massive Generative Pre-Trained Transformers (GPT-3)," *Ethics in Science and Environmental Politics* 21 (March 25, 2021): 17–23, https://doi.org/10.3354/esep00195.
[59] Katyanna Quach, "AI me to the Moon... Carbon Footprint for 'training GPT-3' same as driving to our natural satellite and back," accessed March 30, 2022, https://www.theregister.com/2020/11/04/gpt3_carbon_footprint_estimate/.

novel answers on tests without requiring strenuous effort and understanding from the student. One researcher used the tool to generate the following example regarding the keiretsu networks of Japan in World War 2 by submitting to GPT-3, "write a short academic essay analysing keiretsu networks in post-World War 2 Japan".[60]

In the early days of Japan's post-war economic recovery, it was difficult for businesses in the country to grow because so many had been devastated by war. Businesses that survived were forced to rely on foreign imports. However, when the US began selling weapons to Japan during the Korean War, Japanese companies began importing these goods from American manufacturers. In time, this led to more domestic manufacturing taking place in Japan, which ultimately improved living standards and boosted the economy.

Over the course of the 1950s, this reliance on external businesses led to the creation of several Japanese manufacturers who began to cooperate with one another. Large groups of businesses with interlocking shareholdings and strong government ties began to form, which are now known as 'keiretsu'. By the end of the period, there were around ten such company groups.
This reliance on keiretsu has been criticized by the western world as a form of protectionism, in which smaller companies are kept out of the market to ensure that the domestic products sold by large keiretsu are more competitive against imported goods. However, keep in mind that it is often difficult to tell where one corporation begins and another one ends. Indeed, in a keiretsu network, all of its business concerns form an interconnected body, in which no single group dominates the market. One can think of it like a set of Russian dolls, in which a system contains smaller versions of itself. What's more, the growth of one company contributes profit that allows smaller companies to thrive. Such a structure allows for the stability of the economy, and it can be said that this interconnected 'web' is at the heart of what is often called the 'Japan- ese Manufacturing Miracle'. Toyota is an example of such a keiretsu. Companies like Toyota and Nissan ultimately became feeder companies that others in the group could rely on. However, though such companies rely on one another to ensure that everyone prospers, the government still intervenes if there is a conflict.

This is what makes Japanese keiretsu so interesting: they are internally competitive, yet they still support one another on a wider scale.' In conclusion, the Japanese manufacturing miracle is made possible by the cooperative effort of internally competing yet externally cooperating companies, which together form a comprehensive structure within the national economy.

Depending on the expectations of the student, this text could very well pass as a reasonable answer for a short essay response. This essay and others produced by GPT-3 in this report all passed the plagiarism detection service as completely original texts and, in turn, may not be easy to spot when handed in as an assignment. Examples like this show how far GPT-3, and text predictors like it, have come in terms of generating understandable text. It also raises concerns for the educational sector as these technologies are easily accessible to students who want to find them. Is the student cheating on the assignment? Is the student plagiarising a source? How are plagiarism policies impacted when sources of this document cannot be traced with plagiarism software? What are ways in which we can talk to students about using and even learning from technologies like GPT-3?

[60] ibid.

3.3.3 Analysis of student use of Photomath or GPT-3 language models

GPT-3 and PhotoMath both show how new technologies can enter education practices from the outside world. Educational institutions will have to find a way to deal with new digital technologies that challenge their curricula and educational practices. Institutions might consider banning the new technology, restricting its use, or consider how it changes educational practices and learning goals.[61] We can be sure that students will continue to have access to the vast source of tools on the Internet and their smart devices. The challenge lies in figuring out how these new tools help them create new solutions and work in innovative ways. In other words, we may need to reconsider learning goals as technologies like PhotoMath begin to challenge what we expect of students. For instance, many educators no longer expect students to do long-form versions of square root formulas; they allow the use of calculators for tedious work. Educators can take advantage of these technologies by acknowledging their limitations as well. PhotoMath may give answers that are incredibly long, perhaps helping students realise that strategic thinking can be more beneficial for solving mathematical problems than following rigid rule-following suggestions.[62] In this case, PhotoMath can remind educators that a curriculum is not created in a vacuum or isolation; technologies from outside the institution will challenge or change what learning goals become prioritised in educational institutions.

Can the same be said of GPT-3? In other words, can GPT-3 also be included in the educational curriculum as easily as a tool like PhotoMath? The answer is still unclear for two reasons. The first reason is GPT-3 does a lot of different things, including translating, programming, poetry, or even pretending to write like a famous author. From this, there are a lot of ways that GPT-3 *could* be involved in the curriculum, but the groundwork for how to do this may still be a future ambition. The second reason concerns one of the main goals of education, the *qualification* of students.[63] GPT-3 impacts both the student's development of the skills defined within a program's learning goals as well as the institutional assessment thereof. As GPT-3 creates texts that may pass many writing assignments, this enables students to bypass this task or requirement without learning or developing the relevant skills such as reading, researching, and writing. Perhaps the relevance of the development of those skills diminishes as technology progresses, as it has for long-form square root formulas, but writing skills are currently still very much needed in professional settings. For the student using GPT-3, this may in turn become more of a handicap than a clever companion; a handicap that the student might not be able to spot until it is too late. In addition, this student use of GPT-3 will become a challenge for educational institutions as they have the responsibility to ensure the quality of their education. This is often done through summative assessments, where the summary of skills and knowledge for passing a degree is tested through exams or assignments. While the use of GPT-3 to cheat exams will probably be limited, its potential in passing writing or even programming assignments seems clear. Already there are similar language models that succesfully complete assignments in mathematics[64] and programming[65]. If through GPT-3 students are increasingly able to misrepresent themselves during this assessment phase of education, this could become a real problem for institutions proving the quality of their degrees.

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[61] Corey Webel and Samuel Otten, "Teaching in a World with PhotoMath," *The Mathematics Teacher* 109, no. 5 (December 2015): 368–73, https://doi.org/10.5951/mathteacher.109.5.0368.

[62] Corey Webel and Samuel Otten, "Teaching in a World with PhotoMath," *The Mathematics Teacher* 109, no. 5 (December 2015): 368–73, https://doi.org/10.5951/mathteacher.109.5.0368.

[63] As introduced by Biesta: Biesta, G. (2010). 1. What is education for? *Good education in an age of measurement: ethics, politics, democracy* (pp. 11–27). Boulder, C: Paradigm Publishers.

[64] https://ai.googleblog.com/2022/06/minerva-solving-quantitative-reasoning.html

[65] Finnie-Ansley, J., Denny, P., Becker, B. A., Luxton-Reilly, A., & Prather, J. (2022, February). The Robots Are Coming: Exploring the Implications of OpenAI Codex on Introductory Programming. https://dl.acm.org/doi/10.1145/3511861.3511863

New outside-in technologies will, as they have done in the past, challenge educators and educational institutes and give rise to new questions about the underlying goals of education and how technology contributes to or detracts from those goals.

3.3.3.1 General outside-in technology impact: questions

- Should we ban or restrict the use of this application within our institution? Are we able to?
- Is there clear evidence of how this application is impacting student development, learning goals, or educational practices?
- How do we deal with questions of responsibility and accountability with these applications that are outside of institutional control?

3.3.4 Key Takeaways

Technologies like GPT-3 and PhotoMath show that the technological capabilities of digital tools will continue to develop alongside (and sometimes in) our own educational worlds. PhotoMath, a tool used for solving math problems with smart devices, has made an impact on both classroom exercises and homework. This has led to some educators asking whether to ban the tool, restrict its use, or consider its value in current curricula. PhotoMath's ease of use and desirable functions make for a popular and clever technology that presents how commonplace 'on-demand answers' have become even in education.

Technologies like GPT-3 are becoming more competent in generating coherent and readable texts that can convince teachers of their merit while avoiding plagiarism scans. This may impact both the skill development of students as well as the quality of education programmes. Educational institutions will be challenged by auto-generated texts, while on a societal level we might see these technologies mediating new ways of working. Wider adoption of these technologies, GPT-3 and PhotoMath for example, may impact student learning and skill development that has not been considered before. This leads to opportunities amongst educational institutions to ask whether the skills and lessons their students will acquire is carried out through tools like these, or if a future curriculum should consider the impact of such inventive technologies.

4 Conclusion

AI technology is shaping the landscape of education in a variety of ways. As we get to understand better how to apply these technologies in education, it becomes clear that AI does not provide a silver bullet solution, but will have to be implemented in the existing complexity of the educational domain. This report has reviewed this landscape by analysing AI in education by way of concrete examples of existing applications in educational contexts.

4.1 AI means dealing with change

AI has been around for a long time. In that time, AI as a field has emerged and evolved. As a result, a variety of definitions of AI have popped up, each with their own merit. It is important to recognise this variety of definitions, as they change over time, specifically also as technology continues to develop and impact new domains. A definition of AI for the technical domain has different requirements than a definition that provides the basis for legislation. AI as a technology takes advantage of many methods of algorithmic processes that, when coupled together, can create a powerful system of decision-making applications. A general indicator for successful implementation of an AI application is combining the technology with domain-knowledge, or in other words the intimate knowledge and experience of the context in which the AI application will be applied.

4.1.1 Various applications across the board

With the introduction of AI systems in the educational domain, it is important to keep an overview of these AI applications and their merit. For this report we gathered a collection of existing use cases and applications that use AI methods in their application (to be found in appendix A).

4.1.1.1 Perusall in the classroom (micro)

On the micro level, think of the classroom context, we reviewed applications on how their use impacts educational practices. The in-depth Perusall example displays how learning analytics collected by the application can be reviewed to inform teachers about student educational performance in reading and commenting. From this, Perusall's use of automatic grading, assessment and feedback should be an open discussion in any classroom. Students can and should be made aware that they are being monitored when using the application and should understand how their participation will be (automatically) assessed. Moreover, parameters for grading and engagement should be adjusted by whoever implements this technology in their classroom. Both to gather more useful data, but also to answer the inevitable questions about how grades are automatically generated by the system.

4.1.1.2 Jill Watson AI in the institution (meso)

Broadening the scope to the Meso level, this report considers the interests of support staff, administrative and policy-focused personnel. For these roles, the impact of AI may come in the form of managing the application and curating its database information. This level reviews Jill Watson AI, a conversational agent that converses with thousands of students at once. The use of these technologies can ease pressure from educational professionals in answering frequently asked questions mainly derived from syllabus text. Importantly, no AI is capable of answering every question outside its scope of testing and this becomes apparent when using technologies like a Jill Watson. From this meso level, many agents in various roles and responsibilities are

shown how they are all impacted in some way by the implementation of new AI-driven technologies.

4.1.1.3 Photomath and GPT-3, the outside getting in (macro)

While institutions continue to try to control and curate the technologies available to their students and staff inside their organisation, technologies continue to develop on educational innovations. It is clear that students now have access to tools that can facilitate and shape education in ways that institutions should take into consideration. PhotoMath as a technology offers students a tool always available to them through their personal smartphones. It automates the processes of mathematical exercises to an extent, and leverages AI to become more accessible, faster, and complex. Students find innovative ways to take advantage of this tool, while institutions continue questioning whether PhotoMath can be considered useful or not. Whether or not to act then falls on teachers and students to decide whether a technology like PhotoMath is 'fair' and offering themselves as experimental subjects to new practices. Similar challenges can be seen in language models like GPT-3, where institutions may have deal with students taking advantage of these text-generating applications. As these language models have the ability to not only bypass plagiarism software in a more traditional writing exercises, but also write code, solve mathematics and translate languages.

4.2 Going forward

From here, educational institutions are in a unique position to facilitate conversations about the future effects and uses of technologies both inside and outside the classroom. These include discussions on data ethics and management, but also visions on the future of work and developing smart-er citizens. Without these conversations and visions, educational professionals in the field will continue to be bewildered by which technologies they should focus on, adapt to, or adopt in their working life. An opportunity emerges here to engage students as well on what technologies they find worrying, interesting, or commonly used already within their own circles of concern.

From here, directions on the path towards a correct toolbox of educational technologies become blurry. Relying on technological features and uses alone will not be enough without the values we hold as part of the greater public interest. In other words, public values may be the next best step towards creating clear direction for educational institutions and their future adoption of new technologies. This will require time and multi-disciplinary work, but acknowledging first the effects and changes these kinds of technologies have on our institutions will allow for the first sure footing.

4.2.1 The next steps

This report is just one step in the story of AI in education. As we have shown, when AI systems enter the classroom or institution, this will give rise to new and challenging questions for students, teachers, staff and school leaders. To undertake this journey of discovery together, it is important we do it together. We need to keep experimenting and trying, while not creating unjust expectations within the AI hype. This means building an increasing understanding of AI in education and focus on evidence of working applications. Within institutions it is crucial to have conversations about roles and responsibilities surrounding these new educational technologies. And lastly, we need to keep sharing our knowledge between academics, educational practicioners as well as AI system developers.

5 Appendix

During this research project an elaborate list of applications of AI in education was gathered, which we share in this appendix to provide a starting point for future research. A more complete list will be published online as this list gets updated, this can be found on edu.nl/jdwty.

Title	Description	Link
Ada Bolton College chatbot	A virtual social agent based on IBM Watson that helps deliver personalised learning and assessment for 14000 students.	https://www.boltoncollege.ac.uk/latest-news/praise-for-ada-bolton-colleges-chatbot/
Agent Smith	An Assistant that helps generate a Jill Watson Q&A agent for new documents such as class syllabi.	http://gvu.gatech.edu/research/projects/tool-building-interactive-agents-agent-smith
ALEKS	ALEKS is an artificially intelligent learning and assessment system that has been used by over 25 million students for Math, Chemistry, Statistics and Accounting. After quickly and accurately determining each student's precise knowledge of a subject, ALEKS helps the student work on the topics they are ready to learn. ALEKS intelligence, content and software are unique and proprietary; they have been developed together, and work in unison. ALEKS digital content provides comprehensive course coverage.	https://www.aleks.com/about_aleks
Alelo	Using cloud-based AI simulations, learners engage in interactive conversations with socially intelligent virtual humans in a realistic setting. They role-play with avatars as often as they like on a mobile device, desktop, or virtual reality headset. Immediate feedback provides personal instruction on how to improve. When encountering a real-world situation, learners are confident and adept. Role-playing with Artificial Intelligence (AI) avatars is a breakthrough way for students to practice conversational Spanish, English and HR skills.	https://www.alelo.com
Alphary	Alphary set an ambitious goal to redefine the English language learning experience and accelerate language acquisition by automatically providing learners with	https://www.alphary.net/#/home

	feedback and increasing user engagement with a gamification strategy.	
Alta	A complete course solution, alta is designed to optimize the way students study and learn while completing assignments. All of Alta's content — including instructional text and video, examples and assessments — is organized by learning objective and served up at the precise moment a student needs it.	https://www.knewton.com/why-alta/
AutoTutor	AutoTutor uses strategies of human tutors such as comprehension strategies, meta-cognitive strategies, self-regulated learning and meta-comprehension. In addition, AutoTutor incorporates learning strategies derived from learning research such as Socratic tutoring, scaffolding-fading, and frontier learning. (Alkhatlan and Kalita, 2018, pg. 16)	https://arxiv.org/abs/1812.09628
Bazaar: A Flexible Architecture for Collaboration Support	Bazaar has often been used to implement supportive interventions involving conversational chat agents that participate as facilitators in collaborative learning tasks.	http://ankara.lti.cs.cmu.edu/bazaar/
Braille AI Tutor	Braille AI Tutor is one of the technologies in the ObjectiveEd suite. It lets a student improve their braille literacy using a braille display and speech recognition.	https://www.objectiveed.com/braille-ai-tutor
Century	The artificial intelligence engine creates personalised learning pathways that plug gaps in knowledge and remedy misconceptions. Easy-to-use data dashboards aid teacher-led interventions. Students who need additional support or challenge are quickly identified. Teachers are provided with thousands of high-quality resources for use in a variety of learning models including homework, classwork or revision.	https://www.century.tech/
CIRCSIM-Tutor Project	The CIRCSIM-Tutor project was a language-based intelligent tutoring system for first-year medical students to learn about the reflex control of blood pressure. Students solve small problems and are tutored by Socratic dialog with the computer. (link)	http://www.cs.iit.edu/~circsim/

Comproved	Comproved helps teachers, educators and assessors to assess better. We do this with knowledge and tooling. Years of scientific research have shown that comparative assessment works because people naturally make comparisons. Our comparing tool structures these comparisons and forms a valid, reliable and user-friendly instrument. The tool is perfect for large and small assessments and provides data that teachers and students learn from.	https://comproved.com/
Criterion	The Criterion® Online Writing Evaluation Service is a web-based instructor-led automated writing tool that helps students plan, write and revise their essays. It gives them immediate diagnostic feedback and more opportunities to practice writing at their own pace. The Criterion service frees up valuable class time and helps improve student outcomes by giving instructors and administrators a solution that concentrates on higher-level writing skills and areas of improvement. It is used both by teachers in the classroom, as well as by those teaching remotely as an online distance learning tool.	https://www.ets.org/criterion
DC Circuit Construction Kit / PHeT simulations	PhET provides fun, free, interactive, research-based science and mathematics simulations. We extensively test and evaluate each simulation to ensure educational effectiveness. These tests include student interviews and observation of simulation use in classrooms. The simulations are written in Java, Flash or HTML5, and can be run online or downloaded to your computer. All simulations are open source.	https://phet.colorado.edu/en/simulations/filter?type=html&sort=alpha&view=grid
Deepl	DeepL's neural networks are able to capture even the slightest nuances and reproduce them in translation unlike any other service. In blind tests pitting DeepL Translator against the competition, translators prefer DeepL's results by a factor of 3:1. DeepL also achieves record-breaking performance according to scientific benchmarks. Also has access to CAT tool integration. DeepL is a German company that has set itself the goal of eliminating language	https://www.deepl.com/translator

	barriers worldwide through the use of artificial intelligence	
Denker	Denker is a learning system for developing systems thinking skills in secondary education. It supports learners, provides a teacher dashboard and promotes collaborative learning. Denker also uses Dynalearn.	https://denker.nu/
Digi Revisie	Digi Revisie helps you improve the consistency of your writing product through a series of assignments and 10 focused questions. This site also gives you computer-generated feedback on your text. Based on this, you can make improvements in the coherence of your text. Your data can be analyzed to see if the feedback has the desired effect, and to see what improvements are made based on the feedback. This is always done anonymously. By using this website you agree to the anonymous use of your data for research purposes. With the help of Smart Education funds from the Hogeschool van Amsterdam (https://www.hva.nl/smarteducation), EDIA (www.edia.nl) digitized this checklist and generated automatic feedback for the questions on this checklist.	https://digirevisie.nl/
DynaLearn	Using DynaLearn learners create conceptual models. Doing so they develop insight into what systems are, how systems function, and how the behaviour of systems can be explained. This stimulates a deep and lasting capacity for systems thinking.	https://www.dynalearn.nl/
Examus	Examus Inc. has developed an advanced AI proctoring solution that prevents cheating attempts during online exams as well as monitor and control students' behavior during the process. Examus enables universities to get verified results from online exams. Examus enables students to study and take exams remotely from anywhere in the world. The main aim of Examus is to improve the educational process and make it easy and affordable to for every to study remotely and receive verified trusted results.Examus AI proctoring solution can be integrated into any learning management system (LMS) or testing platform.	https://examus.net

Feedbackfruits	FeedbackFruits offers a complete tool suite to organize interactive and collaborative learning activities. Allowing you to implement blended and online learning more effectively.	https://feedbackfruits.com/
Genie	Deakin Genie App is a part of Deakin's digital frontier for excellence in education. It allows students to easily access their timetable, results, unit information as well as an array of answers to common student questions.	https://genie.deakin.edu.au/about/
Ginger	The Ginger Essay Checker helps you write better papers instantly. Upload as much text as you want – even entire documents – and Essay Checker will automatically correct any spelling mistakes, grammar mistakes, and misused words. Ginger Essay Checker uses patent-pending technology to fix essays, improving your writing just like a human editor would. Take advantage of the most advanced essay corrector on the market. You'll benefit from instant proofreading, plus you'll automatically improve your writing skills as you view highlighted errors side by side with Ginger Essay Checker's corrections.	https://www.gingersoftware.com/essay-checker
Goal Net	Using a combination of micro-MOOCs and learning path construction tools (possibly derived from Goal Net or other similar tools such as the Belief-Desire-Intention (BDI) model), instructors can specify a general syllabus consisting of finely grained learning contents and activities with improved efficiency and flexibility of updating. In courses in which the dependency among topics is not strong, the learning path construction tool could be open for MOOC learners to use in order to personalize individuals' learning paths.	https://www.nature.com/articles/s41539-017-0016-3

Grammerly	Grammarly is a Ukrainian-origin American-headquartered cross-platform cloud-based writing assistant that reviews spelling, grammar, punctuation, clarity, engagement, and delivery mistakes. It uses AI to identify and search for an appropriate replacement for the mistake it locates. (Wikipedia) -- Grammarly can sometimes automatically detect potential grammar, spelling, punctuation, word choice, tone and style mistakes in writing, following standard linguistic prescription, although it may make mistakes. Algorithms flag potential issues in the text and suggest context-specific corrections for grammar, spelling, wordiness, style, punctuation, and plagiarism, although some are only for premium users.	https://www.grammarly.com/
IguideMe	IguideME (I Guide My Education), is a dashboard that was developed at the Faculty of Science (UvA) and is used to provide personalized feedback to (a large group of) students and teachers. The goal of this project is to activate, motivate and provide personal feedback to students during the entire learning process by means of a specific blended learning method in combination with the application "IGuideME" where information about the learning process is conveniently gathered in one central digital location.	https://communities-surf-nl.translate.goog/artikel/de-eerste-ervaringen-met-iguideme-gepresenteerd-op-de-surf-onderwijsdagen-2021-1?_x_tr_sl=nl&_x_tr_tl=en&_x_tr_hl=en&_x_tr_pto=sc
iStart	Interactive Strategy Training for Active Reading and Thinking (iSTART) is a Web-based application that provides young adolescent to college-age students with high-level reading strategy training to improve comprehension of science texts. iSTART is modeled after an effective, human-delivered intervention called self-explanation reading training (SERT), which trains readers to use active reading strategies to self-explain difficult texts more effectively.	http://www.adaptiveliteracy.com/istart#
Jill Watson Q&A	A virtual teaching assistant for answering questions based on educational documents including VERA's user reference guide	https://dilab.gatech.edu/a-suite-of-online-learning-tools/

Jill Watson SA	A virtual social agent that promotes online interactions	http://dilab.gatech.edu/a-suite-of-online-learning-tools/
Lärka	Intelligent Computer-Assisted Language Learning – has as its main aim to draw on the opportunities offered by language resources, such as corpora, lexicons and natural language processing components including lemmatizers, parsers, etc., to build more sophisticated and flexible applications for language learners and students of grammatical theory.	https://spraakbanken.gu.se/larka/archive/#mode=selfstudy&group=linguists&exe=pos1&lang=sv&pos=KN,SN,DT,PP,PN,JJ,AB,NN,VB,PC,RG
LeerLevels	At the moment, LearnLevels contains over 550 videos and infographics that cover the physics high school curriculum in The Netherlands. The next step is adding content for other STEM courses. Our modular approach enables a perfect integration between disciplines, allowing interdisciplinary projects to focus on our societal challenges.	https://www.leerlevels.nl/docent
MATHai	Students stay engaged with MATHia's personalized just-in-time feedback and contextual hints. MATHia uses sophisticated AI technology to adapt at a very detailed, skill-by-skill level.	https://www.carnegielearning.com/solutions/math/mathia/
Merlyn Mind	Merlyn lets teachers do with their voice or remote what previously took many steps and led to wasted time and frustration. Merlyn is natural to use by design and integrates with the apps and devices teachers already use.	https://www.merlyn.org/product
Mi Write / Mi Tutor	MI Write is a web-based learning environment and formative assessment system that allows students to improve their writing through frequent practice and guided instructional support. Available anywhere, on any device, MI Write combines more opportunities to write with immediate scoring and feedback to help students develop effective writing skills. Student writing is instantly evaluated by MI's award-winning automated scoring technology, 24 hours a day, 7 days a week. By streamlining the grading process, MI Write makes it easier for teachers to focus more on developing	https://www.measurementinc.com/products-services/automated-essay-scoring

	learning strategies and interacting with students.	
MY Access! - Virtual Writing	MY Access! is an online writing instruction and assessment program, and teaching tool that improves student writing proficiency and motivates students to write more frequently by providing immediate scores and continual, adaptive, prescriptive feedback and edit suggestions.	https://www.vantagelearning.com/products/my-access-school-edition/
Perusall	Perusal aims to change the nature of reading — from the traditional solitary experience to an engaging and collective one. We aim to change education — so all students do the reading, come to class prepared, and are motivated to do so because they care about the content. And we aim to advance behavioral science and AI research in the service of improving education — using our work at Harvard University and Perusall Labs to improve the Perusall platform and to help students, educators, researchers, and society at large.	https://perusall.com/about
PhotoMath	Photomath is a mobile application that utilizes a smartphone's camera to scan and recognize mathematical equations; the app then displays step-by-step explanations onscreen. It is available for free on both Android and iOS.	https://photomath.com/en/
Scholarcy	Scholarcy, the online article summarizer tool, reads your research articles, reports and book chapters in seconds and breaks them down into bite-sized sections – so you can quickly assess how important any document is to your work.	https://www.scholarcy.com/

Squirrel AI Learning	Squirrel Ai Learning is the first domestic adaptive learning engine based on the advanced algorithm and with the complete independent intellectual property developed by YiXue Education. Squirrel is the symbol for "agility, diligence and management." This aligns with the experience Squirrel Ai Learning provides for its students, to help them advance learning through the real-time adaptive system and cultivate good learning habits with practice.	http://squirrelai.com/about
StuA	StuA, which can help new-comer in a college who are hesitant in interacting with the seniors as they fear of being ragged. StuA is capable of answering all types of queries of a new-comer related to academics, examinations, library, hostel and extra curriculum activities.	https://www.researchgate.net/publication/323373220_StuA_An_Intelligent_Student_Assistant
Taylor	The Open University (UK) uses Taylor, an AI-based digital assistant, to improve the student experience for disabled learners... takes the student through topics such as their disabilities, study materials, and access to tutorials. Taylor can use natural language processing to 'understand' what the student has said, for example when identifying which recognised categories their disabilities fit with. This can then lead to appropriate responses, allow the student to use their own terms and result in more useful data being captured from the conversation."	https://nationalcentreforai.jiscinvolve.org/wp/2021/09/27/how-digital-assistants-are-promoting-enhanced-accessibility-at-the-open-university/
TurnitIn	Turnitin solutions promote academic integrity, streamline grading and feedback, deter plagiarism, and improve student outcomes.	https://www.turnitin.com/
VERA	A virtual experimentation research assistant for supporting inquiry- based learning of scientific knowledge. Currently the AI focuses exclusively on Epidemiology and Ecology assistance.	https://dilab.gatech.edu/vera/

Write & Improve	Write & Improve uses new technology developed at the University of Cambridge to mark English writing accurately, in seconds. Submit your work and Write & Improve will score it on the CEFR (Common European Framework of Reference) scale, giving it a level from A1 (lowest) to C2 (highest). Write & Improve also shows you the parts of your text that may need improvement. So you can work more on these areas and keep improving.	https://writeandimprove.com/
Writing Mentor	The Writing Mentor application offers two writing modes. In Paragraph Writing Practice, get more comfortable writing by working with "Sam", using Writing Help, proofreading, and earning badges! In Extended Writing, review the feedback. Feedback is not only about correcting errors! The feedback is intended to help you to reflect on, and revise your writing to make it well-developed, coherent, well-edited, and more convincing!	https://mentormywriting.org/
Writing Pal	Writing Pal, a web-based software tool, was developed to provide a means of automatically scoring essays in the same way as a teacher might while also providing writing strategy instruction, game-based practice and individualized formative feedback to help students improve their writing proficiency. This system is not intended as a replacement for classroom instruction or homework, rather as a supplemental writing practice.	http://www.adaptiveliteracy.com/writing-pal
WRTS	WRTS is the online learning platform that helps you learn words and concepts faster and easier. You can use WRTS anytime, anywhere. Quickly find the right lists from your textbooks and practice the words with the different practice and quiz options.	https://wrts.nl
X5GON	The recommendation engine is designed to increase content engagement, quality assurance, audience engagement and footfall, directly improving site metrics. X5LEARN's core product is an AI engine connecting millions of pieces of OER content from different sites, cultures and in different languages in one interface based on relevance and personal learning needs.	https://x5learn.org/about

Yuja	Yuja allows users to create audio/video content on their computer and upload it to the Yuja online storage and streaming environment. In addition, the software automatically captions any/all content created. YuJa Panorama automatically improves the accessibility of digital media and course content. Panorama brings market-leading Artificial Intelligence and Machine Learning capabilities into the digital accessibility process.	https://www.yuja.com

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