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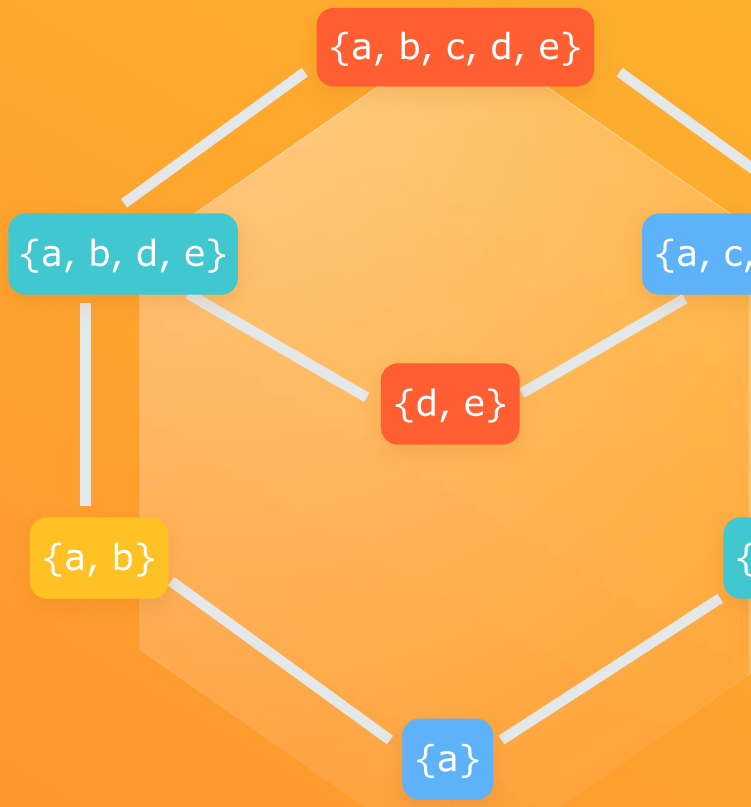

AI in Education – Looking to the Future of Learning

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Overview

Introduction

AI in EdTech (AIED) is gaining traction, mainly due to rapid global digitalization and the widespread use of smart devices. AIED applications combine machine learning, deep learning, and advanced analytics to determine and monitor students' learning processes – for instance, test scores and individual learning speed. Technology can help provide students with personalized learning experiences, allowing them to absorb and retain materials at their own pace. Teachers can leverage AIED to better understand their students' baseline levels, strengths, weaknesses, and rate of progress over time.

Teachers, parents, students, governments, and regulators must recognize the potential AIED has to transform education. As the world's technological landscape evolves, our schools will change. AIED is poised to improve the learning process in primary and secondary schools, as well as in higher education. Overall, the global AIED market reached $1.1 billion in 2019 and is forecast to reach $25.7 billion by 2030.

In this White Paper, we will examine the AI applications in EdTech, how the technology works, its market volume, relevant educational materials, and more.

Definition of AI in Education (AIED)

The use of AI in education has been researched for over 30 years. This field investigates learning no matter where it occurs – be it in a traditional classroom, in the workplace, through formal education, or lifelong learning. AIED brings together AI (which is inherently interdisciplinary) and pedagogy (including linguistics, education, neuroscience, psychology, anthropology, and sociology). Its end goal is to produce adaptive learning environments and inclusive, engaging, personalized, and flexible study tools.

Furthermore, AIED can give us a deeper insight into how individuals learn – for instance, it can provide data on how a learner's performance is impacted by their physical capabilities, socio-economic status, and the technology available to them. This insight can then be used to develop future AIED software, and it may also drive approaches to learning that don't involve technology.

Scope of AIED – Looking to the Future

A lot of "e-learning" currently involves uploading offline content to an online space; as it isn't interactive or engaging, it cannot effectively address students' needs. It's not that school districts don't have their students' best interests in mind; rather, there is a lack of funding and little accessible information on how educators can implement AI technology.

With machine learning, artificial intelligence, and other emerging technology, educators can monitor and control their learning environments more effectively than they could in the past. Therefore, there is a need to redesign and realign core learning processes to leverage these technologies and effectively improve learning efficiency. This process will raise learning standards at scale, as well as optimize costs.

One such practical example is the creation of virtual learning environments that are more conducive to teachers. Let's look at VIPKid, an English language teaching platform based in China. On this platform, any native English speaker can sign up to provide instruction to primary students. They use a pre-designed curriculum and provide regular feedback after classes. Giving feedback can take a significant amount of time, as VIPKid teachers can have large, ever-changing student rosters. This is where AI could come in. Machine learning could automate the feedback process, leaving teachers with more time to improve the quality of their lessons.

We could take it even further – machine learning could provide personalized lesson plans for students based on their learning progress and needs. Since teachers often give lessons in a 1-on-1 or small group format, this could be the ideal solution for providing tailored content.

The above is just one example of how an online educational space could use machine learning and other AI processes to provide engaging, individualized instruction.

Main Application Areas

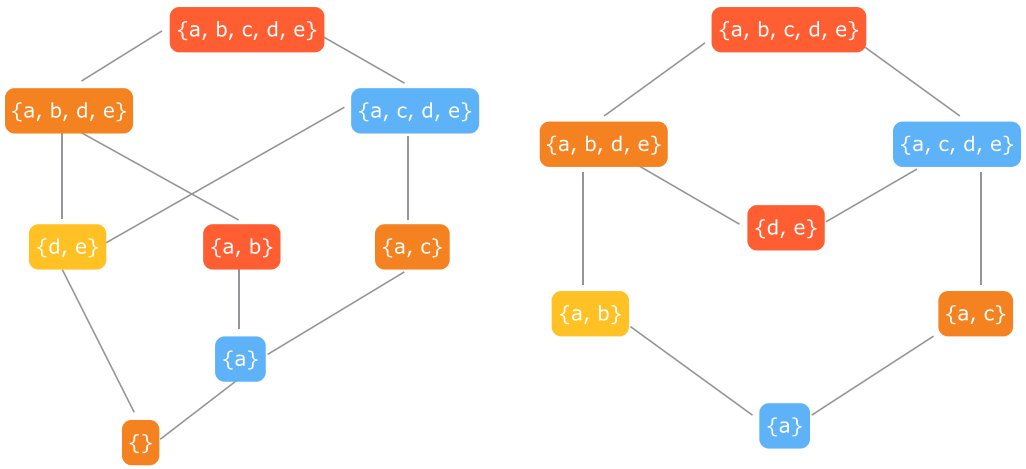
In traditional formal educational environments, students are taught in large groups. They all have varied needs – yet they receive the same instruction from one individual teacher. Unlike teachers, AI systems can scale quickly and efficiently to provide educational differentiation based on real-time sensory inputs. AIED systems can recommend suitable content, learning paces, and instruction methods for any individual learner at any given time.

Adaptive learning, which is often used alongside personalized learning, refers to an AIED system's ability to adapt to a learner's changing needs in real-time. Machine learning enables these systems to take newly introduced data into account and re-craft statistical models. These are the capabilities of AIED systems, but how can they be applied to transform study processes?

Personalizing Education

AI can determine what a student does and does not know, and it can then use that information to build a study schedule addressing those knowledge gaps. This application allows students to increase their studying efficiency, so they only spend their limited learning time on areas that need improvement.

To train AI systems to provide personalized education plans, the Knowledge Space Theory comes into effect. It defines and represents knowledge gaps while at the same time considering the relationships between each gap (for instance, one area can stimulate learning in another area).



Producing Smart Content

Currently, smart content comes in three main forms: digital lessons, information visualization, and learning content updates.

- **These digital lessons**
  contain bite-sized training and study guides generated with the help of AI. These, as well as digital textbooks, are combined into a digital learning interface.

- **This information visualization**
  refers to innovative, AI-powered methods of perceiving information, such as web-based study environments and simulations.

- **These learning content updates**
  use AI to generate and update lesson content, ensuring that all educational material is up to date.

Contributing to Task Automation

AI can help simplify administrative tasks typically done by teachers, such as grading, assessing, and providing feedback to students. By entrusting routine tasks to AI, teachers free up time for more complex tasks, such as improving lesson quality, self-education, and grading assignments that AI can't tackle.

Providing Tutoring

AI tutors are excellent time savers; as personal assistants or chatbots, these systems can provide students with additional support without placing an extra burden on the teachers. This also addresses the fact that many students are embarrassed to ask their teacher for help in front of classmates, and their parents may not have the spare time to assist in explaining concepts after school. With an AI chatbot, a student's queries are kept private.

Ensuring Accessibility

AIED applications open up new possibilities for teaching students with learning disabilities or other special needs. For instance, Automatic Speech Recognition (ASR) technology helps universities produce transcriptions and captions for videos quickly. For example, BYU Idaho used ASR technology to reduce their media captioning wait-time from months to mere days. Deaf and hard of hearing students could receive immediate access to YouTube videos, lectures, TedTalks, and other audiovisual content.

However, AI in EdTech is not without its difficulties; some problem areas include:

- Available datasets are limited; this, in turn, limits the resulting AI progress.
- Current AI EdTech applications do not pay close enough attention to learner differences and equity.
- AI technology can be costly and strain a school district's already overly-extended budget.
- There is often bias present in data.

Technology Overview

Glossary of Common Terms

Adaptive Learning Environment	A virtual learning environment that modifies learning approaches and teaching methods to meet the needs of individual learners.
Big Data	Data sets that are too big and complex for simple algorithms to analyze. They require machine learning or more complex data analytics to gain usable insight from them.
Machine Learning	This is one way to create AI: a computer system that learns from data instead of following a ruleset. When given enough data, machine learning algorithms can learn to solve problems and make predictions.
Neural Networks	A form of AI that takes inspiration from the human brain: it is created using artificial neurons or processing nodes, which are layered. Each node is given data from the nodes above it – and then passes the data down.

Categories of AI in EdTech

There are three main categories of AI in EdTech: learner-oriented, instructor-oriented, institution-oriented.

Learners

Learner-oriented AI provides a personalized or adaptive learning management system, enabling students to study a subject domain effectively. Such platforms may facilitate the collaboration between learners, give automated feedback on simple responses, diagnose knowledge gaps, and curate/stagger learning materials based on learner needs.

Granted, sophisticated AI is not required to complete all of those tasks; rules-based programs can offer adaptive learning. However, advances in machine learning have made more sophisticated learner-facing EdTech platforms possible. For instance, rather than making students follow one of a set of human-designed learning paths, machine learning algorithms use a student's strengths, weaknesses, and knowledge gaps to scaffold individualized learning.

Instructors

Instructor-oriented AI tools can automate administrative procedures, plagiarism detection, assessments, and feedback provision. Furthermore, instructor-oriented systems can monitor learning progress and flag instances where teacher intervention is required. Teachers now have time for innovation and experimentation with different teaching methods; what's more, they now have concrete evidence showing these methods' effectiveness.

Although some parents are concerned that AIED seeks to replace teachers altogether, this is likely not possible in the foreseeable future, nor would it be desirable. As Rose Luckin notes in Intelligence Unleashed, "teachers will be the orchestrators of how and when to use AIED."

Institutions

Institution-facing (or system-facing) AIED helps school administrators and district leaders predict inspection performance, organize timetables, see and anticipate biases inherent in big data sets, and measure a student's suitability for a school during the admission process. Currently, institution-facing AIED is the least widespread out of the three varieties.

How AI in EdTech Works

AI involves computer software that can interact with the world in a manner that would usually require human intelligence. This means that AI requires knowledge about the world and algorithms capable of processing that knowledge. Take, for instance, an AIED system that needs to give a student appropriate, personalized feedback. In order to be successful, the AIED system must have knowledge of effective teaching approaches, the academic subject, and the student.

"Models" contain the knowledge necessary for an AI system. There are three key models in AIED: pedagogical, domain, and learner.

Pedagogical Model

What it represents

Knowledge of the teaching process

Examples of specific knowledge

Assessment for informing and measuring learning, feedback triggered by student input, productive failure

Domain Model

What it represents

Knowledge of the subject matter

Examples of specific knowledge

Causes of World War II, how to multiply fractions, how to structure an argument in an essay

Learner Model

What it represents

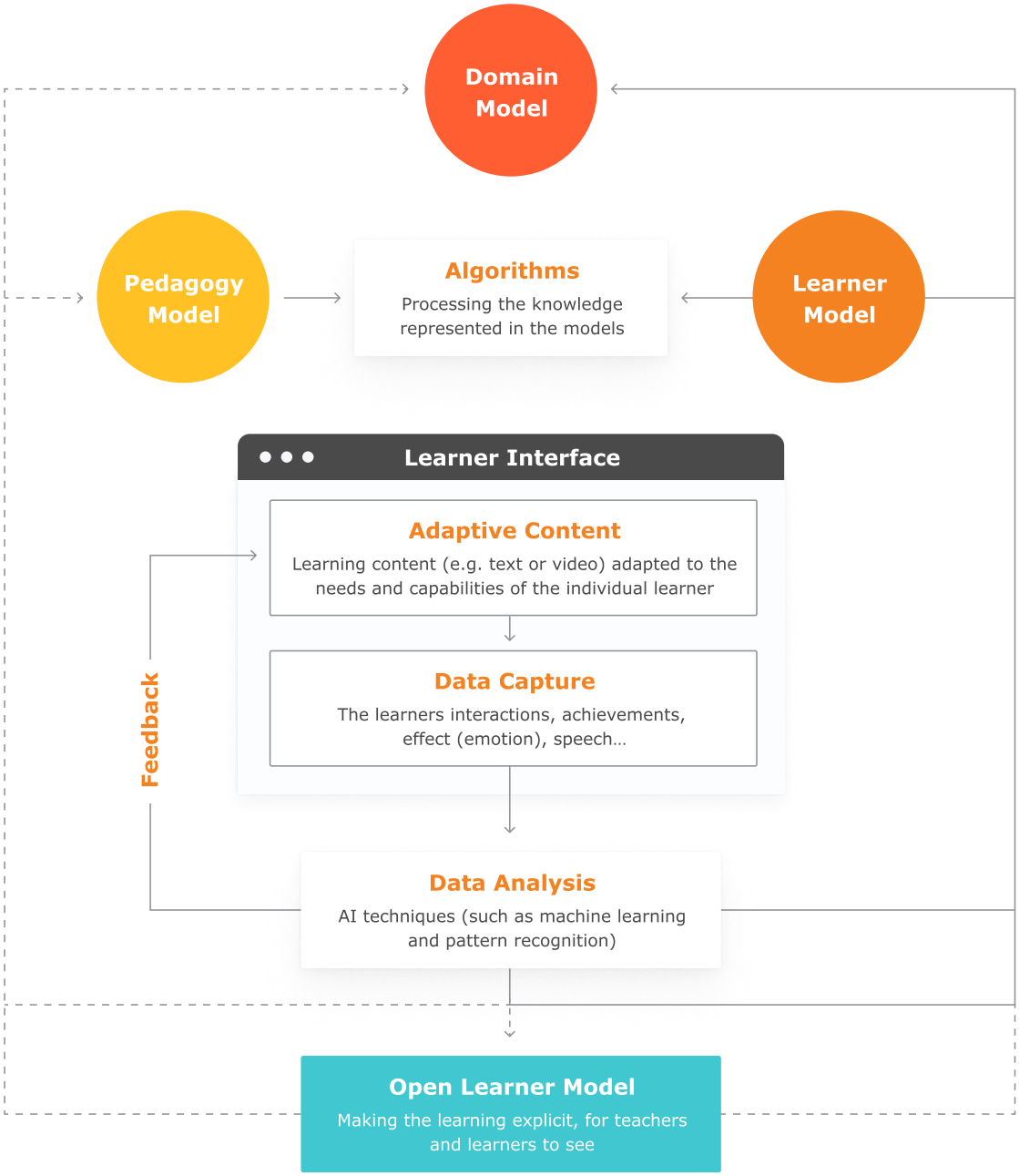
Knowledge of the learner

Examples of specific knowledge

The student's emotional state, accomplishments, weaknesses, and learning engagement

What AIED Technology Looks Like

The figure below shows a simplified depiction of a standard model-based, adaptive tutor. It uses the three core models (pedagogy, learner, and domain) – then AIED algorithms process the knowledge and select the content to deliver to the student.



Content delivery could be in the form of a video, an activity, a sound, an animation, or a piece of text. Regardless of the form it takes, it is selected for its relevance to the individual's capabilities and needs. While the content is being delivered to the student, the system continuously analyzes that learner's interactions and provides feedback. Interactions might include their current answers and actions, past achievements, or information on their psycho-physiological state.

A deep analysis of these interactions helps the student progress through content and updates the learner model accordingly. AIED technology can more accurately estimate a student's current state (including their motivation and understanding) and ensure that the learning experience is fully customized to their needs.

Some systems use Open-Learner Models; these present analysis outcomes back to the students and teachers. These outcomes contain valuable information that helps teachers understand their students' learning approaches better – thus enabling them to shape future learning experiences accordingly. Learners can also benefit from this model, as they can track their own progress and reflect on their learning journey.

Key Players Involved

The top AI-based EdTech providers include:

1. Google Inc.
2. Microsoft Corporation
3. IntelliResponse System Inc.
4. eGain Corporation
5. Next IT Corporation

Of course, there are far more significant players across various niches, including Jobs & Upskilling, Assessment & Credentialing, Learning Content & Resources, Management Systems, Learning Environments, and more.

HoloniQ – December 2020

History of Development

Though AI in Edtech has flourished over the past decade, researchers began to delve into this area in the 1970s. Eliza, an early NLP program built in the 1960s, was incorporated into Jaime Carbonell's SCHOLAR – a student-facing instructional program. SCHOLAR asked questions on South American geography and then provided natural language feedback on the quality of the student's response.

Another significant AI EdTech prototype was MYCIN, which helped physicians diagnose bacterial infections and prescribe therapies. This system was embedded with tutoring approaches so that knowledge would be accessible to physicians. This model paved the way for Intelligent Tutoring Systems (ITS).

Initially, ITS was very rudimentary. Rather than using machine learning, the systems followed step-by-step programmed learning paths. Then, in the 1980s, pedagogy became more important. This was when the BUGGY approach was born, working under the assumption that students have "bugs" in their thinking. Nowadays, we call such bugs "misconceptions." A bug library was created in 1975 by J.S. Brown and R.R. Burton, attempting to break down a task into smaller components, reproduce the student's behavior, develop a diagnostic model, and then identify procedural bugs the student might acquire when solving problems. The teacher then used BUGGY's feedback to diagnose and "treat" the student bug.

In the 1990s, dynamic student models came onto the scene. These models paid greater attention to what the student learned over time, and they used that information to update the dynamic student model. Significant focus was placed on providing relevant hints and feedback.

In the 2000s, AIED used Bayes Nets, Artificial Neural Networks, and other AI approaches to form the educational data mining field. This refers to tools designed to automatically extract insight from large datasets related to learning activities in an academic setting.

The Market

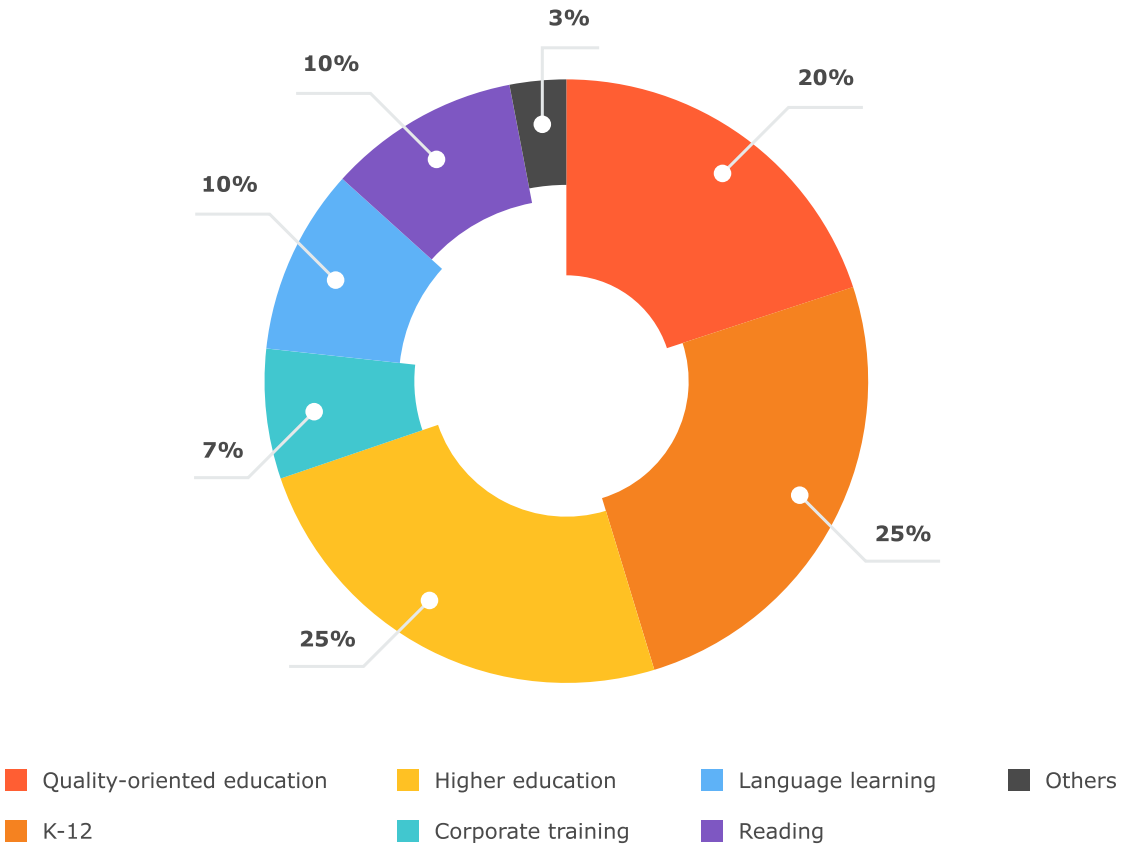
According to PS Market Research's AI in Education Market Report (Feb 2020), the 2019 global AIED market size was 1.1 billion. The market is predicted to achieve a 32.9% annual growth rate between 2020 and 2030 and reach $25.7 billion by 2030. The key factors driving the market include the ever-growing need to provide personalized, AI-based education and to automate administrative tasks.

GLOBAL AI IN EDUCATION MARKET

2019	2030	Market Growth Rate (2020–2030)
Market Size	Market Size	
$1.1 billion	$25.7 billion	$32.9%

According to Deloitte's report on the Global Development of AI-Based Education (2019), the most most common services provided by the Top 30 AI Edtech companies are K12 (25%), Higher Education (25%), Quality-Oriented Education (20%), Language Learning (10%), Reading (10%), and Corporate Training (7%). The "Other" services account for only 3% overall.

PERCENTAGE OF TOP 30 "AI + EDUCATION" COMPANIES PROVIDING THE FOLLOWING SERVICES



Sourse: iyiou.com, Deliotte Research

The Competitive Landscape of the AIED Market

Google, Blackboard, Microsoft, IBM, Carnegie Learning, and other major players in the AI EdTech market have been ramping up their partnerships and product launches. Take, for instance, IBM's collaboration with Edmodo in 2018. They collaborated to create a personalized recommendation engine for Edmodo's education platform. Using the IBM Watson Classroom Cognitive Library, teachers can provide customized content recommendations to students based on their performance.

How It Works

To train a deep neural network model, you must use a highly tuned system with carefully selected drivers, software, computing power, memory, network, and storage resources. One such system is Fabric for Deep Learning (FfDL). It offers a stack that enables data scientists to use the deep learning framework of their choice to execute training jobs at scale in the cloud. FfDL allows scalability, multi-tenancy, resilience, and security without modifying the desired deep learning frameworks – and with little to no changes to the model code. FfDL can be used with PyTorch and TensorFlow frameworks, which we will discuss in the following core section, Main Tech Architectures Used.

FfDL Architecture

FfDL uses microservices architecture: essentially, with this architecture, an application is structured as a collection of services that are:

- Organized around business capabilities
- Independently deployable
- Highly maintainable and testable
- Loosely coupled

These microservices include:

REST API

This microservice takes care of REST-level HTTP requests while acting as a proxy to FfDL's lower-level Trainer service. The REST API also handles authentication and load-balance requests.

Trainer

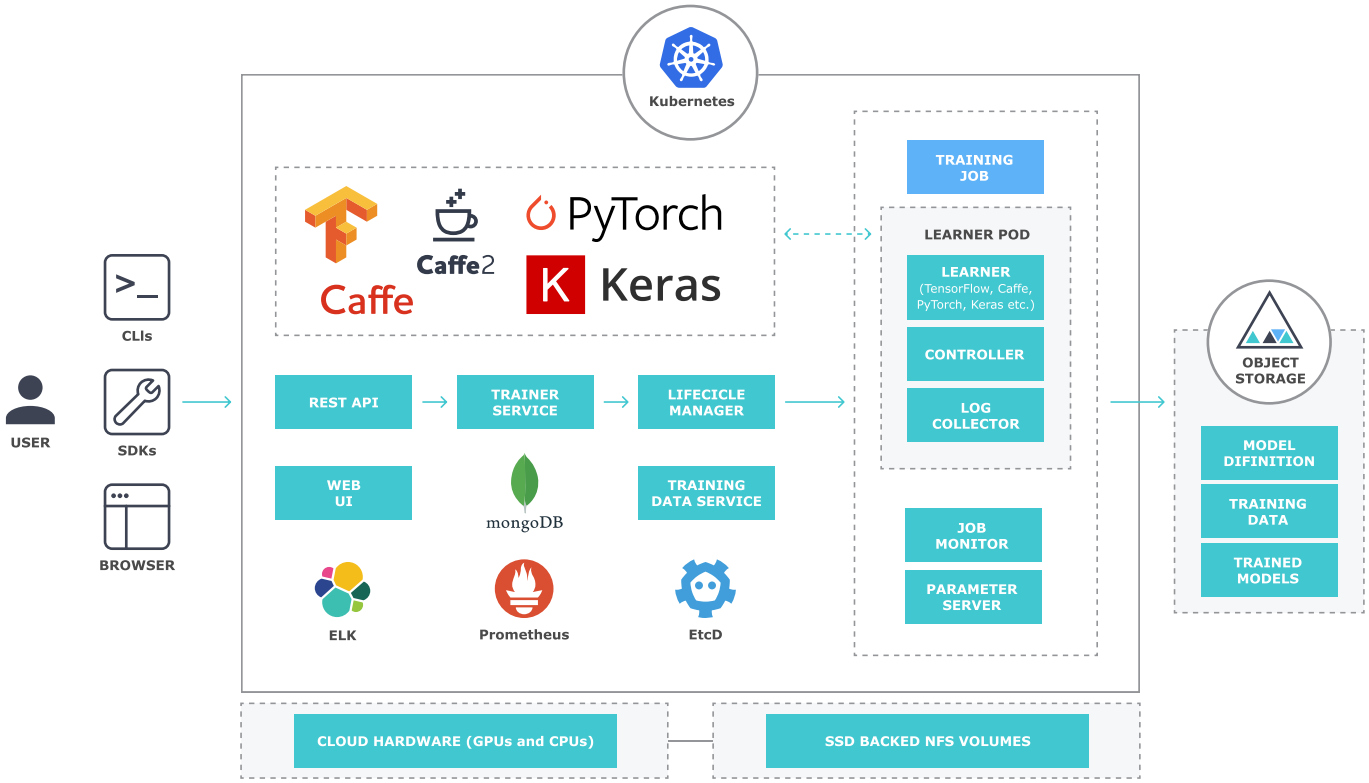
This microservice admits training job requests, model input configuration, and persisting metadata to the MongoDB database. Trainer initiates job deployment, halting, and user-requested termination by calling Lifecycle Manager's appropriate gRPC methods, which we will look at momentarily. Trainer also gives each job a unique identifier, used for tracking purposes by all other components.

Lifecycle Manager (LCM)

It halts and terminates training jobs, and it also deploys training jobs that arrive from Trainer. LCM uses Kubernetes cluster management for deployment; each job consists of a set of interconnected Kubernetes pods - and all of the pods contain at least one Docker container. LCM determines the learner pods, interconnections, and parameter servers based on the job's configuration. It then calls on Kubernetes to deploy the job.

Training Data Service (TDS)

When a learning job is running, training data is extracted from the learner and pushed into TDS, then feeding said data into ElasticSearch for future retrieval.



Diving Into the Technical Details

Two of the most popular deep learning frameworks are TensorFlow and PyTorch.

Key Facts About PyTorch:

- Developed by Facebook's AI Research Lab
- Released in 2016
- Meant to be used in Python but also has a C++ interface
- Has dynamic computation graphs
- Supports CUDA (Compute Unified Device Architecture)

PyTorch Case Study

> Erin Song, a STEAM teacher from North Carolina, used Pytorch to create MineTorch: a platform that teaches children how deep learning works. Minetorch was Song's entry for a "hackathon", in which 77 contestants had 48 hours to build a project in PyTorch.
>
> Key Facts About TensorFlow:
>
> - Developed by Google's Brain Team
> - Version 1.0.0 was released in 2017
> - Provides workflows to develop and train models using Javascript or Python
> - High-level Keras API for deep learning practitioners working in Python
> - Graph construction is static, unlike PyTorch

TensorFlow Use Case

> AI can be used to grade students' handwritten assignments. Gradescope is one such example: this online grading app from UC Berkeley can identify single-word, numerical, and one-line answers. To train the algorithm, developers use Tensorflow and CuDNN (a deep neural network library). Teachers can use Gradescope to shorten grading time by up to 75%.

Main Applications and Impact Delivered

AIED is, as mentioned earlier, categorized into learner-oriented, teacher-oriented, and institution-oriented applications. Now, we'll take a closer look at the specific types of applications in each category.

Learner

- Intelligent tutoring systems
- Language learning applications with pronunciation detection
- AI collaborative learning
- AI continuous assessment
- AI learning companions
- Course recommendation
- Self-reflection support
- Exploratory learning environments

Teacher

- Essay scoring
- Forum monitoring
- Learning diagnostics
- AI teaching assistants
- Automatic test generation and scoring
- Plagiarism detection
- Student emotion and attention detection

Institution

- Educational data mining and resource allocation
- Diagnosing of learning impairments
- AI as a research tool for education processes

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Institutional AIED Case Study: Intetics Creates a K-12 IEP Management System

A provider of special education services and software had an outdated product that helped schools automate the management of Individual Education Planning (IEP) forms. These forms contained crucial information about students with disabilities and what school services they needed. Form management needs to be accurate, timely, and compliant with government requirements. Therefore, the client desired system modernization in accordance with the new technologies stack.

After analyzing the client's requirements, Intetics put together a dedicated offshore team of software engineers responsible for database and software development, system architecture, data entry, and testing.

After the team modernized the existing application, they developed new features for the product, which were created as modules. The final product automatically files health forms, scans and recognizes paper-filled forms, manages IEPs, completes smart scheduling of activities, and much more. The interface is user-intuitive and designed for easy access by district administrators and medical professionals alike.

The primary outcomes of this use case are:

★ 01

The client now has more time to focus on providing quality service and fulfilling business requirements rather than getting caught up in technical details.

★ 02

School districts now have better document automation, improved Medicaid access, and more scheduling options.

★ 03

The platform is compliant with local regulations and HIPAA requirements.

★ 04

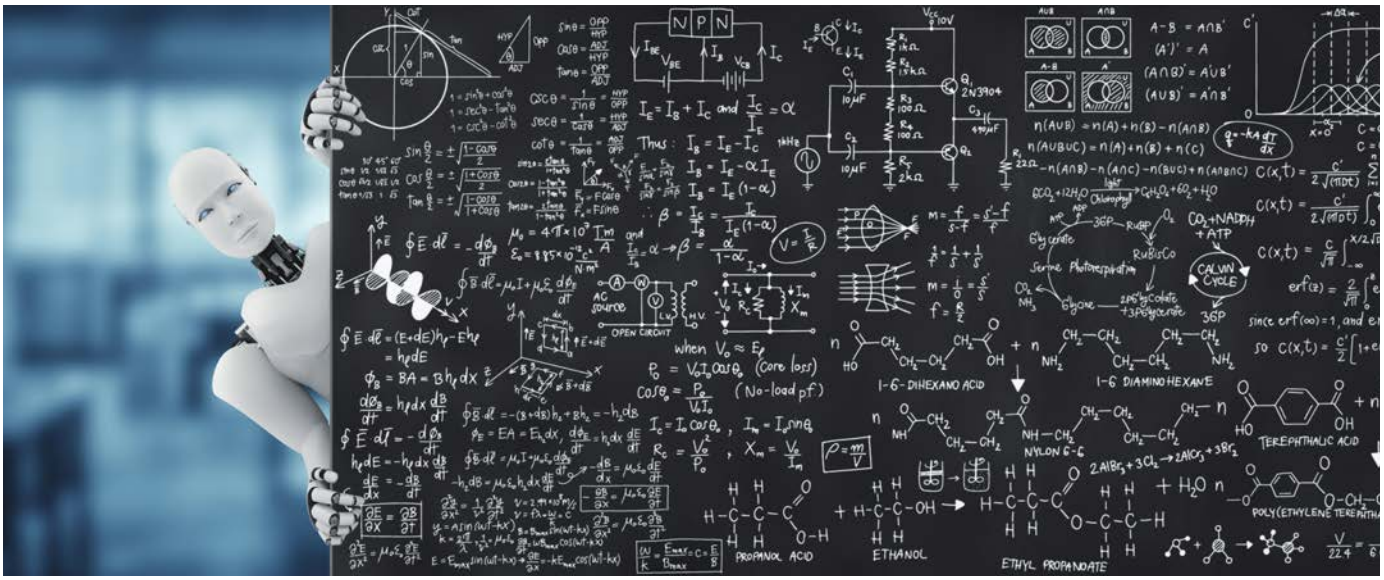
The product can be used as a major migration platform for related projects.

★ 05

District IEPs can now accurately streamline, create, and control student checkups.

★ 06

The client has become a market leader in IEP management software and expanded into 13 states.



Teacher AIED Case Study:
Intetics Creates a Learning Management System for a Tutoring Company

A tutoring company was notified that their vendor would terminate their subscription-based service in 12 months. The tutoring company contracted Intetics, desiring a complex ERP system that could manage all business activities. The timeline was quite limited, as the new solution would need to be fully implemented before the vendor canceled the existing subscription.

Intetics analyzed the vendor's software and noted the required modifications that could not be made in the old version. Intetics' development team created a solution that would meet the client's business needs and support new features. The developed solution offers:

- Management of all business activity from one system
- More comprehensive data analysis
- Streamlining of business processes
- An improved customer experience

Student AIED Case Study:
Intetics Creates a Test Content Management System

Because of COVID, students are temporarily unable to take tests in large group settings. Therefore, educational organizations need digital solutions so that students can take their tests online. Intetics' client helps students prepare for such tests, and to do this effectively, they require a digital test platform that can match the UX/UI of the actual tests.

Intetics created a test content management system that contained all major test types: ACT, SAT, PSAT, and ISEE. When students take a test using this system, they have a near-identical user experience to the original digital test. What's more, the score results are available in just a few minutes. The Intetics team is continuing to add new features to the platform.

Standards Applied

Currently, there are no concrete standards in use for AIED. However, the world's first international standards committee, ISO/IEC JTC 1, is working to standardize the entire artificial intelligence ecosystem. The committee was created in 2018 and has a goal of providing guidance to ISO, JTC 1, and IEC committees that develop AI applications. Some standards under progress include:

- Reference architecture of knowledge engineering
- Guidelines for AI applications
- Data quality for analytics and ML
- Risk Management

Published standards include:

- Big data reference architecture
- Trustworthiness in artificial intelligence

Industry Resources

Some associations and magazines for AI practitioners include:

- Association for the Advancement of Artificial Intelligence (AAAI)
- Emerj Artificial Intelligence Research
- AI Magazine

Some associations and magazines for AI practitioners include:

- International Society for Technology in Education (ISTE)
- International Conference on Artificial Intelligence in Education
- Edu-Tech Business Association

Authorities

These companies are paving the way for the innovative merger of AI and organic learning systems:

1. **Knewton** creates adaptive learning technology for college-level education. Its program, "Alta," identifies the gaps in a learner's knowledge, provides relevant study material, and helps the students get back on track in their college-level courses. Currently, this program is used for chemistry, statistics, general math, and economics.

2. **Cognii** created AIED products for K-12, higher education, and workplace settings. Cognii's virtual learning assistant uses conversational technology to present students with questions that foster critical thinking. Questions are open-format rather than yes/no, and feedback is provided in real-time. What's more, the answers are used to develop and implement one-on-one, customized AI tutoring.

3. **Querium** delivers AI-enabled STEM tutoring lessons to college and high school students. Querium's AI analyzes answers and session length; then provides teachers with insight into their students' learning habits and areas for improvement.

4. **Century Tech** launched a platform that combines data analytics with cognitive neuroscience; it harnesses this power to create personalized learning plans, thus reducing teachers' workloads. The platform can track progress, identify gaps in knowledge, and provide feedback and study materials.

5. **Kidaptive's Adaptive Learning Platform (ALP)** is making big waves in AIED. The platform uses AI algorithms to collect learner data and improve engagement. AI is also used to challenge students relative to their strengths and weaknesses. Furthermore, the platform analyzes underlying patterns and relationships to predict future academic performance.

Certifications

While there are currently little to no available certifications specifically for AIED, there are plenty of general certificates for AI professionals. These include:

- The Artificial Intelligence Engineer Certification by Artiba
- Machine Learning by Stanford University
- Applied AI Professional Certificate by IBM
- MicroMasters® Program in Artificial Intelligence by Columbia University

Your Health Check

Are you unsure whether your EdTech solution needs to be AI-powered? Work through the following checklist to determine if you can benefit from AI:

1. Does your solution provide personalized learning? AI can determine gaps in a student's knowledge and create a customized study plan.
2. Are you producing Smart Content? Digital lessons, learning content updates, and innovative information visualization can all be powered by AI.
3. Do you need to automate repetitive tasks? Providing feedback, giving assessments, and grading homework are time-consuming activities – but AIED can handle this instantly and with personalization. By automating such tasks, teachers now have more time for improving their lesson quality.
4. Are you trying to improve student engagement? Personal content recommendations, custom tasks, digital interaction, and individualized schedules help each student feel special, thus raising their engagement and interest in the content.
5. Do you need to reduce pressure on students? Students may choose not to ask for help when classmates are around – by asking the teacher aloud; they could face teasing. But with an AI-powered virtual assistant, students can discreetly ask questions and receive a comprehensive, expert answer. And, by reducing that pressure, students have less stress and more motivation to study.

6. Do you want to use content analytics? AI can analyze content taught to learners and determine whether it is of maximum effectiveness. Educators and providers can receive important insight on eLearning content.

Further Reading

While this Whitepaper provides a general overview of AI applications in the education sphere, the following resources can provide deeper, more focused insight:

- Artificial Intelligence Explorations and Their Practical Use in Schools: This 30 hour, self-paced course from ISTE offers ongoing instructor support. It is designed for middle and high school teachers, as well as school tech coordinators. No previous knowledge of AI is necessary; you will learn about the different kinds of AI, learn about upcoming AI innovations on the horizon, and build some basic AI tools of your own.

- Artificial Intelligence In Education: Promises and Implications for Teaching and Learning (Fadel, Holmes, Bialik, 2019): Learn how the emergence of AI has caused rapid changes in the landscape of education. The book takes a look at how school curriculums must be updated to accommodate an AI-driven world. Readers will also learn about how AI helps teachers become more effective and about various AIED applications.

- TED Talk: How to Empower Education With Artificial Intelligence: Dr. Luca Longo, an assistant professor at the Dublin Institute of Technology, presents ways that AI can transform education.

Miscellaneous

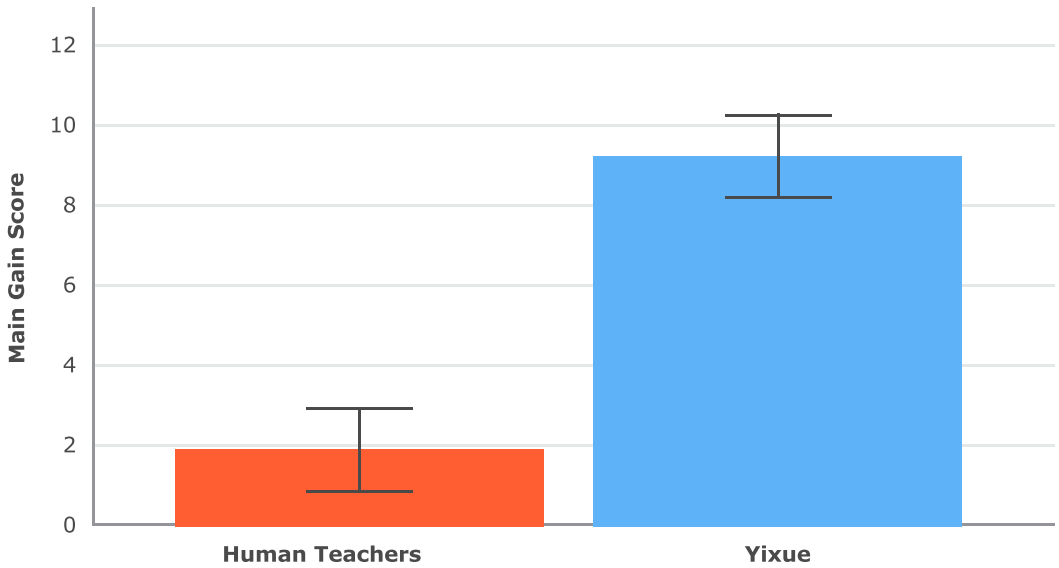
China's Grand Exploration of AI Education

Over the past few years, China's investments in AI-powered education have skyrocketed. Education incumbents, tech giants, and startups have all hopped on board. Tens of millions of students across China are now using AI to learn through digital learning platforms, extracurricular tutoring programs like Squirrel, or even in their principal, physical classrooms.

Interest is making its way westward: in 2019, Squirrel opened a joint research lab with Carnegie Mellon University. Their plans are to research personalized learning at scale and export it internationally.

Some experts are concerned that China is rushing towards AI in education. Poorly developed AIED solutions could make it more difficult for teachers to accurately identify and address their students' strengths, weaknesses, and interests. However, companies like Squirrel are yielding remarkable results in traditional education.

For instance, in a 3-day study that measured 203 middle school students' test scores, Squirrel found that their AI tutoring system was better at lifting scores than experienced teachers. The students were split into two groups: the treatment group (which received AI instruction) and the control group (which received instruction from human teachers. Both groups received introductory content, filled out a questionnaire, and then took a pre-test. Afterward, they received instruction according to their group classification. Then they took a post-test. The results showed that students who received AI content showed 419% greater gains.



One thing that must be considered: even if AIED improves teaching and learning, it also reshapes the nature of the workforce, which should also be addressed in school curriculums. As computers become better at machine learning and fulfilling tasks, humans will need to master skills unique to their species: problem-solving, collaboration, communication, and creativity. This means that the modern classroom should strive to uncover and bolster each student's strengths rather than drill in an old-fashioned set of knowledge.

Summary and Conclusions

AIED offers solutions to many educational challenges and can deliver learning experiences that are more personalized, inclusive, flexible, engaging, and effective. Not only that, but AIED can be applied to learning experiences in both formal and informal settings, during K12, higher education, lifelong learning, and the workplace.

Over the last decade, AIED has grown leaps and bounds; it has moved from lab work to large-scale deployments – yet, school districts aren't leveraging this technology as effectively as they could. One key reason that some educators and administrators remain skeptical is that they believe AIED has insufficiently rich learning models. One of the main focuses of AIED over the last ten years has been to develop incredibly comprehensive learner, teacher, and domain models – however, research on those models was typically only published in conference proceedings and specialist journals. This meant that the average teacher and school district could not see how AIED was evolving – only now is AIED's progress becoming more visible.

For AI to reach its full potential in educational settings, the AIED community needs to explain better the value and the nature of the models it uses.

AIED has made significant progress, but there are still plenty of exciting developments to come as the existing applications develop, mature, and scale. And the future of AIED isn't just "more of the same" – instead, developers are becoming more skilled at blending machine and human intelligence effectively. As AIED technologies evolve, we could see AI teaching assistants introducing new management and teamwork skills, AI applications teaching students 21st-century skills, such as financial literacy and cultural awareness, and even AIED incorporated into augmented reality systems.

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