THINKZ!
HELP ME WITH...

MATH

WRITE STYLE

GRAMMAR

THINKING

The device that recognizes and corrects your handwritten notes in a real-time!
It indicates your mistakes on the screen of your electronic device and significantly helps to better focus during studying and learn faster.

1. Project participants

1.1. Mentor/Faculty advisor

Prof. Michał Kuciapski is lecturer and researcher at University of Gdansk, was member of its E-learning Council from 2006 to 2016, and member of PLAIS—Polish Chapter of Association for Information Systems. His research work regards technological, economic and educational aspects of knowledge transfer in organizations. Studies conducted in recent years included an exploration and validation of the factors and moderators that impact employees' intention to use mobile technologies during knowledge sharing processes, with the use Structural Equation Modelling approach. In this regard he published a number of articles also in prestigious journal indexed in Journal Citation Reports. Prof Michał Kuciapski is an experienced software developer and from 2006 to 2017 was Microsoft Certified Trainer. As MCT he realized over 50 certified courses for a significant number of companies, in the field of developing desktop, web, mobile and cloud applications.

1.2. Members

Hubert Kołcz
In charge of project management and web development.
https://www.linkedin.com/in/h-kolcz/

University of Gdańsk (Poland) - *Informatics and econometrics, 2nd year.*
University of Bremen (Germany), Business Administration, 2019-2020
Higher Socioeconomic School (Poland), *Management, 3rd year.*

- Finalist of the Polish Development Fund - School of Pioneers (Poland)
- Participant in AIESEC projects for reaching SDGs (Italy, Romania).

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Mateusz Kusiak
In charge of prototyping IoT solution (device).
https://github.com/dancesWithMachines

University Of Gdańsk (Poland) - Informatics and Econometrics, 2nd Year.

- Arduino hobbyist

Mateusz Łukasiński
In charge of developing mobile solution (Android)
https://www.linkedin.com/in/mattlukasinski/

University Of Gdańsk (Poland) - Informatics and Econometrics, 2nd Year.
- Freelance Mobile Developer
- Vice-Chairman of KNSI E-Xpert (since October 2019)

Damian Jaszewski
In charge of prototyping grammar module, administrating landing page.
http://linkedin.com/in/damian-jaszewski

University of Gdańsk (Poland) -Informatics and econometrics, 1st year.

Weronika JóŹwiak
In charge of managing marketing and business aspects.
https://www.linkedin.com/in/weronika-j

University Of Gdańsk (Poland) - Informatics and Econometrics, 2nd Year.
- Finance Specialist at KNMI (since October 2019)
- Member of KNSI E-XPERT
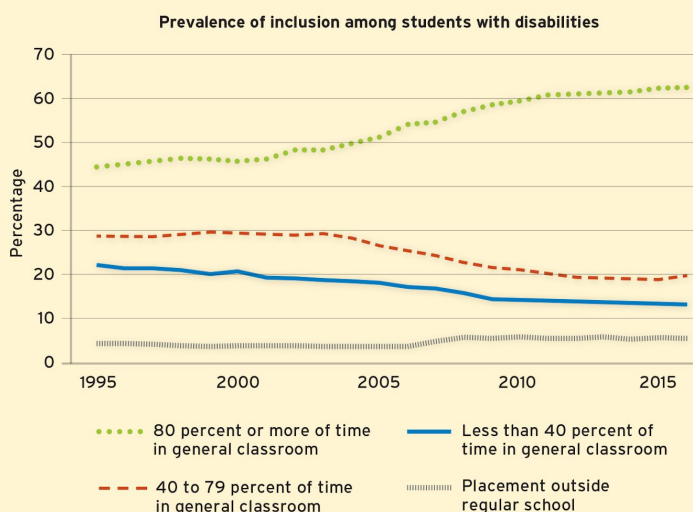- Experience in making a couple of events at University of Gdansk

2. Problem Significance

2.1. Societal problem that can be solved by Thinkz

Learning is much more effective when the teacher works individually with a student. **Private tutoring, however, is expensive** and it is *not an affordable option for everyone*. In large classrooms, the **teachers are not able to focus on the individual needs of each student** and *it is difficult to ensure individual learning*. On the other hand, a *significant number of students can't attend standard schools as* **they are not adjusted to accommodate students with disabilities**.

Growing Prevalence of Inclusion (Figure 1)

The inclusion of special-education students in general-education classrooms has become increasingly common, particularly in the last decade. In 2016, more than 60 percent of all students with disabilities spent 80 percent or more of their school day in regular classrooms, alongside their non-disabled peers.

Prevalence of inclusion among students with disabilities

- ••••• 80 percent or more of time in general classroom
- ▬▬▬ Less than 40 percent of time in general classroom
- ─ ─ ─ 40 to 79 percent of time in general classroom
- ||||||| Placement outside regular school

NOTE: Data presented by calendar year in which the school year ends.

SOURCE: National Center for Education Statistics, Digest of Education Statistics

"The model of special education known as inclusion, or mainstreaming, has become more prevalent **over the past 10 years, and today, more than 60 percent of all students with disabilities (SWDs) spend 80 percent or more of their school day in regular classrooms**, alongside their non-disabled peers". "**Unfortunately, research has yielded only weak evidence that inclusion confers benefits on SWDs**. (…) **Further, studies of inclusion seem to assume that SWDs are educated in a vacuum; that is, they fail to examine the experiences of non-disabled classmates.**"

"Consider the following two examples. A 1st-grade student with a speech or language impairment might require one hour of speech therapy a week from a speech/language pathologist to improve his enunciation. His IEP team may also decide that he needs accommodations in the classroom, as his impairment influences his reading fluency. Apart from his weekly speech therapy, the student would attend a general-education class with the occasional accommodation for his reading skills. Removing this student from the regular classroom because of an enunciation problem would be inappropriate(…).

Contrast this student with a 5th-grade student receiving special-education services for a specific learning disability who is struggling with sounding out words while his non-disabled peers are focused on reading comprehension. (…) These examples illustrate **the individualized nature of placement decisions**."
Source:
https://www.educationnext.org/edstat-60-percent-students-disabilities-spend-80-percent-school-day-regular-classrooms/

2.2. Considerations

- Ensure affordable and **effective education** for everyone **regardless of financial status**.
- **Minimize the influence of uncontrollable factors**, such as the background and natural predispositions, on the children's future and access to resources.
- Provide **support for ambitious and hardworking adolescents** who suffer from impairment or come from unprivileged backgrounds.
- **Reduce the time that young people spend on the core curriculum at school**, so that they can **spend more time exploring their interests**.
- **Liberate teachers from redundant work**, so that they can **give more individual attention to their students** and help them with finding passions and determining career goals.

By meeting the above needs, we would help to achieve the below Sustainable Development Goals stated by the United Nations:

- "**Reduced inequalities**" (Goal 10) - by providing equal access to education to everyone regardless of financial status and background.
- "**Quality education**" (Goal 4) - by offering high quality educational resources and academic support.
- "**No poverty**" (Goal 1) - by boosting the economies through educating young people and preparing them for future employment.
- "**Gender Equality***" (Goal 5) - by supporting personal and academic development regardless of gender.
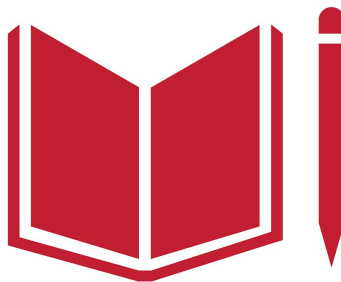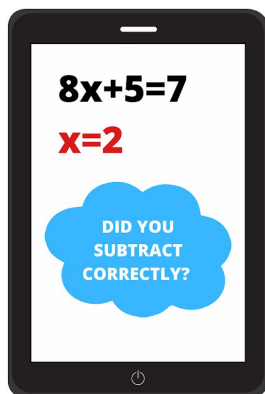
3. Solution

3.1. Description

Thinkz is a system that recognizes and corrects handwritten notes in real time. It indicates user' mistakes to the screen of electronic device. Thanks to the Socratic method of formulating questions, our solution helps to better focus during studying and learn faster.

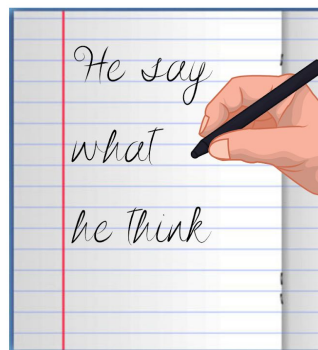Thinkz is a valuable solution during situations, such as:


MATH TUTORING
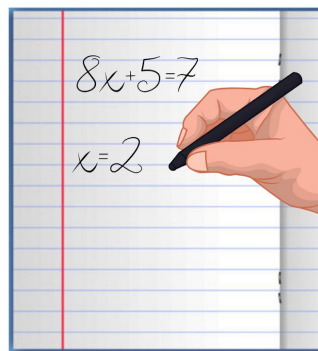
A student made an error while solving a math problem. The device will let them know promptly, provide hints and offer additional practice resources, based on their error history.

LANGUAGE TUTORING

If a student struggles with grammar, Thinkz will recognize and memorize the mistakes and encourage progress by correcting them and offering ways to improve.
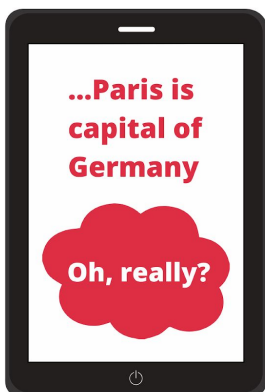

FACT CHECKING

Let's say a student confuses some facts and for example, includes false information in their essay. Thinkz will let them know and enhance their knowledge about the world by correcting the factual errors.

Our solution will be continuously extended with new features. The goal is to help with wide categories of subjects at school, whether it's humanities, sciences or languages.
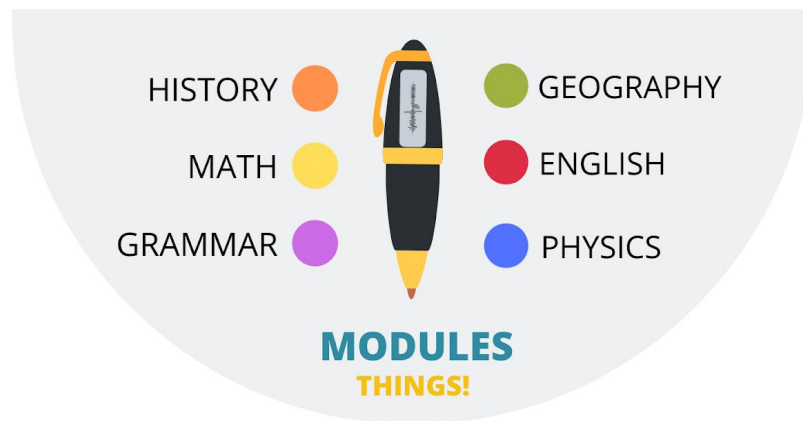

3.2. Examples of use

- Teachers who utilize the platform in their classes, will be able to **assign their own problems to their students**. In this way, the students will be able to gain access to real-time tips and corrections on homework problems.
- **Teachers would indicate the best students in class**, based on statistics of made mistakes.
- **Teachers easily would find problems in own curriculum** - when particular task is to hard for majority of the students, they will receive an information about that.
- Students would **self-improve themselves through using additional resources and exercises, given by Thinkz - based on the student's most frequent mistakes**.
- Students will be able to **make a repetition of material, just by making notes** - in case of making mistakes, device will prompt and indicate what student needs to learn more.
- **The best students will be easier reachable for the best universities** - statistics will indicate the ones with most skills in particular areas.
- Thanks to Grammar Module - **helping with preparation on language skills test**.
- **Help with homework in general**.
- **Digitalization of notes**, so to make it easier to share those with teachers or another student.
- Kids with autistic disabilities would made better grades. It is minimizing a need of speaking with a teacher; **autistic kids don't have to communicate with teacher through words - Thinkz let them go deep into their own world, giving them sometimes advices (or by teacher).**
- During solving math problems, **students would focus on great ideas for finding a way to solution, instead of making boring calculation** - thanks to Math Module.
- **Recognizing individual needs of student** - based on algorithms that would recognize disadvantages and disabilities.

4. Innovativeness of Solution

(presented in parts with a description of the architecture)
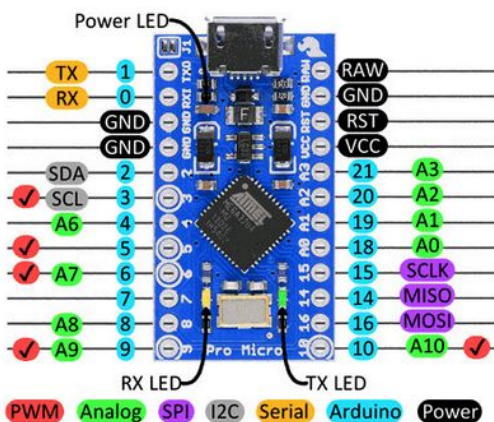
4.1. Main device
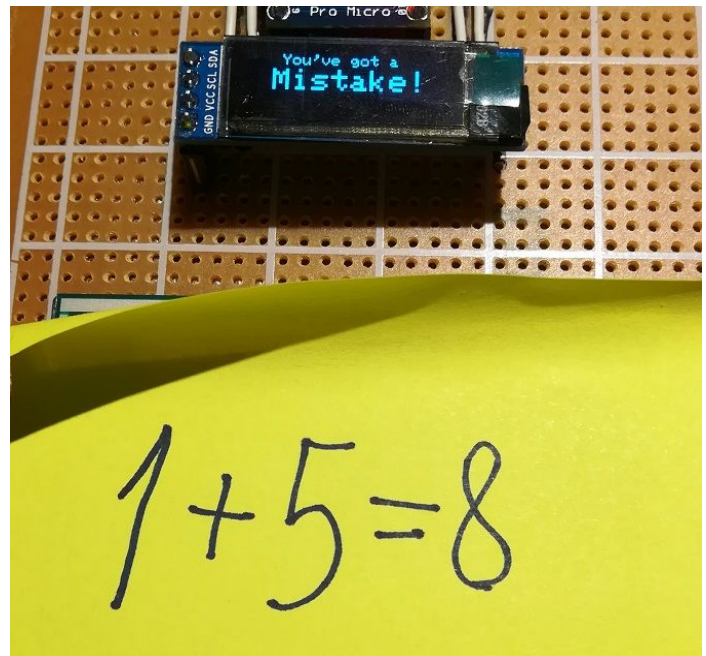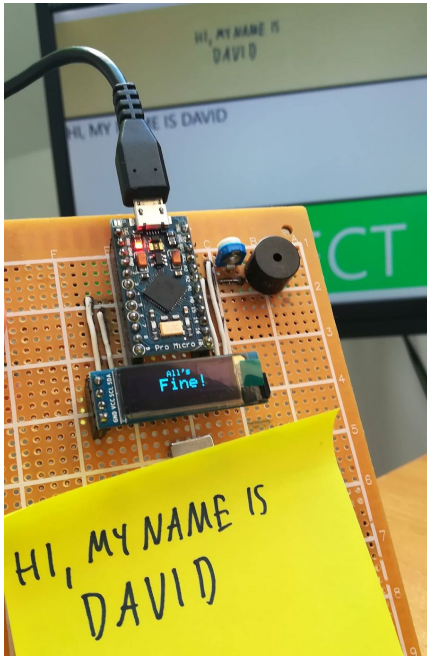
Technologies used to build the device:
- Arduino Pro Micro (clone)
- Resistive Touchscreen (from Nintendo Ds)
- Oled Display
- Additional electrical parts: potentiometer, buzzer, breadboard, cables

Importance of individual elements:

4.1.1. Arduino Pro micro

This is the heart of our device. It contains ATmega32u4 microcontroller with has additional features over it's biggest brothers, like Arduino Uno or Nano, the main one being mouse emulation, with makes our developing process easier. The microcontroller reads, processes and sends data from the resistive touchscreen to the selected device, as well as reads data from this device and interprets it. It also controls the screen, buzzer and potentiometer. Pro Micro communicates via USB using serial bus but we are planning to upgrade to Bluetooth in the future.

Source:
https://osoyoo.com/zh/2018/06/25/osoyoo-pro-micro-board/

4.1.2. Resistive touchscreen
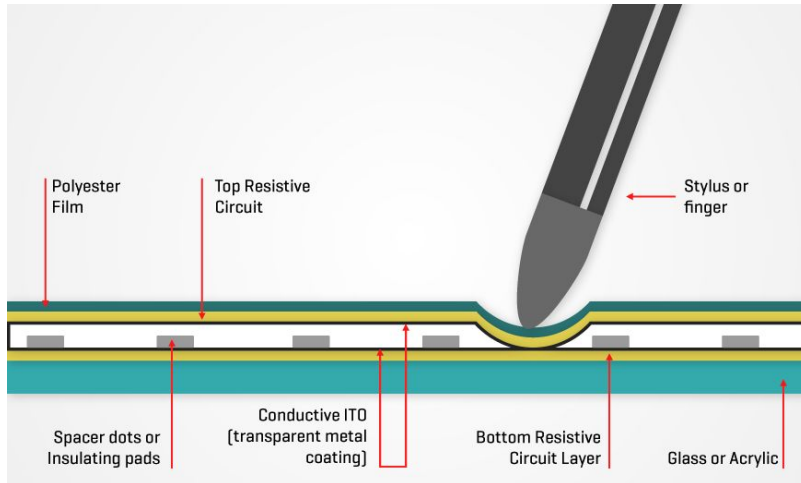
Everybody thought that the resistive touchscreens era is over with appearance of first smartphones, but we found a different purpose for it. This touchscreens are extremely precise and react to pressure on their surface. They come in very different sizes and their cost of production is extremely low. We use the touchscreen to read user's handwriting.

The screen works as resistors, Arduino can read this values and process its as a coordinates and signal when user is writing. Our individual touchscreen is acquired from Nintendo DS.

Source: https://riverdi.com/resistive-or-capacitive-what-is-the-right-touch-panel/

4.1.3. OLED display

We use display to interact with the user. It can show if there's a mistake in the notes, status of the device etc. They are widely available on the market and very cheap to acquire. They use I2C bus to communicate with microcontroller.

4.1.4. Principle of operation

We use Arduino Pro Micro (AtMega32u4 microcontroller) to communicate with external devices (PCs, laptops, tablets, smartphones) via USB using serial bus. In the future we are planning to add Bluetooth communication. Arduino sends high voltage to the resistive touchscreen and reads how much it weakened. This information is processed to coordinates, and is send to external device. External device can also send information to microcontroller. Microcontroller processes the information and display appropriate information on the screen. When device gets a message, that user has made a mistake buzzer is also activated. In our prototype there is also a potentiometer with is used for regulating touchscreen sensitivity.

4.2. Module - a software that recognizes mistakes

The prototype of the Math Module
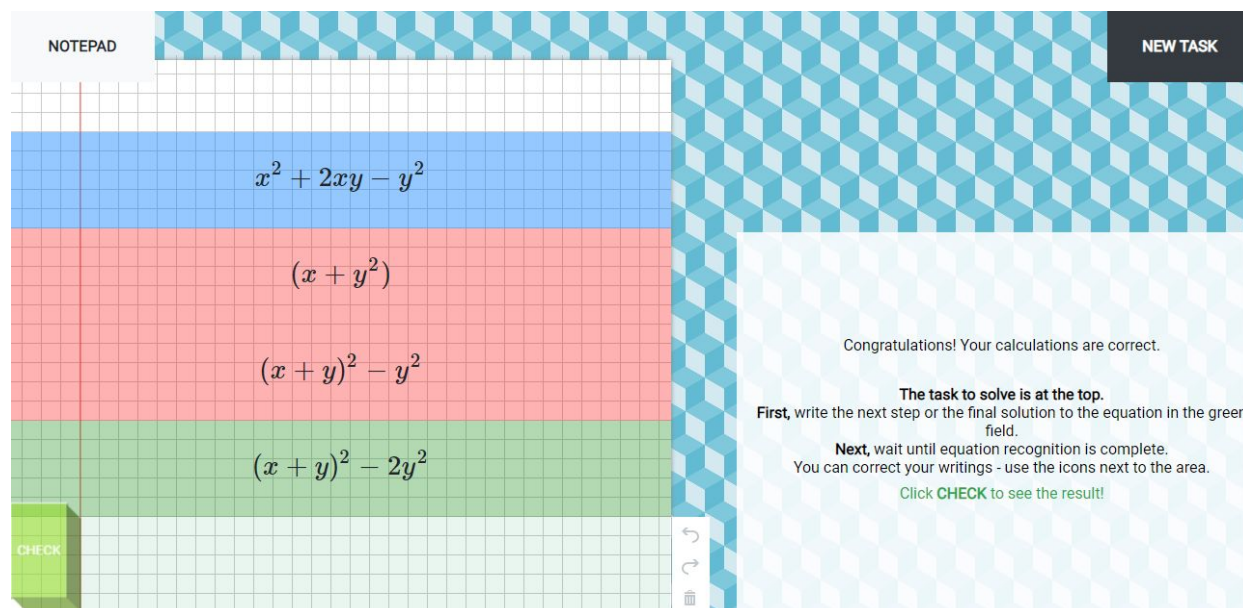
4.2.1. Architecture

Front-end	Back-end	Handwritten Text Recognition + Calculation	Azure services
HTML5, **Bootstrap** (CSS framework), **jQuery** (JavaScript framework)	**Flask** (Python web framework), **C++**	**Seshat** (HWR), C++ **latex2sympy** (parser, Python) **SymPy** (math library. Python)	Azure Virtual Machine (Ubuntu 18.04)

4.2.2 Explanation

4.2.2.1. Actuale state of the module

Currently, the math module works without the need of using an external device. It is possible to use the module directly from a computer, tablet or mobile phone.

After redirecting to the website, the first step is to save the equation that the user wants to solve, for example X^2 = x. Next, the user should type in the next step that leads to solving the equation. For example, x^2 - x = 0. The system will recognize that the equations are equivalent and it will allow the user to continue solving the problem. (x-1)x=0 will also be recognized as a correct transformation. If the user makes an error, for example, if they enter (x-1)x+1=0, they will be automatically informed, so that their error can be fixed quickly. If the user enters the correct result in a dedicated field, for example, if they indicate that x=1 and x=0 solve the equation, they will be notified appropriately. Alternatively, they will be informed about the incorrect results.

4.2.2.2. Idea for final product - connection between software and the device
After an equation is written down in a notebook, the system recognizes the category of the problem. For example, the first equation, $x^2=x$, is recognized as the problem to be solved. While the student writes down the solution to the problem in their notebooks, they can see the same equation on their smartphone or tablet. Together with consecutive transformations, eg. $x^2 - x = 0 \rightarrow (x-1)x = 0$, the correct parts are underlined with a green line. In case of an erroneous step in the solution, eg. $x-1 = -x$, the system underlines it in red and offers hints to correct it.

4.2.3. Grammar Module
Analogously, the prototype for the grammar module is currently being developed and *it will check phrases and sentences for grammar errors*. Ultimately, the character recognition system will be transferred to that offered by Microsoft Azure, i.e. Microsoft Ink Recognition. Grammar is checking through Language Tool library.
The purpose of that module is to effectively analyze sentences in the context of a given text and to accurately assign categories to math problems.

4.2.4. Factographic Module - the idea
Example of working a hint-module for phrase "Salmon is toxic".
From the front-end site, the first step would be to change the sentence order - from declarative to questioning. In English it is not particularly difficult: salmon is toxic -> is salmon toxic? There are certainly also ready-made libraries for more complicated structures - in the area of NLP.
Then we enter Google and see a view similar to the one below. We can use Google search results via API, for example Serpapi.
The key is the value of answers given by Google. At the level of user prompts - authenticity is at the level of the authenticity of Google responses. Their programmers are working on that.
As an oracle, whether something is true or false (absolutely) - this can be problematic. At most, we can build a system based on premise which, if you assign a sentence a certain value, will inform you that it is "suspicious".

4.3. Education platform

Concept of portal, which gives educational materials - based on mistakes made by user.

4.3.1. Database Architecture

The project consists of 7 main modules:

- **User module** - used to add, edit and delete users,
- **Course module** - used to add, edit and delete courses, the course can contain many lessons. The course consists of a title, description, picture (cover),
- **Lesson module** - the lesson belongs to a specific course. The lesson consists of a description and a picture (cover). The lesson can contain many tasks,
- **Task module** - each task belongs to one lesson, the task consists of a description and as many milestones and hints as possible,
- **Milestone module** - one milestone is represented by a specific mathematical formula,
- **Hint module** - a hint is a fragment of the solution and is related to the auxiliary question preceding it that helps to reach the milestone,
- **The auxiliary questions module** - auxiliary question is a question which is leads the student to the correct solution.

There are 4 types of users: **guest, student, teacher** and **administrator.**

- A **guest** is a visitor to our site, an unlogged user.
- A **student** is a user with permissions to solve tasks.
- A **teacher** is a user with permission to create, edit and delete courses, lessons and tasks.
- An **administrator** is a user with all the above rights, in addition to the ability to create, edit, block, and delete accounts of other users.

4.3.2 Explanation

The Thinkz platform let the users create tasks and courses. Thanks to which, we will be able to gather information about the content and context of notes taken by students in different countries. Furthermore, the solution can be sold not only to individual customers, but also to educational institutions - schools and universities. Most probably, the teachers at schools have their own set of problems that they wish to assign to their students. We could allow for adding the problems to Thinkz and assist the students solving the problems step by step.

4.3.3 Challenge

While creating the solution, we state research question:
How can we find the context of problems that students write down in their notebooks?

We are aware that the better the system understands the content and context of a problem, the more accurate tips it is able to provide. To make our Artificial Intelligence more intelligent and successful at categorizing different problems, we should first deliver big amounts of labelled data and utilize supervised learning for effective classification. The database will keep being updated and new problems will be continually added. In addition to the resources provided by our key partners (such as the educational platform - Brainly), we will make our own collection of problems.

4.4. Summary

4.4.1. General look
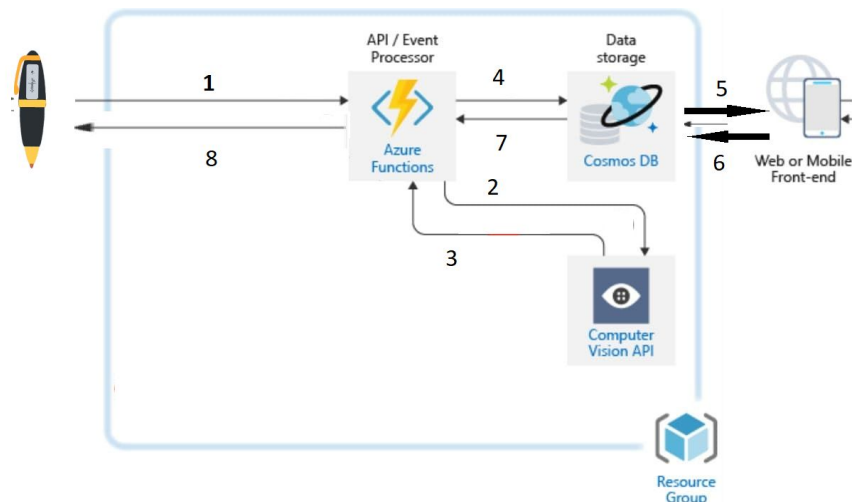
4.4.2 Challenges

The most crucial issue is to develop an artificial intelligence that is able to understand the student's handwriting and based on that, provide useful and relevant tips. Moreover, the solution should be flexible enough to let the student follow their approach to solving the problem if the approach is correct. Another challenge is to develop a tool, that will be both, effective and affordable for the potential clients.

Lastly, creating a databases of courses and problems will be a challenge in this project.

4.4.3 Innovativeness

There exist software solutions on the market that support learning by fixing grammar errors or solving math problems (Grammarly, Microsoft Math Solver). Moreover, Khan Academy, a popular educational platform, allows students to familiarize themselves with various concepts and expand their knowledge. There also exist devices, that allow to transfer notes from a notebook to a digital device in real-time (LiveScribe, etc.).

The opportunity that the team saw was found in the **synthesis of these solutions.** Retaining the advantages of creating notes in a notebook, while improving the learning process through providing continuous feedback. A student receives an electronic assistant that checks for mistakes, advises on how to learn better, and selects additional exercises from the database to help the student improve.

5. Business Aspect of Solution

5.1. Market demand

Our potential clients are students, parents and teachers. According to the data provided by the World Bank, 32,5% of all people are between 10-19 years old. That means that 2,47 billion people are now in the age where education in usually obligatory and definitely extremely important.

We consider that demand for Thinz would be similar as a demand for private tutoring. Based on The Guardian, "More than 40% of pupils in London have had a private tutor at some time, (...) typically costing £27 an hour but sometimes much more, fuelling an industry that is valued at £2bn a year, the report claims.". That creates concerns about an increase in education inequality. What's more, the same report says:

"The subjects pupils struggle most with and most frequently need extra help to understand include **maths** – which is the single most tutored subject, according to data from the private tuition agency Tutorfair – followed by **English, the sciences, Spanish and French**." - in fact, we are making solution that would minimize demanding for private tutoring. The most important thing, however, are raising inequalities:

"Predictably, children from wealthier backgrounds are the main beneficiaries of private tuition with independent school students twice as likely to have received private tuition as their state school peers, despite their parents having already paid school fees.".

Source: https://www.theguardian.com/education/2016/sep/08/sharp-rise-in-children-receiving-private-tuition

5.2. Example of persona

A high school student, from a family with a $350 monthly income per person, having difficulties with learning math (and other subjects at school, for example, English grammar).

5.2.1. Feedback

"For me, this is just the beginning of the end of the teaching profession. If the program can ask Socratic questions and if it can indicate the errors in the calculations in real time - that is huge. This is exactly what the schools today are missing. Truly awesome! Now you only need to add a robot that shows human emotions and we have something extraordinary, you don't need anything more."

5.3. Marketing

We have already started promoting our solution on social media, in cooperation with few well-known media companies in Poland, as well as a company that is assisting crowdfunding campaigns. We would like to make our project a social case, that will raise national discussion about state of education in Poland, but also in other countries. Our plan is as follow:

At the beginning, we use want to use our facilities and own resources to create a prototype of the device and innovative software - making this process public, so followers will be able to look on our development process.

In order to accelerate the development and improvement of the product, we will receive financial support from the audience - thanks for cooperation with a crowdfunding company, we are organizing the first collection - announcing that we are going to take part in AIS competition and looking for possibility to finance a participation from funds of fans of the projects. Than, after making huge audience, we will use the power of fans and prepare second crowdfunding campaign, this time for preparing final product - device with SaaS.

5.4. Financial sustainability

Thinkz will be based on a paid-subscription model with one-time purchase of device. The cost of a monthly subscription will be equal to 1 hour of private tutoring in a given country, ranging between $25-$50. Students who can't afford the solution and provide a reason will be able to gain access for free. The subscriptions will be also sold to schools, especially those that pursue the highest quality of education and where there is a shortage of teachers that can provide lessons on appropriate levels in selected subjects. Thinkz will also allow schools to cut down on costs if not enough resources are available. The device will be sold for less than $150.

5.4. Competition

The main competitors of Thinkz are popular educational platforms and technologies like smartpens and iPad. However, all of them have some disadvantages that are addressed by Thinkz. The main competitors include:

- **Khan Academy** - a very popular educational platform that doesn't offer an individual, personalized approach to the student.
- **Grammarly** - helps with correcting grammar mistakes, however, it doesn't memorize errors and doesn't offer a personalized plan with tips and exercises for improvement.
- **Microsoft Math Solver** - works similarly to Thinkz Math Module. Nevertheless, it solves the problems for the student instead of teaching them how to do it.
- **Socratic App -** provides solutions to problems in different subjects based on a provided picture. However, it offers complete solutions instead of enhancing the student's understanding and providing hints and tips that lead the student to solving the problem on their own.
- **iPad** - allows for taking digital notes, however, doesn't offer the advantages of taking analog notes.
- **LiveScribe** - Smartpen with real-time transfer to an electronic device.
  Similar to Thinkz pen, but doesn't include content analysis.
- **reMarkable** - Digital notebook.
  A much more expensive solution than our solution - costs at least $400. Similar to LiveScribe, it provides a complex solution for collecting handwritten data and reading them on a dedicated device. No content analysis.
- **Private tutoring** - the prices varies between different countries, about $50 per hour on average. One tutoring session a week in 1 subject results in about $200 per month. In 3 subjects - 600$. Much more expensive than Thinkz.

5.4. Business Model Canvas

Table 1.

Key business partners	Key activities of solution development	Offered benefits	Consumer relationships	Customer Segments
- **Brainly** (*"Brainly is the knowledge-sharing community where 150 million students and experts put their heads together to crack their toughest homework questions."*). - **Brilliant** ("*offers guided problem-solving based courses in math, science, and engineering, based on National Science Foundation research supporting active learning*", 4 mln users).	- Developing database with materials and resources that create the context for giving accurate tips. - Developing Artificial Intelligence to understand and explain the concepts that users write down in their notebooks. - Adapting Azure services for recognition of notes in different subjects (eg. Math, Physics, Biology, Grammar). - Creating the device that is accurate, easy to use and affordable. - Maintenance of the system. **Key resources** - Learning platform - Database of categorised problems - Prototype of the device - Problem category recognition - Hints, based on mistakes - Database of problems from potential clients - Social audience, which would be ready to support this project free of charge	- Saving money on private tutoring thanks to a solution that acts as a personal teacher. - Ensuring individual learning for all students in large-size classes. - Providing statistics of learning progress made by the user - visualization of work effects, acquired skills and problems solved. - Saving a significant amount of the student's time by prompt recognition of errors at all stages of solving a problem. - Keeping students focused and engaged based on Socratic questions that allow the student to find a solution on their own.	- Give the students an option to select desired modules according to their needs. - Support the most ambitious students by giving them free access to some functions, when a specific number of problems has been solved (gamification). - Promotion of parent's active engagement in the children's education. Giving the parents a chance to see the progress that their children make in learning. - Developing trust to digital technologies by mixing them with traditional learning methods(i.e. taking analog notes). **Marketing channels** - Social media. - Mailing. - Google Adverts. - Promotion in Schools - Whisper marketing through students and parents.	- Parents of students from elementary school to the last class of high school - Administration of elementary, middle and high- schools. - Students, PhD students. - Learners without institutional support. - Hobbyists.

Cost structure

- Thinkz IT system preparation costs
- Costs of maintaining the platform
  - Azure services
  - Providing a new collection of problems
- Advertisement
- Device production

Revenue streams

- Paid subscriptions for individuals.
- Access to the platform for a specified number of students in a given school.
- Ads in the free part of the platform - an open problem database with full solutions and a knowledge base.
- Device's sale.
- Recognition modules (for sale as individual modules or packages), monthly subscription

6. State in progress

Project is in the process of constant development. Changes in software and concepts are still being made. We invite you to visit our page: https://thinkz.me and fanpage: https://www.facebook.com/thinkz.me/. Furthermore, prototype of Math Module is ready for testing: https://lyon106.pythonanywhere.com/.

Thank you.