Adaptive Learning Platform

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Abstract—**The world has been changing towards more personalized solutions in different fields and education is one of the fields that is being changed. Personalized learning will help students to faster identify their difficulties and by doing that professors will be helped to and teach more efficiently. For that we created a solution that bases on text analysis in order to provide personalized learning in free-form open answers.**

Keywords— Personalized Education, Text Analysis, Web Platform, EdTech, National Exams, High School)

I. INTRODUCTION

Most of us have passed by the school system, and we know the process of studying for evaluations, and my focused for this thesis has been that process in High School, because students have tests during the 3 years, but in the end, they have the so-called National Exams. These exams grade plus the average grade of the 3 years of High School will define our college course, because each has a limited number of students accepted and has an entry average, giving priority to the student with higher average.

In order to improve the study process of the student and increase the awareness of the professors I develop a solution that aims to provide insights about the students' knowledge as we will see with further detail in next sections and more described in the dissertation, and it will be verified by analyzing current educational platforms its uniqueness.

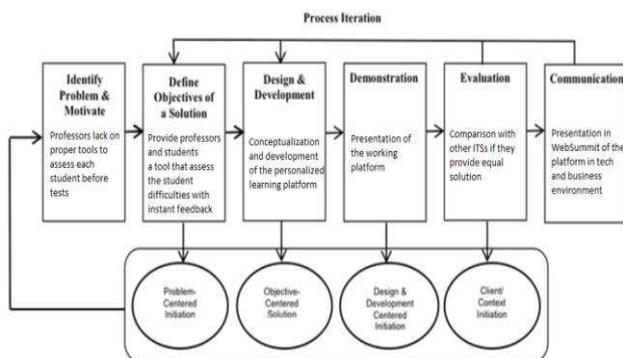For this thesis we use as research methodology the DSRM – Design Science Research Methodology.

Figure 1 – DSRM scheme

Through the DSRM there are the following steps that we have worked on:

A. Intro

Schools are having troubles with the traditional schooling system, students have more distractions than ever and self-development is a harder process for the young individual, besides the number of students in a classroom is too big for only one professor to be able to track every student difficulties, the educational sector is also becoming part of the digital transformation and the evolution is moving towards personalized education, the objective of this work is to present a solution to track student difficulties via open answers and by acquiring those we can display to the student and the professor.

B. Objective-centered Approach

The objective of this project is to provide better tools to the professors so they can assess the difficulties of each student. For this it was conducted a set of interviews in some schools and understand the existing dynamics in the schooling ecosystem starting from headmaster, professors, students and parents.

C. Problem identification and Motivation

There are too many students in a classroom for only one professor to be able to acknowledge every student difficulty, as a student passed to the same difficulty.

D. Objectives of the solution

The objectives of the solution are to provide a tool for professors to be able to validate each student difficulties, provide personalized support for students and pass that information to professors. All of this made via open answer questions.

E. Design and Development

What we propose is a platform that lets the student to write answers, free form, and notify them which mistakes they have made, if any, and by capturing those we can pass it to the professor. The part we are focused on is analyzing what the student writes as answer and its evaluation.

F. Demonstration

The platform developed showed to detect the steps missed in the answers, and providing that information to the student, being able to correlate with the associated subject

and let the platform to select more exercises to do in those subjects.

G. Evaluation

The evaluation will be based on a testing of the platform by real students in which they have a demo at school and then at home they are free to use it to solve exercises and get instant feedback, our goal here is to validate that the students get a personalized learning, so when the student is not writing the correct answer they can check where they failed and understand how to solve the exercise, the reasoning associated.

H. Communication

This project was presented in Web Summit by application and selection to the Alpha program, besides many previous events of pitching there was a possibility of presenting the project to the Portuguese Prime Minister itself.

II. PROBLEM

A. Professors lack proper tools to recognize in proper time the student difficulties

This is the problem that was identified, the 4 key elements of the schooling system, school directors, professors, students and parents have different focuses/worries.

School directors want to ensure that they have more students each year studying in their school, professors want to teach all the subjects defined by the Education ministry, students want to feel part of the community built around other colleagues and parents are only focused on the grades.

Many situations can be observed and develop solutions I decided to focus on the part between professors and students, in to provide tools able enough to help the teacher to be aware of the knowledge base of each student and overall class, so it can better manage the class to train more efficiently the student for evaluations, whether tests or national exams.

Because it is humanly impossible only one professor to track each student difficulty in a class with twenty to thirty students, professors don't have the proper tools for it.

In short, in our current times professors do not have the proper tools to track every student difficulty in a classroom, professors normally have classes with 30 students and have the obligation to teach every subject in the curricular plan so the students can do the national exams. As in older times new educational approaches were used and due to technological advancements not only the demand of new skills from future workforce but also technology has made possible to create ITS, Intelligent Tutoring System.

III. RELATED WORK

The needs of the workforce have changed and more will change, it is necessary to also adapt the education sector to better prepare the future workforce. That will mostly be achieved by personalized learning that is being more and more developed with the usage of current technology, in the industry EdTech.

A. Algorithms

Related to our project we found techniques for text analysis, so we can correct a student answer, free-form. Instead of using multiple choice it is corruptible, the student can detect the correct answer by brute force and then falsify his/her performance.

The four algorithms discovered were:

A. Expectation and Misconception Tailoring

B. Model Tracing

C. Constraint-Based Modeling

D. Bayesian Network Modeling

Our solution follows a similar pattern as the expectation and misconception tailoring in which the text analysis is based on a specific key words and its specific order.

Besides algorithms it was also research learning theories to better provide knowledge to the student, this happens due to some emails exchange between me and Mr. Alan Kay which mentioned to me a work of his friend Jerome Brunner which contributed a lot to the Educational field.

The educational technology industry has changed in the last few years, they all tend to teach a specific subject or a set of knowledge in an easier way. In terms of adaptive learning the common approach has been through multiple choice answers, but can be misleading in terms of properly evaluating. So new approaches based on text analysis algorithms can be obtained. We also provided an overview about the educational ecosystem in terms of understanding what matters the most to the key elements of the schooling ecosystem, High School Directors, Professors, Students and Parents. All this complemented with educational theories that were very fruitful for the interviews taken and thus the development of this solution.

B. EdTech Platforms

Additionally, in the following table result of a research made to the related work in the industry by the major EdTech platforms, we can see some of the key features the platforms in overall provide.

Platform Name	Videos	Assignments	Peer Grading	Instant Feedback (Quizzes)
Coursera	✓	✓	✓	✓
Lynda	✓	✓	✗	✓
Udemy	✓	✓	✓	✗
Udacity	✓	✓	✗	✓
Khan Academy	✓	✓	✗	✓
Iversity	✓	✓	✗	✗
Skillshare	✓	✓	✗	✗
edX	✓	✓	✓	✗
Alison	✓	✓	✗	✓
Open Yale Course	✓	✓	✗	✓
Knewton	✓	✓	✗	✓
Cerego	✓	✓	✗	✓
RealizeIt	✓	✓	✗	✓
Fishtree	✓	✓	✗	✓
Magoosh	✓	✓	✗	✓

Table 1 – Features Chart

Platform Name	Videos	Assignments	Peer Grading	Instant Feedback	Open Answer (free form)
Coursera	✓	✓	✓	✓	✗
Lynda	✓	✓	✗	✓	✗
Udemy	✓	✓	✓	✗	✗
Udacity	✓	✓	✗	✓	✗
Khan Academy	✓	✓	✗	✓	✗
Iversity	✓	✓	✗	✗	✗
Skillshare	✓	✓	✗	✗	✗
edX	✓	✓	✓	✗	✗
Alison	✓	✓	✗	✓	✗
Open Yale Course	✓	✓	✗	✓	✗
Knewton	✓	✓	✗	✓	✗
Cerego	✓	✓	✗	✓	✗
RealizeIt	✓	✓	✗	✓	✗
Fishtree	✓	✓	✗	✓	✗
Magoosh	✓	✓	✗	✓	✗

Table 2 – Comparison Chart

In the following table we can see an additional validation/comparison of all the platforms with the existence of the feature of Open Answer (free form) feature, it's possible to see that this is a point not yet provided and this may be mainly due to the fact that major examinations in USA, like SATs are based on multiple choice questions.

C. Learning Theories

I started doing more researching in the psychological and scientific research, after personally exchanging emails, with Mr. Alan Kay, that started in April 2017. Due to Mr. Alan Kay I started reading the works of Mr. Jerome Bruner which contribution for the education methods and processes were very interesting, the name of Jerome Brunner came due to the connection of this project with education and due

to Mr. Alan Kay and Mr. Jerome Brunner being friends and both interested in the education industry.

Bruner had different stages in relation to Theory of Education, in his early years he defended that cultural transmission was a crucial mission to schools. That is because it is more natural for the learner to acquire knowledge based on the reality that surrounds and during the growth expand the perception of reality and thus forward the knowledge.

This perspective of Jerome Brunner made me look more deeply into the subject of learning theories, and found three main perspectives: behaviorism, cognitivism and constructivism.

- Behaviorism

Behaviorism combines elements of philosophy, methodology and psychology theory. It assumes that all behaviors are either reflexes produced by a response to a certain stimulus or a consequence of that individual's history, including precisely reinforcement and punishment.

This interesting to notice because the human being can react in a methodological way, and build upon it the layer of radical way. The existence of an introspective perspective makes the person to solidify its thinking and personality, top athletes normally use a radical behaviorism they mold their thoughts around achieving a goal and training more and more for it, the same happens as well for top performing students.

- Cognitivism

This perspective retains the empirical framework of behaviorism but goes beyond behavior by explaining how human memory works to promote learning. It refers to learning as "all processes by which the sensory input is transformed, reduced, elaborated, stored, recovered and used" by the human mind[15].

Cognitive concepts of working memory have been facilitated through research and technology in the computer science, the topics more researched are cognitive load (refers to the effort being used in the working memory), information processing (change of the information in a form detectable by an observer) and media psychology (interaction of human behavior and media and technology).

- Constructivism

A philosophical viewpoint about the nature of knowledge, in which is located the theory of cognitive development created by Piaget, that focus on the nature and development of human intelligence, it defends that cognitive development is a progressive reorganization of mental process which results from biological maturation and environmental experience.

Educators that use constructivism focus more in an active learning approach in which the learner is centered in problem-based learning where real-world problems are stated and students have to develop critical thinking skills.

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These perspectives converge in the philosophy of the platform, which aims to be more than a tool for students to have better performance in college admission exams but also to help them to perceive a wider reality that provides them more freedom and lets them find their zone where talent meets hard work in a self-motivated way, instead of walking in a self-imposed path.

Due to the education become "disciplined understanding" this leads to his famous spiral curriculum and discovery learning. Spiral learning is a cognitive theory advanced by Bruner in 1960: "*We begin with the hypothesis that any subject can be taught in some intellectually honest form to any child at any stage of development*". Discovery Learning is a method of inquiry-based instruction, it defends that is best for learners to discover facts and relationships for themselves.

IV. PROPOSAL

This project as it is being approached in the thesis started to be developed some time before the thesis itself. I was in a research scholarship for a MIT Portugal project in which I learned how to develop Ruby on Rails web apps, work with SQL Server and Talend.

This technical knowledge leads me to develop a better solution, because at that time I was only thinking in providing solved answer to students but that would not be very beneficial, in terms of not fully testing if the student understood the subject or not.

Then the idea of correct the student answer came. I started to focus on National Exams, because already had seen a scalability problem in terms of doing that solution for the universities, so I decided to focus on High School, more precisely college admission exams, because they are few courses and the solutions are provided by the Education Ministry.

In the first version that I developed I was focused initially on the formula, input, processing and output, in a mathematical way, easy for the student to understand. After doing it I decided to show to high school directors, professors and students, mainly because at that time I was doing TBE (Tech Based Entrepreneurship) course and one of the points studied was customer validation very helpful and that lead me to conduct the demos at school as we will see in the Evaluation.

Our solution proposed is a platform with a text analysis feature that can evaluate a students' open answer. Providing to the students the steps which are missed or not correct and display a complete solution of that problem with focus on the reasoning necessary to solve the exercise.

The platform is developed in Ruby on Rails, and it is deployed on a Private Cloud available for the any student, available 24/7.

The implementation had four main phases, initially the front-end, define how it would look in first instance (because the goal was having a working prototype), then the back-end, design and think a bit forward what features will be need, not only about the data, but in reverse engineering perspective it was asked questions like what information is useful for the user and then what data is required to obtain that information and hosted on a Virtual Private Cloud at Digital Ocean and is published at: www.app.headexam.eu .
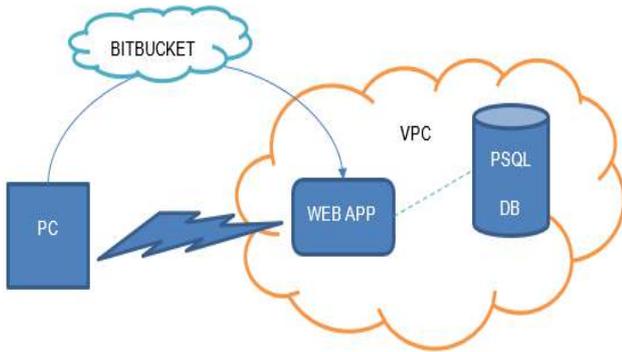
Figure 2 – Simplified platform architecture

The proposal presented is a platform that makes of a totally developed from scratch algorithm of text analysis that makes possible to track the answer provided by the student and correlate with criteria. If the student misses one step of the criteria can get that info and have a full display of the correct answer. The development followed the DSRM.
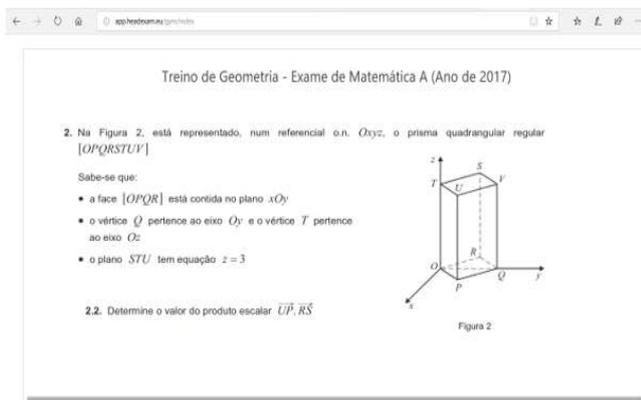

Figure 3 - Platform exercise display

Our approach towards adaptive learning is: we show an open answer question and what we do is we receive the answer and we text-analyze it, in an approach more near the EMT (Expectation and Misconception Tailoring) and Model Tracing, because we base ourselves on the criteria from the Educational ministry, but also ensure two factors the writing easiness for the user and ensuring that the student answer makes sense (each phrase inserted).

For such we develop a syntactic analysis algorithm that possesses many models of an answer making it possible to evaluate the student answer, by correlation with the criteria defined.
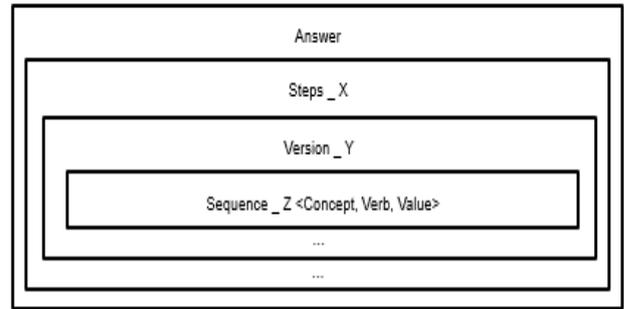

Figure 4 – Conceptual Drawing of the Algorithm

For that I created an abstraction of, Concept, Verb, Value. This let me breakdown the problem to easier pieces. The following scheme shows the logic behind this algorithm.

Each question has one or more answers. Inside the answer can have one or more steps, with a quotation associated so it is possible to grade the step as it is done in the exams.

As we can see in the following images the student receives a question just like in figure 3, and has a answer area in which it is possible to write the answer in mathematical for, through the use of latex, but this is just for better visualization, the student can write the formulas like he would do on a calculator.

Figure 5 - Answer in mathematical form

In here we can see an answer based on mathematical form and the platform is able to evaluate the student answer:
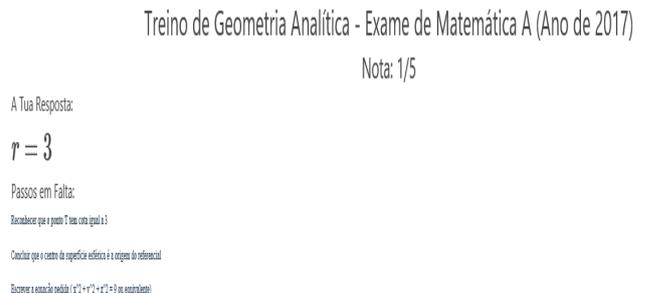

Figure 6 - Evaluation of the answer in mathematical form

In the two following image we can see the same answer but now based on a simple text form and the platform is able to evaluate the student answer too:

Figure 7 - Answer in text form

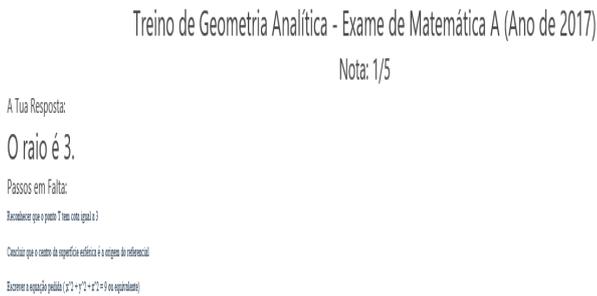And the result of the evaluation is the same:

Figure 8 - Evaluation of the answer in simple text form

In there are some limitation has we will se in the evaluation, to give a perspective, it takes in average 75 hours to insert an entire exam, but there are always answers that are correct, but not accepted, which we will see in the Future Work how to tackle this problem. So the solution presented provides, if the result is correct it is because it really is, and if it is wrong it may be possible that the answer provided by the student is right but it hasn't been added yet to the system as a possible correct answer, we will see this in detail in our tests of the platform with real students in which there were occasion in which they would insert correct answers but yet not accepted as correct. Besides due to costs and limited time available a complete exam would be impossible for me to do, so we narrow down to a prototype that we could use to conduct experiment and validate its functionality as we will se in the next chapter, Evaluation.

V. EVALUATION

In this section we do an overview of the main EdTech platforms to validate how many provide open answer questions as we compared in the related work.

We can see that there are several EdTech niches in this industry, that will be mapped, the EdTech industry and its niches, additionally we will map the location of the solution that we propose, which areas are we tackling. For that we will use an image obtained from CB Insights.

Figure 9 - EdTech Market Map

Analyze the results of the usage of the platform by students for that we conduct visits to schools interviewed high school directors, professors and students. We demo the platform at the classroom in a 15-minute presentation and let a student to solve the exercise, later on the students, at home, can access the platform register and login and attempt to do exercises.

In this 15-minute presentation, I would make some questions about the school, what do they do when they have doubts, if they ask the teacher, ask to the smartest classmate, ask their private tutor if existed or used any application or so. Then I would invite a student to test the platform by solving an exercise, without class support, by inserting the answer they would receive a result and if it was completely correct I would show the same exercise but giving a wrong answer to show the feedback of the steps missed and collect feedback from the students about if it was useful that information or not and get an overall appreciation of the platform if they would use it or not.

The tests were conducted this way because the costs of having many concurrent users wouldn't be possible for me to hold them, in average monthly have been paying 30€, having 3 users concurrently which if I had 30 students concurrently the bill would be too much for me.

As we can see in the appendix A there are 22 users registered in which 17 are valid, and they registered at home because in class was only possible to present and demo with one student the platform. From those 17, there were 9 students that used the platform at home without my support we will see in next sub chapter the results of it.

A. Validation

Before the demos at students in their mathematical class I presented the platform to high school directors and mathematics professors, and talked about the project and the goal I aim to accomplish. The feedback based on the idea was well received and there was a lot of interest shared by the professors in the idea presented, in classes I demoed the project and we are able to see in class that students would solve the exercise and may solve it wrong but due to the feedback provided by the platform they were able to pinpoint where the mistake occurred.

Furthermore we can see on appendix B exercises solved by students on their own, I mean, without my supervision,

and results are interesting, meanwhile it's good to have in mind that the number of students is little but as mentioned previously I didn't have resources to go more times to schools and financial resources to hold a classroom to solve the exercises or even an exam at the same time, but anyway despite the small number of students testing the solution it's possible to see some achievement of our goal with this project.

We see that there are students that solve the exercise at first attempt, and others that don't get it at first time but understand on the next attempt. This can be interpreted as the students recognize what is missing, the usability of the application is not so hard, at least for this set of students, and that there may exist correct answers that are corrected as wrong, see appendix B, id 7, in which it is correct the answer but the model wasn't added to the system at that time.

Meanwhile by correlating each step with a specific subject the professor can get that information as well as the student answer and prepare better classes. With this we can start a path to research furthermore about the usage of open answer questions to track the points in which the student is having troubles and by pointing to those missed or wrong steps we can provide a more efficient learning comparing to the current learning process they use currently.

B. Indicators

- How many students solved correct at first attempt the exercise?
  - From 9 valid students (appendix B, user ids: 3,9,13,14,5,15,19,18,22), 4 solve the exercise at first attempt.

- How many students solved correctly after first failed attempt?
  - There were 3 students (appendix B, user ids: 3,14 and 15), failed the exercise at first attempt but made it correct in the second attempt

- How many students retried after failing?
  - There were 5 students (appendix B, user ids: 3,14,5,15 and 22), that failed the exercise and 3 students retried, and all that retried got a correct answer, and there were 2 that didn't try more.

- How many improved results after failing?
  - Those that retried got the answer correct, 3 students in this case as showed in the previous question.

- How many valid students registered?
  - The platform has 22 users registered but only 18 are valid, the others are not valid because it's my personal account, professor, friend, and an unknown user

that hasn't been accepted to the platform (Appendix A, id: 20)

VI. CONCLUSION

We can verify that through open answer questions, as developed, there is no feature alike in current EdTech platforms, as we saw in the comparison chart. An also we can validate the usefulness of the platform in which students that failed and retried were able to get a correct answer.

Meanwhile this project had many limitations, mainly in time and budget, because to insert a complete exam would be necessary 75 hours and get an entire class to solve a test, 30 users concurrently would surpass my possible financial resources. it proved its way to start a correction model that can be useful for students and professors. Despite the limitations it was possible to see that the platform indicates student improvement, at least in a small scale.

A. Lessons Learned

- Feedback from school's ecosystem elements was positive, high school directors found it a very useful tool to manage classes, track results of students and predict grades on tests but also on exams;

- Students save time in trying to get someone to explain why they answer wrong an open answer question and how to make it properly;

- Professors found it useful too because it saves time from correcting student answers and have a better perception of what difficulties student have and thus, they can manage better classes;

- Parents also found it useful because it helps to track their children difficulties and help before tests.

- At Web Summit is was seen good feedback too from people that were parents, which had their kids at high school and found the platform useful to help students and train faster for exams;

- Also, some government entities were interested in having such platform to the public schools; additionally, investors were seeking to test it in

other countries (because this project was focused in Portugal National Exams, but the algorithm can be applied to any time of answer);

- Besides there was interest too in bringing to corporate learning trainings, so students could train easily without instructor support;

- We also learned that personalized learning is being more approached but through multiple choice and true or false questions the evaluation can be altered so the efficiency of it may be affected, in other hand with open answer in which the student has to write the reasoning it becomes more easy to understand the knowledge base of the student and guide the student properly to acquire better results;

B. Limitations

- The platform can correct answers, when it says that is right is completely right, anyway there can be false negatives, this means, the answer is right and is considered wrong. This happens because there are infinite ways to answer a problem but it is followed certain (specific) evaluation criteria even though there are possibilities to answer in a non-initially defined in first instance. In future work we tell how to solve this problem;

- The data in platform, due to having little time and few financial resources, the number of questions was small, and the number of users to test it was small, because the costs of usage can sky rocket and in average it has been costing 30€/month. Anyway, the goal of this project has been to demonstrate that it can correct student answers and that this feature doesn't exist in other EdTech platform, at least in the major platforms that we analysed.

C. Future Work

There is lots of space to grow this project, mainly making it a business but in terms of this project another thing that could be done and to make this platform more robust and solve the problem of False Negatives is to make use of ETL (Extraction, Transform and Loading) tool, so in case a student asks for review the professor can accept that answer as correct and the ETL will add that possible answer as another possible one. This will make that with time with more the students answers the platform can identify more possible ways to solve that exercise.

In terms of making a project to sell it would require the development of the professor area, high school director area, administrative area, parents' area. So, after this (that has more specific details later like handling payments, communication between users, etc…) it is possible to make it commercialized, being that my mid-term goal.

Additionally, by taking this project to Web Summit 2018, and present to Portuguese Prime Minister and Education Minister from other countries has helped validate the interest in a tool as this and personalized learning in order to create a more capable workforce for the future.

Figure 10 - Presenting the solution to the Prime Minister of Portugal at Web Summit 2018

Future work relies on adding Big Data algorithms and Natural Language algorithms to generate more options (answers) to wider the possibilities, because the platform may have in current version false incorrect answers, which can be solved with this part.

to accept this project as my thesis, a student self-proposing his thesis has its own risks, but Professor Carlos Mendes accepted and made this possible. Thank you, Professor.

Additionally I would like to thank several people that directly or indirectly supported me in this project, but directly with no doubt had an impact in me, this was only possible because of all the social interactions I have had during this years and all of those made me who I am. Firstly Professor João Miguel Sanches, the first Professor from IST that I worked with and it all started in 2010 after a Summer Internship of Ciência Viva invited me to keep learning Python and Java and discover more about MSc and PhD research in Sleep e-Diary. Also I would like to express my appreciation to Professor Teresa Vazão for being my first research scholarship supervisor in my 2nd year of college, taking trust in me and making possible to visit high schools and talk with students, experience that later on for this project would be very fruitful when I was going to visits schools and talking with High School Directors, Professors, Students and Parents, all by my own. I want to thank Pooja Ganatra a student from Gujarat India that I met through developing some projects with Leap Motion and provided me a huge shift in my way of being because we (European students) take too much things for granted like water, electricity, wi-fi and don't enjoy many times the process and that influences us too feel like we don't know/we don't have much, but in reality we are very rich, so being humble and always help others is very important, शुक्रिया.

Another very important moment was my second research scholarship thank you Diogo Frazão for talking with me about that MIT Portugal project, Casa Energia, that I fortunately could be part of, such a brilliant team I never felt like working but truly learning, learning by doing from people experienced and willing to share knowledge, thank you Henrique Pombeiro and Miguel Carvalho.

Also, very important persons to me have been Otoniel since High School always supporting me when most needed, Kelechi also like Pooja made me keep in mind the gratitude it is necessary to have for all the simple things we may take for granted like health system, water, no war, we must stress ourselves to daily become better even if it hurts a bit but it is easier to do it here with the conditions we have here, also a great friend from college that made part of the group going to Web Summit has been Fábio Gomes, giving fruitful opinions about certain things that could be tuned in order to perform well at Web Summit, thank you Kelechi and Fábio for being so professional and working so hard to make Web Summit the success it was.

Thanks to StartUs Magazine to accept me as writer to talk about entrepreneurial ecosystem in Lisbon, being able during 2016 to interview CEOs, Investors and Incubators, such experience made me more prepared for Web Summit. And thanks to Mr. Alan Kay who shared his time and attention to reply to some emails exchanged about education, technology and very insightful work of Mr. Jerome Brunner.

Finally, an appreciation to my relatives Anita for being such a creative human being and João for talking with me also about school, those insights extended my perception and tuned me better during school interviews. Last, but not least, my parents that are very hard to satisfy thank you for paying for my education I think I nailed so far, now it is time to make money and pay you all the effort you both took with me.

Thank you everyone, you made me.

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