# EME32 Bètadidactic design - Schools of the Future: Mozambique

# Design draft

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# Table of contents

# Introduction

In this design draft the

# Analysis

**Wishes of the client**

Our client is Engineers Without Borders (EWB). EWB is a non-profit organisation that has the goal to promote, teach and implement sustainable technical solutions in developing countries to enhance the local quality of life (*About Engineers Without Borders*, n.d.). The EWB project we will contribute to, is called “Schools of the Future: Mozambique”. The aim of this project is to empower teenagers in Mozambique through technical education and entrepreneurship (*Schools of the Future—Mozambique*, 2019). The goals of this project are to spark interest in science and technology and to give teenagers fundamental knowledge about technical and societal development. The long term objective is to inspire and facilitate students to undertake a higher education path in a technical area, and inspire students to put to practice the knowledge they obtained to improve the wellbeing of the local community.

The client would like to realise these goals by means of a hands-on workshop accompanied by teaching of the underlying theory. EWB has executed two of these workshops before in Mozambique, starting in 2017. The first workshop was focussed around building solar powered toy cars. The students learned about cog-wheel systems, and were introduced to the fundamentals of electrical circuits, batteries, motors and solar cells (*Schools of the Future—Mozambique*, 2019). In 2019 EWB built small electrical piano’s, calculators and radios with the students. Both iterations of the workshop were executed by EWB engineers. In the future they want to include students from *Eduardo Mondlane University* (Maputo). To be sustainable in future iterations of the workshop these university students should be able to execute the workshop by themselves.

Our objective is to design a new workshop for this project, which should be able to be executed by the Eduardo Mondlane University students. The workshop should be aimed at Mozambican teenagers of 14 to 16 years old, who are attending the $10^{th}$ grade. The client restricts the subject of the workshop to be electrotechnics. The workshop should be hands-on and accompanied with explanation and exercises about the theory related to the hands-on part. Ideally the budget per student should be less than 15 euro, to keep the project sustainable in the future. The workshop will consist of multiple modules. The modules in a workshop should not require any foreknowledge about electrotechnics. The exact learning goals of the workshop is for us to determine. According to the client, is not required that the workshop has to fit into the Mozambican high school curriculum.

The most important requirement from the client is that the workshop should be modular. Meaning, that the individual modules should be able to be taught independently. In Mozambique the absence rate of students is high, so a student who misses one or more of the modules should be able to join other modules without a problem. Therefore, the individual modules should not require any pre-knowledge obtained in any of the other modules. Preferable the level of the modules should also be able to be adapted to the student needs. When the module would prove to be too difficult in practice, the level should be able to be reduced. On the other hand, when the module would prove to be too easy for some students, more in depth material should be available. The exact time available for the

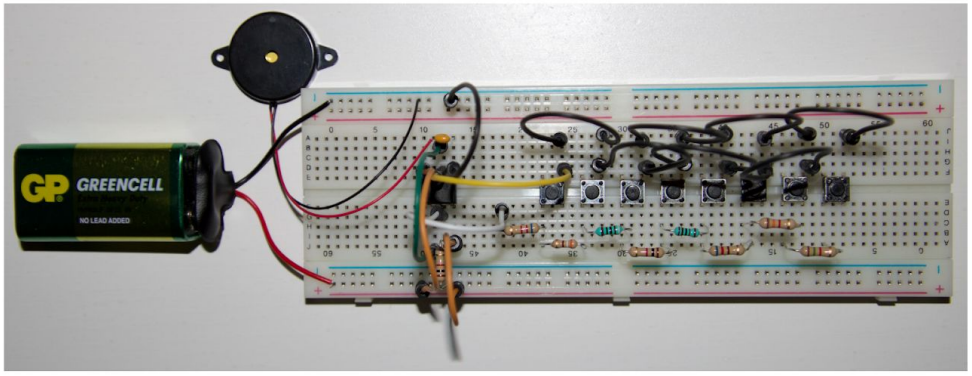
workshop is not exactly known, but the estimation is given that the workshop is held over three to four days (not necessarily consecutive), for two to three hours each day.

The workshop has to be accompanied by a teaching manual. This manual should include a list of all required materials that are available in Mozambique (or can be imported). The manual should be complete enough, that the university students (without teaching experience) should be able to execute the workshop by themselves.

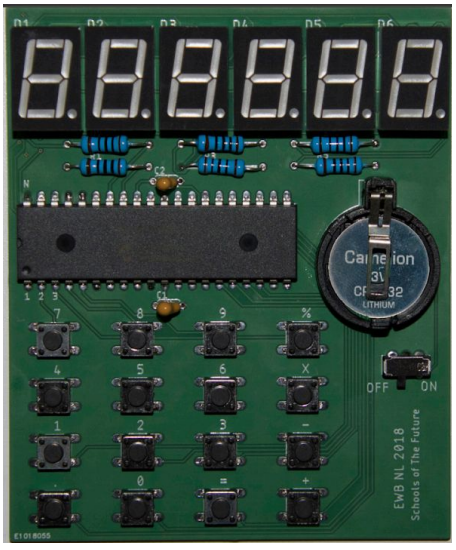
**Source Materials**

EWB has carried out multiple workshops which aim to spark interest in the technical field and motivate students to use the new knowledge to improve the wellbeing in their local community. In one such workshop they taught the Mozambican students using several different modules. Examples of these modules are shown below (Grassi et al., 2019).

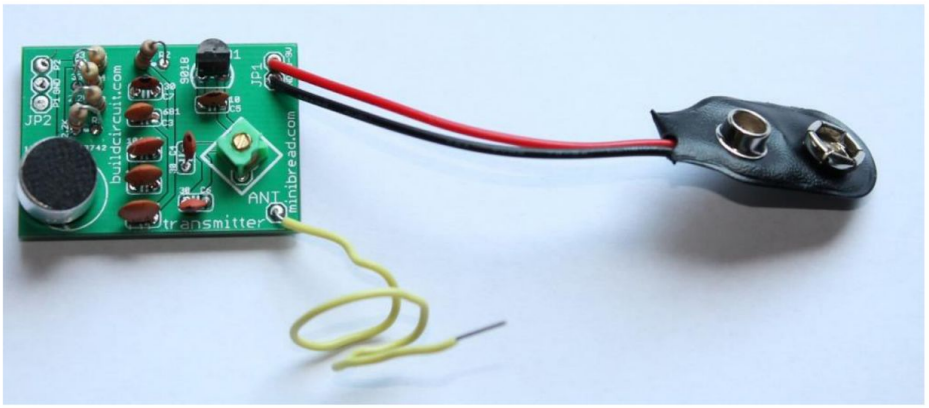
*Piano*




*Calculator*




*Radio Transmitter*




The modules are based on simple electronic components (breadboards, resistors, wires, switches, capacitors, batteries, etc.). These electronics were imported by the organization, where a toolkit (the purchase of electronic components per student) was set at 30 euros. This was done because the school does not have any materials that can be used for a workshop. In this project, a toolkit expense of 15 euros is aimed for. To be able to have multiple modules in one workshop - where the modules tackle different kinds of learning goals - the components should be reusable. Therefore, it is recommended for the modules to be based on breadboards (as is used in the piano module). Also, in this way, the modules can be executed in the next few years. However, because components get missing over time in the school, this is not the main reason why reusable components are used.

The modules which have been executed in Maputo, also have been evaluated. In this evaluation, the radio transmitter had relevant concepts which are nicely explained in this module. However, it turned out to be a too expensive toolkit. The calculator also had some drawbacks. Here, the soldering of the components took a lot of time. Because soldering was no learning goal, this time was considered wasted. In our modules therefore, no soldering should be required to build an electrical circuit. The piano was, according to the executors, a success. It captured the attention of the students. In all modules, there were exercises attached which the students had to make. These exercises helped with the theoretical parts of the modules and also helped the students learn a concept. Because in this project the modules will not be connected to their curriculum directly, it is important that we also make suitable exercises.

Before students could join the workshop, a selection was made by having all students make a test which evaluated their prior knowledge and motivation. Only students that were interested in electrical engineering, and had some kind of prior knowledge could join these workshops, as there was a lack of materials and teachers. This test could be reused in our project to also select a group of students for our workshop.

**Audience Analysis**

In this section we will describe the target audience for our project. We chose to split this analysis up in three parts: The macro, meso and micro level. The macro level describes briefly the living and education standard in Mozambique. The meso level describes the school and the students that are selected for the workshop. Finally, the micro level describes the daily life of the students.

*Macro*

The “Schools of the Future – Mozambique” project targets teenagers in developing communities in Mozambique. The official spoken language in schools is Portuguese, although many other languages are spoken, so proficiency in Portuguese should not be expected (UNICEF Mozambique, 2016).

Mozambique is one of the poorest countries in the world, ranking 180 out of 189 countries on the Human Development Index from the United Nations Development Programme (United Nations Development Programme, 2019). The life expectancy in Mozambique is just 60 years old and on average the inhabitants only attended school for 3.5 years. Enrolment rate in the first cycle of high school (grade 8 to 10) is only 49% (Republic of Mozambique Ministry of Education, 2012).

So the level of education is low and only basic literacy can be expected. This means that in our project we should only include simple language, and enhance communication via diagrams and/or figures.

*Meso*

In the first iteration of the project EWB targeted multiple schools in Mozambique to execute workshops. In the last iteration (2019) the workshop was executed on one school, São Joaquim high school, in the Munhuana district in the suburbs of Maputo.

From contact with University students in Maputo, we understood that school is not always well structured. The times of day that lessons are being held, might differ from day to day. It’s also not certain if the school will be open every day.

The previous workshop started with an admission test on basic arithmetic, fractions, logic, electronic circuits and motivation for students in the 10th grade (age 14 to 16). 163 out of 196 students scored less than 50%. The test helped selecting students for the workshop, so that the student had a basic knowledge of mathematics and electromagnetism concepts, interest in the workshop and willingness to follow an engineering professional path. From the 196 students, 36 students were selected to partake in the workshop.

So we can assume that the students that are selected for the workshop have a basic understanding of physics and mathematical concepts. Furthermore, the students that follow the workshop have some motivation for science, technologie and the workshop themselves.

*Micro*

Unfortunately we don’t know much about the daily life of students. They don’t use much technology in their daily life, but most of them have (basic) cell phones, but no internet. Some high school students have a computer at home on which they play video games,

again mostly without internet access. In their free time a lot of them play football, we don't know about other hobbies or how they spend the time on a normal day.

**Foreknowledge**

To obtain an understanding of the foreknowledge of high school students in Mozambique we analyse the demographics, the structure of the educational system and the degree of informal education. The demographics will show statistics about literacy and numeracy. The analysis of the education system shows how students learn. The informal education can show what students learn outside of the school.

*Demographics & Educational system*

The educational system is divided into Primary (age 6-13), High school (age 14-16), and Secondary school (age 17-18). The ages can be (much) older, high school (our target group) may even include up to 20 year olds (*Mozambique Education System*, n.d.).

Although 100% of the appropriate age groups of the population are enrolled at schools, only about 50% actually take primary education. Education is mandatory until age 12, but school fees are a burden; about 38% live on less than 1 USD per day (U.S. Department of Labor, 2006). An even lesser percentage completes high school, as most want to start working around age 14.

Female-male is quite unbalanced, most females enter primary education, but in the levels thereafter the relation female/male is more and more unbalanced (more males than females) (*U.S. Agency for International Development*, 2016). More than half of females drop out by the fifth grade, only 11 percent continue on to study at the secondary level, and just 1 percent continue on to college.

In order to have an indication on the level of students, we can look at the (*Education in Mozambique—SACMEQ*, 2009) document. In this the reading and mathematics levels are described. Grade 6 students mostly have a reading achievement of "Reading for meaning" / "interpretative meaning", but more interesting for us is the mathematics level: of grade 6 students, only 45.3% is at the "beginning numeracy" level, and 13.2% is at "Competent numeracy". In order to understand this, let us quote the definition of these levels:

- Math Level 4: Beginning Numeracy: Translates verbal or graphic information into simple arithmetic problems. Uses multiple different arithmetic operations (in the correct order) on whole numbers, fractions, and/or decimals.
- Math Level 5: Competent Numeracy: Translates verbal; graphic; or tabular information into an arithmetic form in order to solve a given problem. Solves multiple-operation problems (using the correct order of arithmetic operations) *involving everyday units of measurement and/or whole and mixed numbers. Converts basic measurement units from one level of measurement to another (for example metres to centimetres).*

Thus, the *slanted* part is the part on which a significant part is not proficient.

Mozambique's overall literacy rate is 47 percent; male and female literacies are 60 and 28 percent respectively (*U.S. Agency for International Development*, 2016).

*Informal education*

There is no reliable information available on informal education in Mozambique.

*Conclusion*

The found data is about 15 years outdated, but we have not found any indications of significant changes. Thus, we can expect that solving a linear equation is about the most difficult operation we can let them do. As such, we should focus mainly on having clear tasks, using simple language, showing many pictograms and pictures, and making rather simple exercises.

**Relation to developments in interdisciplinary education**

The subject of the workshop is electronics, which can be covered by STEAM education. While the focus of STEAM tends to include the use of arts, the workshop lends itself especially well to work out the factors of Science, Technology, Engineering and Mathematics (Riley, n.d.). The goal of EWB is to attain better understanding of STEAM in Mozambique, and improve the overall wellbeing through engineering. However, the focus of STEAM is on online and computerized learning, which might not be possible in Mozambique.

Besides the idea of STEAM education, there are several organisations that are interesting to look at when designing the content for the Mozambican students. We might learn something from the following organisations: JET-NET, MUVA Mexe and the National institute for Education Development.

JET-NET is an organisation focussing on making students more aware of technology, and letting them choose for a further education in a technical setting (*Jet-Net & TechNet*, n.d.). JET-NET does this by bringing together students and teachers with companies in the technological sector. Through workshops, lectures and projects they try to activate youth to obtain an understanding and love for technology. Jet-Net is a community that wants to give the beta technical discipline a realistic and positive image among the dutch students. Maybe that is what the students in Mozambique need as well. Most of these students do not even have a realistic and complete idea of what technology can achieve. Before they can be interested in technology, this picture should be complete.

The use of an overarching technology medium for the students and teachers to structure lesson material was tried by MUVA Mexe. This organisation did a pilot to introduce a mesh network (local intranet) in a public school, which acted as a basic platform for teachers to upload educational content and for students to access this content ('MUVA Mexe', n.d.). One main point they found was that students are very developed in the use of technology, which

was not expected. The pilot showed technical possibility, however, it requires more development for larger scale publication.

In 2010 the National institute for Education Development (NIED) researched the introduction of a mandatory ICT subject in the last three grades of secondary school in Mozambique. Before introduction they did a pilot to see how many public schools had access to computers and how teachers and students used them (Matavele & Camcundimo, 2009). The results showed that most of the schools had little to no computers available for their students; one rural school only had 1 computer for 400 students available. However, the pilot also showed that teachers and students were very happy to use computers. Teachers mainly said that it costs less time to write tests in Word, instead of on the board, and that the calculation of marks in excel is very fast. Students noted that learning English and learning how to write words got easier with the use of Word's dictionary. This research shows that on the national level, developments are taking place for improving education transcending the division of courses.

**Involved persons and parties and their roles**

Our project is in coöperation with Engineers without borders, an organisation which provides workshops and projects for bettering communities in Africa. We will provide a workshop to a high school in the capital of Mozambique. We are communicating with Bernice d' Anjou, who is working with EWB. She is the spokesperson for contact with EWB. From the side of Mozambique, we had contact with students from the Eduardo Mondlane University, who will be giving the workshop for 14-16 year old students of the São Joaquim high school with the help of volunteers of EWB. The goal of the project is that the university students will be able to give the workshop independently, such that EWB can focus on new projects. Therefore, the opinion of the university students about the workshop will be very important. The project must fit within the vision of EWB, which will be checked by Bernice. Her role in this project will be to make the vision of EWB resound in our project. The project should also be within the teaching abilities of the university students, and the learning abilities of the high school students of 14-16 years old, which will be checked by talking to the university students. Our role will be to combine the knowledge of EWB, the university students and our own knowledge about didactics into a well rounded workshop that can be delivered to the group of high school students without problems.

**Wishes of the students**

As the high school students in Mozambique rarely or do not have access to computers and the internet, communication with this group will be all but impossible. Therefore we got in contact with the university students who will be giving the workshop. Here, we asked several questions about the daily life of the high school students, what motivates these students, what is their level of education and what do the university students need to be able to efficiently deliver our workshop. Also, we asked in what time schedule the university students would like to deliver the workshop so that our workshop is aligned with their wishes. Furthermore, the wishes of the students are taken into account by knowing what motivate these kids and what it is in science that inspires them or would be fun for them.

**Rationale**

As many efforts are made to improve the wellbeing of the citizens of Mozambique by the local government, local and international organisations, knowledge to adapt and use these improvements is needed (Matavele & Camcundimo, 2009),(*Schools of the Future—Mozambique*, 2019). As has been said many times, “The youth is the future”, thus, students of high schools in Mozambique should be educated to tackle the societal and technical problems in their communities. We think this can best be done by sparking interest in technology and science, in the hope that these students will choose to pursue higher education in these fields. Thus, during our workshop the students should be inspired to tackle problems and improve their community. They should learn about the possibilities technology and science can bring to improve the wellbeing of people. The workshop should activate students to continue learning by applying for higher education.

**Summary using the curricular spiderweb**

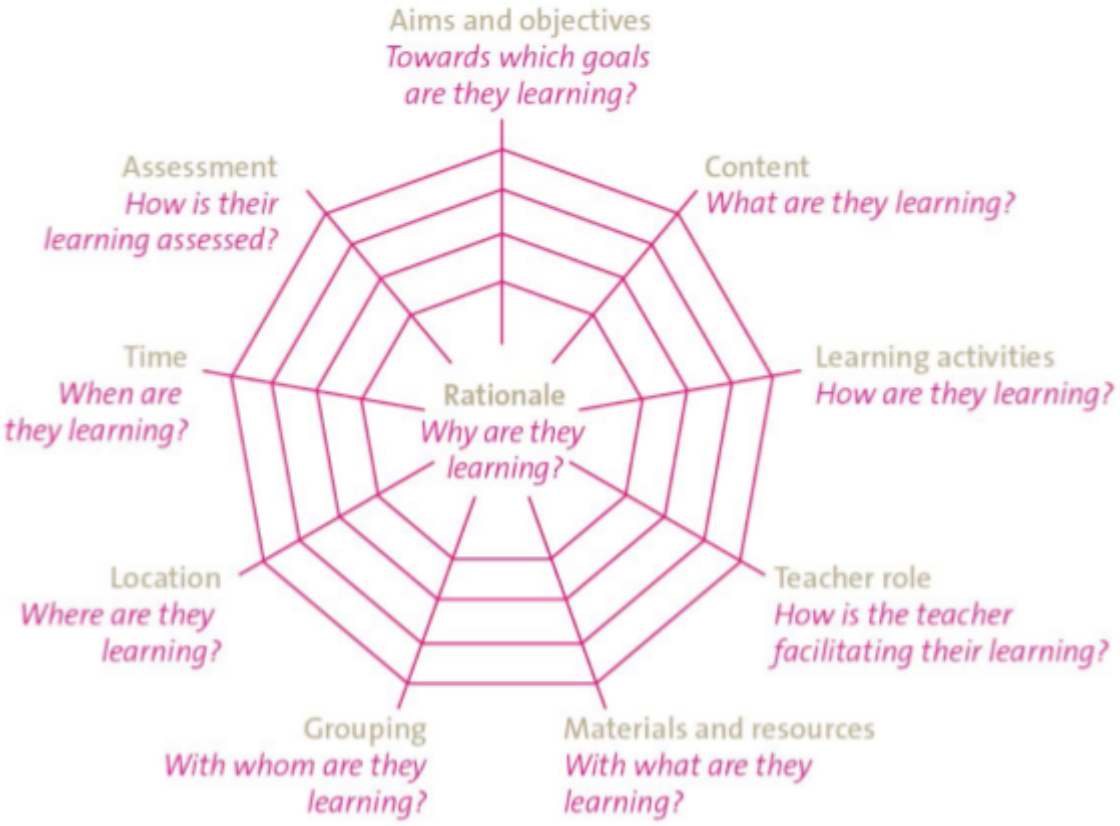



*Figure 1: Curricular spiderweb (*Van den Akker, J. 2004*)*

**Rationale:** Inspire to learn about technology and science, tackle community issues, inspire to pursue higher education.

**Aims and objectives:** The learning objective will be different for each module in the workshop. The modules can be teached independently from each other, so no foreknowledge of other modules is needed in order to participate in a module.

**Content:** The lessons will be focussed on electrical technology.

**Learning activities:** Modular workshop consisting of hands on experiments, theoretical explanation and exercises.

**Teacher role:** Students of the Eduardo Mondlane University will be guiding the workshop to the high school students. They need to guide the high school students actively throughout the whole workshop since these students have extremely little foreknowledge.

**Materials and resources:** The school does not have any materials that can be used in the workshop. So everything has to be ordered while staying within a price range of 15 euros per student.

**Grouping:** The students with the highest educational level and motivation for technology are chosen to participate in the workshop. These students will largely be in the age range from 14 to 16 years old, but may be older.

**Location:** The workshop will be given at the São Joaquim high school. No technical equipment can be expected to be provided by the school.

**Time:** The workshop will be divided in different modules, in which the modules will vary in length, difficulty and learning goals.

**Assessment:** The results of the workshop will not be formally assessed, but the workshop executors will analyse if the learning objectives are achieved. There is a possibility to show the results on a science fair.

# Design Choices

**Challenges (curriculum issues) to which this product will pay attention**

In this project, the challenging part will be having the students learn from a practical base. Because the students are only used to theoretical knowledge and have no experience with practicals, they will have to be supervised during the workshop. How to (efficiently) work in groups and understanding the materials they work with (e.g. different components in an electrical circuit) will be two aspects of the workshop in which the university students, which will teach the workshop, will have to guide the high school students. In these aspects, we can help the students by making our workshop clear for them without interference. In this, we can use texts and images to transfer our learning goals and the workshop itself to them. Learning goals have to be explicit in each module, so the university students also know what should be learned by the high school students in each module. Also, the concepts can be made clear by letting the high school students work on small exercises before they work with the actual materials. These exercises can have the form of multiple choice questions, or discussions about certain concepts within the group or within the class.

The most important goal in this project is sparking interest in (electrical) engineering for the pupils. Therefore, “motivation for bèta” is a concept which we will pay attention to.The concept “irrelevance” can be easily linked to this. In the workshop we will link everyday activities to the practical work. Also, the goal of the workshop is for pupils to see how knowledge of electrical engineering can lead to beneficial things, for example: being able to work as an engineer, or to transfer this learned knowledge to other citizens. More knowledge about electrical engineering may lead to an environment in which the community is less dependent on knowledge from other countries concerning techniques and products.

**Learning objectives and connection with the existing education**

The client does not state any specific learning goals for the project. Their main goal is to spark interest for science and technology, and to motivate students to partake in technical higher education. Furthermore, the students should learn skills that should be applicable in their community. However, the high school students should learn “something” from the workshop, the only request the client has, is that the content should focus on electricity.

So, it is up to us to decide on the learning goals for the workshop. The workshop has constraints, mainly about the cost of materials and teaching competency, but also have a high degree of freedom in the design, we don’t want to pin down the learning goals too much at this stage of the design. We want to keep a broad enough scope to design a practically usable workshop that fulfils the request from the client. Therefore, in this section we will outline the general ideas we want to keep in mind for deciding on the learning goals, instead of concrete learning goals.

Firstly, we want to focus on providing the students with learning opportunities for skills that will be useful in their daily life, further education and work. Some important skills are outlined

in the 21st century skills. The 21st century skills are a set of skills/competencies that are deemed important to function in the rapidly developing 21st century society. There have been many studies about what skills should be included in this set. We adhere to the model outlined by the SLO (Thijs et al., 2014). A brief overview of the skills included in Appendix A.

While some of these skills are mostly aimed at developed countries, especially the technological literacy skill, we still believe these are useful skills in developing countries. Particularly important are the communication, collaboration, and technological literacy skills in our design.

In our workshop we want the students to present what they have learned. Therefore *communication* is an important goal for our project. We will reserve time in our workshop for preparing the students to give these presentations. Communication and presenting is an important skill that is useful in higher education and in the workplace.

Another skill that takes a central role in our design is *collaboration*. Due to restricted resources it is more efficient to have students collaborate in small groups. This makes it possible to share resources (toolkits) between multiple students. The students mainly get taught in a plenary setting. Therefore, they are probably not used to collaborating with other students. We have to keep this in mind while designing the workshop, and in particular the learning goals.

*The technological literacy skill* are a combination of basic ICT skills (knowledge about concepts and functions of computers and networks; being able to use office applications; using mobile devices and the internet), Computational thinking (thinking processes focused on problem-solving; data collection, analyses and representations; using ICT techniques and tools to solve problems), Media literacy (skills and mentality necessary to consciously, critically and actively use media), and information skills (being able to signal and analyse the need for information; being able to search, select, process and use relevant information). Most of these skills are not directly applicable in Mozambique, as access to a computer or internet is rare. But we strive to include a more basic variant of technological literacy: The workshop should help students to realise the application of, and use technology in their daily life.

The client does not require the subject of the workshop to relate to the local curriculum of Mozambique. However, we, as designers, think it is still important to take the curriculum into account. If the workshop relate to the curriculum, students might be more motivated in the subjects taught in school. Following the curriculum also can help in facilitating students to partake in higher technical education, as they might have a smoother transition from high school to university.

Unfortunately, we could only access the physics curriculum. In Appendix B an overview of this curriculum can be found (INDE/MINED – Moçambique, 2010).

As the subject of the workshops should be electronics, we are particularly interested in the “electrical current” unit of grade 10, especially since grade 10 is the target audience. In this unit the students learn about electric charge and current, Ohm’s Law and the Joule-Lenz

law. Ideally these subjects should be covered in a practical way in the workshop. The curriculum also provides “recommended experiences”, for the electronic current (and electromagnetism) these are as follows:

- Installation of a simple electric circuit
- Creating a lemon battery
- Creating a salt battery
- Verification of the behaviour of U and I in an association of series and parallel resistors.
- The electromagnet (for example, rolling a nail through conductor wire and connecting the wire to the terminals of a pile, then bringing pieces of iron together, it is observed that the pieces of iron are attracted by the nail wrapped in the wire. The magnetic properties are not only of the permanent magnets).

Note that these are recommended experiences. Due to lack of resources many schools in Mozambique can probably not afford to provide these “experiences”. Therefore it might be a good idea to encompass at least some of these experiences/learning goals in our design. We want to give the students the opportunity to obtain practical experience with these concepts.

Like previous workshops executed by EWB (Grassi et al., 2019), we want to conclude the workshop with a science fair, where students can show what they learned and made to others in their school. In the report about last year EWB stated the success of these science fairs. In particular it highlighted that the motivation for technical subjects of students that did not partake in the workshop increased. The report also stated that the students had some problems with presenting their work, as they were not used to giving oral presentations

As we don’t have access to the curriculum of other subjects in Mozambique, integration of multiple subjects is difficult. There is some natural integration between physics and mathematics, for example working with formulas. Integration with other subjects is harder, as we don’t know the contents of the curriculum for other subjects. Also, the requested focus on electronics in combination with limited resources makes it difficult to include other subjects in the workshop. Although the report of the workshop of last year EWB stated that the organisation wants to include other subjects, such as Civil, Mechanical or Chemical Engineering, our client specifically asked for workshop focused on electronics.

**Strategy to consider foreknowledge**

Describe how you plan to keep your lesson series into account students' views on the subject. Leverage this knowledge both from literature and from practice.

In this workshop, we will take into account the rather low numeracy and literacy of students by using simple texts and many pictures in our workshop (see section foreknowledge). High school students have little foreknowledge or practical experience with science subjects and therefore, the theory will be taught at a slow pace. This will be done by dividing the workshop in different modules of various lengths, so each module can cover a part of the theory.

Since the students have little foreknowledge, we will encourage them to actively engage with the subject by giving them problems or concepts to think about before they participate in the workshop. These concepts and problems will be discussed at the start of the workshop and will serve as an icebreaker as well as activating their foreknowledge.

**Diversity**

The main three diversities our student population will have is in sex (male/female), level and opportunity (i.e. not all students will be present at all times).

Sex: we can expect that there will be a small minority of females in the workshop. It would be good if we can either keep our workshop sex-neutral or female-positive. Most probably we will opt for the former, as our descriptions and assignments will focus on the objects we will be making. We are aware that certain assignments might be more interesting to males in general, but it is hard to predict for us or to take that into account. As such, we will essentially ignore this issue.

Diversity in level and opportunity: this will be an issue in the design. We plan to make the workshop in separate modules, where not all modules need to be done by all students. As such, more capable/more present students may be able to work faster and do more modules.

The motivation of the students in beta education is taken into account by taking a test among these students. The students with the highest motivation for and level in technology are chosen to participate in the workshop (Grassi et al., 2019). As such, we can expect only students with a high level of motivation to participate.

In order to diversify our didactical approach to various types of students, we may use the


*Figure 2: Bèta-Techmentality diagram showing the five different student types*

Bèta&TechMentality-model (*Bèta&TechMentality*, n.d.). This model distinguishes in various types, as indicated in the below (dutch) picture.

We will elaborate on the five different student types:

*The renewer ("De Vernieuwer")*

- Like to work with technology
- Confident in their abilities
- Positive associations with technology

*The applyer in society ("De Maatschappelijke Toepasser")*

- Do not have affinity with technology
- Associate technology with difficult, unattractive (dirty hands)
- most choose careers in caretaking, culture, economics etc.
- A few fit well with technology, since it plays an important role in their main field of interest.

*The Do-er ("De Doener")*

- Doers are practically inclined
- Like to work with their hands.
- Dislike theory

*The Discoverer ("De Ontdekker")*

- Searching for what they like
- Might be technology, might be something else.
- May be uncertain about their own capabilities w.r.t. technology.

*The Creative Makers("De Creatieve Maker")*

- Like to work with technology, positive associations.
- Strong intrinsic motivation w.r.t. technology
- Like to be challenged.

The percentages from the picture are from the Dutch demographic, so it may not apply to our group. However, since we will get selected (motivated) students in the workshop, they may have more inclination towards the technological subgroups. Thus, in the design of our work, we do not need to take into account the Applyer in Society.

We can expect any of the other groups, and from this we can extract a recommendation for our project. To accommodate the do-er, we should include various options for the students to work with their hands. To make sure the discoverer and creative maker are engaged, we should include parts where the students themselves are responsible for discovering the theory behind certain practical settings. As the renewer is interested in all aspects of technology equally, these will engage the practicals together with the doers and creative thinkers.

**Beta-didactic approach**

The beta-didactic approach we take for our workshop will be to stay close to the mindset of the high school students. The concepts we teach them should be meaningful to them, otherwise the knowledge will not be transferred efficiently. Therefore we will adapt the “Authentic approach” and the “Concept-context approach” to teaching. Both of these approaches are centered around the fact that learning is easier if you have a clear idea of the implications on your own life of what you learn. Learning about electronics is nice, but if we can transfer the knowledge by relating the use of electronics to simple devices each and everyone uses in their daily lives, motivation rises.

If we look at the definition of authentic approach to learning, translated from (Roelofs & Houtveen, 1999): “Authentic learning is a process of learning in which the learning person acquires meaningful insights for him or herself, starting from intrinsic motivation and building on prior knowledge. It takes place in relevant, practical and real-life contexts, in which the learning person takes a constructive and reflective role, partly by communication and interaction with peers”, we see that authentic learning builds on prior knowledge and relevant societal contexts. This is exactly what is important for us, to make the connection between what we teach and what the high school students already know from their own use of technology.

An analysis of the “Concept-context approach” shows that this form of education, where the focus lies on connecting knowledge to real life context, does not improve the learning curve in itself, but it does increase the attractiveness of the content (Bennett et al., 2007). Thus, this approach can particularly well be applied to our workshop, where the main goal is to motivate and inspire students.

The main consequence of the chosen focus on the “Authentic approach” and the “Concept-context approach” on the build-up for our product is that we should very much be aware of the world the Mozambican students live in. If we want to couple the experiences the students have during our workshop to relevant context, we have to obtain a fair understanding of what that context looks like. To obtain a clear understanding what kind of lives the Mozambican high school students have, wel held an interview with university students in Mozambique. These university students told us what kind of technology is known by the high school students: telephones, computers and simple mechanical household items are the kind of technology they know. From these we can draw some situations to use as context for teaching them electronics.

Understanding the context of the knowledge is linked to four of the points of the curricular spiderweb: the rationale, the aims and objectives, the content, and the learning activities. The rationale, aims and objectives dictate what and why we think the students should learn, and this should obviously fit within the real life of the high school students. If any of these would not fit in their world view, the students will probably not learn a lot. In the section of content and learning activities we have the freedom to design a product that both inspires the students for technology and science, but also strikes them as useful. This feeling of

usefulness will become more apparent if we design the content and learning activities to be authentic and context focussed.

**Use of ICT**

Unfortunately, the prevalence of technology on schools, including computers, mobile devices and internet access is low. According to a report analysing the use of computers in high schools in the capital of mozambique, each school does have a few computers, but the ratio of people per computer ranges between 18 and 456, with the average value being 180 (Matavele & Camcundimo, 2009). From these computers, often no or only a couple were connected to the internet. Therefore, we cannot assume that we can use computers or any ICT for this project. Even if the São Joaquim high school does have computers connected to the internet, if we keep reproducibility in mind, the workshop could ideally also be given at other locations where no such ICT infrastructure is present. Thus, we choose to design a product that is independent of ICT infrastructure.

**Activating and motivating students**

The main goal of the workshop will be to motivate the participating students for technology and science. Therefore this part of the design choices is of huge importance for the workshop. We will use three methods to activate and motivate the students.

First of all, each module will start with an ice-breaker. The goal of this is to make the modules accessible for the high school students. It can be assumed that these students do not have much knowledge of technology and science. So the first assignment they receive should be fun and easy in order to spark the first interest. If their first experience on technology and science is boring and hard, then their image of technology and science will probably never change for the better.

Also, the workshop will be practical. In the execution report of EWB (Grassi et al., 2019) It is stated that the workshop with a practical approach were more successful among the students. The students were more engaged during these workshop. They needed hands-on experience in order to understand the abstract knowledge behind the workshop.

Lastly, the beta-didactic ‘authentic’ and ‘concept-context’ approaches will be used. The workshop will consist of multiple small modules. If the students made all (or just a part) of the modules they will be able to use their experience to make a large module that results into a “product” that they can use, maybe even in their daily life. In this way the students can directly see how they can use their new retrieved knowledge and developed skills in an authentic and context centered approach.

**Teacher's Guide**

The students of the Eduardo Mondlane University will be teaching the workshop to the high school students. They should understand the setup of the workshop. The workshop consists of modules that vary in length. These modules all have different learning goal and the students will not need any foreknowledge of other modules in order to make one of the modules. While no foreknowledge is required for the students, the teachers should be well

read in the subject which they have to teach. In order to successfully teach the workshop, the foreknowledge that is relevant for the teacher should be summed up in the teacher's guide.

Next to that, the teachers should know that the students should be divided into groups. This group does not have to consist of the same students every module. The teacher's guide should inform the teachers about how many students each group should consist of and what the teachers should take into account when dividing the students.

To be able to check whether the students reached the learning objectives, the teachers need to know what these learning objectives are and how they know when these are achieved. So, there should be an explanation in the teacher's guide on the learning objectives: What do they mean? What should the teachers pay attention to? When are they achieved? A checklist for the teacher could help to tackle this problem.

Lastly, the teachers should be supported with helping the students during the workshop. The teacher is in this case a university student who does not have a lot of experience with teaching high school students. So, in order to support the teacher with this, there should be an section on 'how to guide the students in the workshop'.

**Summary of design choices**

The challenges that will be tackled in the workshop are 'motivation for beta' and 'irrelevance'. This will be done by providing a practical workshop and connect it to real life problems and situations the students may be familiar with.

The learning objectives of the workshop are the 21st century skills collaboration, communicating and technological literacy. The students will learn how to collaborate, since they will be working with other students. Their communication skills will be developed when they present the results of the workshop at the science fair. The students will learn about technology, since that will be the focus of the workshop.

The contents of the workshop will be centered around electronics. We will try to adhere the Mozambican physics curriculum when deciding on the final learning goals for each module in the workshop.

Since the students have little foreknowledge, the workshop will be divided in several modules. In this way the theory can be taught at a slow pace. Also, to take into account the foreknowledge, the students are asked to make an assignment prior to the workshop.

To accommodate different types of students, the workshop will be practical as well as theoretical. Also the students have the possibility to discover the possibilities of technology themselves.

The didactic approaches 'authentic education' and 'concept-context education' will be used to motivate the students.

# Evaluation

Evaluation of our project is difficult, as the target group is in Mozambique, and our project is planned to be used outside the scope of this course. Therefore testing on the actual target group will be practically impossible. We came up with a few alternative approaches for the evaluation using (SLO, Enschede, n.d.): Trying out the workshop on a group of students in the netherlands, letting the university students, who are going to execute the final product, analyse the workshop, letting EWB executors from previous workshops analyse our workshop, and/or evaluating our final product ourselves by using a checklist.

Ideally we want to try out our workshop on a Dutch target group, as this would give the most useful information about our workshop in actual use. EWB tests their workshops in cooperation with JINC. For previous workshops JINC selected groups consisting of grade 6 (Dutch: groep 8) pupils and VMBO (preparatory secondary vocational education) students. Our contact person at EWB would check if it was possible to arrange a similar test group for our workshop. It is unsure if this is actually possible. Due to the COVID-19 outbreak this option became even less sure.

Alternatively, we want to interview the Mozambican university students that are going to execute the workshop in a focus group setting. This will not provide as much information as actually using the workshop, but it will give insight about the usability, connection to the daily life of the students, and motivational aspects of the workshop. Note that communication with the Mozambican students is hard, because of bad internet connections, availability of the students and a language barrier, so this option is also not guaranteed to succeed.

As a backup, we also want to interview EWB executors from previous workshops, or use them in a focus group setting. They have knowledge about the environment in which the workshop will be held, and have some experience with what works and what does not. They might have useful insights about the level, practicality and motivational aspects of our workshop. At the moment of writing we don’t have confirmation if the EWB executors have time to cooperate with us.

Finally we will create a checklist with desired features for our workshop. We, the design team, will go over this checklist when the workshop are being finalised, to make sure all desired features are taken into account.

In the next section the mentioned evaluation methods will be explained in more detail.

**Assumptions and design choices to be evaluated**

In the curricular spiderweb we mainly focus on the rationale. Our main goal is to inspire students to learn about technology and science, in the hope that these students will choose to pursue higher education in these fields. Our secondary focus will be on the learning activities, since we think we can spark the most interest by using learning activities that will suit the students. Therefore, we want to evaluate if the learning activities included in the

workshop actually do motivate students. As such, we are highly interested in the experience the Mozambican students have while doing the workshop. However, as has been noted in the introduction of this section, testing our workshop in Mozambique will be nigh impossible. Thus, using a Dutch try-out, a focus group with the Mozambican University students and the executors of EWB, or a checklist, we want to check the following assumptions and design choices, which will show us if our rationale and learning activities are fitting.

The following assumptions should be evaluated:

1. A workshop based on the reality of the students will contribute to a higher interest in technology, since they can directly see how they can use there new retrieved knowledge and developed skills in their daily life.
2. All design choices are translated into the design.

The following design choices should be evaluated:

1. We want to use a modular workshop, to discriminate in level and opportunity.
2. The workshop must motivate the participating students for technology and science, while transferring knowledge comes second.

**Methods, Tools and norms to evaluate assumptions and design choices**

Each of the assumptions and design choices that are to be evaluated are sorted in one of the four categories: Relevance, Consistency, Usability and Effectiveness. In these sections the methods, tools and norms to evaluate the assumptions and design choices are given. When multiple methods are used to evaluate a single assumption, a table will be presented.

*Relevance*

The first assumption that should be evaluated: “A workshop based on the reality of the students will contribute to a higher interest in technology, since they can directly see how they can use there new retrieved knowledge and developed skills in their daily life.” tells us about the relevance and effectiveness of this workshop. For this assumption to evaluate to true, the first part of the assumption (the pre-condition) should evaluate to true. Therefore in this section we will evaluate if the workshop is relevant. Later we will evaluate if the students interest in science and technology is increased, which is also captured in the second design choice (effectiveness). If the workshop is both relevant and effective, the first assumption evaluates to true.

**Desired:** The students see a link between the workshop and their reality, and thus the relevance of the workshop.

**Methods & tools:**

| **Method** | **Tool** |
|---|---|

| | |
|---|---|
| **Try-out or micro-evaluation with Dutch students** | Survey taken by the Dutch students.<br>Question: Can you link the knowledge and practical skills retrieved from the workshop to something in your daily life? |
| **Focus group with University students** | Interview with the university students.<br>Question: On a scale from 1 to 10, how relevant do you think the workshop is for high Mozambican high school students? |
| **Focus group with EWB executors** | Interview with the EWB executors.<br>Question: On a scale from 1 to 10, how relevant do you think the workshop is for high Mozambican high school students? |

**Norm:**

| **Method** | **Norm** |
|---|---|
| **Try-out or micro-evaluation with Dutch students** | At least 70% of the students of can link the retrieved knowledge and skills to their reality by formulating an example of a link between the workshop and their daily lives. |
| **Focus group with University students** | On average the university students rate the relevance of the workshop for Mozambican high school students at least a 6 or higher. |
| **Focus group with EWB executors** | On average the EWB executors rate the relevance of the workshop for Mozambican high school students at least a 6 or higher. |

*Consistency*

Here, the second assumption is evaluated: “All design choices are translated into then design.” If not all design choices are translated into the actual design we should know that our design might be lacking at these points. Using this evaluation we can see where our design would be lacking and then we can redesign to make all design choices apparent in the design.

**Desired:** The finalised product is based on all the design choices posed in the design plan.

**Method & tool:** The screening method will be applied, where the designers make a checklist summarising all design choices. This checklist is then used to check if all the choices that have been made in the design plan are translated into the workshop.

**Norm:** All the choices that have been made in the design plan are translated into the workshop.

*Usability*

The first design choice that should be evaluated: “We want to use a modular workshop, to discriminate in level and opportunity.” tells us about the usability of this workshop. The modularity should enable us to discriminate in level and opportunity, while not making it too difficult for the teacher to give the workshop.

**Desired:** The modularity of the workshop does not affect the ability of students to follow the workshop in whole, or the teacher to supervise the workshop. Even if students miss a module they should be able to continue the workshop and contribute to the final module. The average level of the modules should fit the level of the class, such that all students should be able to successfully finish every module. For teachers it should be clear how the workshop is structured by reading the teacher’s manual, without any external help.

**Method & tool:**

| **Method** | **Tool** |
|---|---|
| **Try-out or micro-evaluation with Dutch students** | Observation.<br>What to observe: Do students get stuck during a module if they did not do a certain other module? How actively (1-10) do students participate during the workshop? |
| **Try-out or micro-evaluation with Dutch students** | Interview with teacher of Dutch students<br>Question: How high (1-10) would you rate the average involvement of your students during a normal lesson, and during the workshop? If some students do not participate well, do you think that this is due to the level of the workshop or due to the level/character of the student? |
| **Focus group with University students** | Interview with the University students.<br>Question: Which section of the teacher’s manual did you find most difficult to understand? Why do you think it was difficult to understand? Are there parts that are too difficult, which can lead to the workshop failing? Which percentage of the teacher’s manual did you find clear to use? |

**Norm:**

| Method | Norm |
|---|---|
| **Try-out or micro-evaluation with Dutch students Observation** | The teacher should be able to answer all questions of the students during a module with the information given in the teacher's manual of that module. So students should not get stuck after that explanation. Only 10% of the student can have a rating below 6 on involvement, based on the our rating of the observation. |
| **Try-out or micro-evaluation with Dutch students Interview teacher** | The teacher's rating of the involvement during the workshop should not be lower than the teacher's rating of the involvement during a normal lesson. The level of the workshop should not demotivate students, resulting in lower involvement. |
| **Focus group with University students** | The teachers supervising the workshop value the workshop as usable, i.e. they see no problems that will lead to a workshop failing. They rate at least 90% of the workshop clear to use. |

*Effectiveness*

The second design choice that should be evaluated, "The workshop must motivate the participating students for technology and science, while transferring knowledge comes second", tells us about the effectiveness of the workshop. The workshop must motivate the participating students for technology and science, while transferring knowledge comes second.

**Desired:** Students are more interested in technology and science after the workshop.

**Method & tool:**

| Method | Tool |
|---|---|
| **Try-out or micro-evaluation with Dutch students** | Survey: Ask students to rate (1-10) their interest in technology and science before and after the workshop. Let them explain why there is or is not a difference. |
| **Focus group with University students** | Interview with university students.<br>Question: Do you think this workshop will increase the interest of Mozambican high school students in science and |

| | |
|---|---|
| | technology? (on a scale from not at all, not much, somewhat, to very much)<br>Question: Would this workshop have made you more interested in science and technology when you were in high school? |
| **Focus group with EWB executors** | Question: Do you think this workshop will increase the interest of Mozambican high school students in science and technology? (on a scale from not at all to very much) |

**Norm:**

| **Method** | **Norm** |
|---|---|
| **Try-out or micro-evaluation with Dutch students** | 70% of students say they are equally or more interested in technology and science than before. 50% of students say they are more interested in technology and science than before. The content of the workshop should not be the reason that students lose their interest in technology and science. |
| **Focus group with University students** | Every university student thinks the workshop will increase the interest in science in technology of Mozambican high school students somewhat.<br>The majority of the university students would have been more interested in science and technology after taken this workshop in high school. |
| **Focus group with EWB executors** | Every EWB executor thinks the workshop will increase the interest in science in technology of Mozambican high school students somewhat. |

**Accuracy of the content in our product**

To ensure that our the information in our workshop is factually correct and interpretation is clear and unambiguous, we must check the content of the multiple modules.

We will try to attain this factual correctness by asking an expert to analyse the workshop. This expert will likely be an university teacher with a degree, or at least a lot of experience, in the field of electrotechnics. This expert can check whether there are any faults in our explanation of the theory, or in the documentation on the practical parts of the workshop. When an university teacher would not be available, we can also ask a student of the electrical engineering department of the TU/e.

A second manner in which we can check the correctness of the information in the workshop is to test the workshop. During testing there will be a thorough check of all the information and interpretation of this information. When the test subjects get stuck on certain parts of a specific module, we will know that some information might be lacking in that section. The feedback from the subjects is crucial. Therefore, before starting the test of the workshop, we should activate the subjects to actively check the information which is given by the workshop.

**Recommendations for a redo of the design**

At this moment we have not performed any evaluation yet, therefore there are no recommendation for a redo at this point.

# References


*About Engineers Without Borders*. (n.d.). Engineers Without Borders. Retrieved 2 March 2020, from https://www.ewbnl.org/about/

Bennett, J., Lubben, F., & Hogarth, S. (2007). Bringing science to life: A synthesis of the research evidence on the effects of context-based and STS approaches to science teaching. *Science Education*, *91*(3), 347–370. https://doi.org/10.1002/sce.20186

*Bèta&TechMentality*. (n.d.). Platform Talent voor Technologie. Retrieved 24 March 2020, from https://ptvt.nl/kennisbank/betatechmentality/

*Education in Mozambique—SACMEQ*. (2009, March 23). https://web.archive.org/web/20090323020810/http://www.sacmeq.org/education-mozambique.htm

Grassi, A., Cunha, A., Correia, B., Scharanberg, C., Kustra, J., Luis Pedro Oliveira, Pereira, S., Kruger, M., Godinho, M., & Lopes, S. (2019). *School of the future Engineers without Borders 2019 Execution Report*. Engineers Without Borders.

INDE/MINED – Moçambique. (2010). *Física, Programa da 10a Classe*.

*Jet-Net & TechNet*. (n.d.). Jet-Net & TechNet. Retrieved 21 February 2020, from https://jet-net.nl/over-ons/jet-net-technet/

Matavele, J., & Camcundimo, V. (2009). *Mozambique Report* (pp. 76–83). National Institute for Education Development.

*Mozambique Education System*. (n.d.). Retrieved 24 March 2020, from https://www.scholaro.com/pro/countries/Mozambique/Education-System

MUVA Mexe. (n.d.). *MUVA*. Retrieved 24 March 2020, from https://muvamoz.co.mz/muva-mexe/?lang=en

Republic of Mozambique Ministry of Education. (2012). *Education Strategic Plan 2012-2016*. Republic of Mozambique Ministry of Education.

Riley, S. (n.d.). What is STEAM Education? *The Institute for Arts Integration and STEAM*. Retrieved 24 March 2020, from https://educationcloset.com/what-is-steam-education-in-k-12-schools/

Roelofs, E. C., & Houtveen, A. A. M. (1999). Didactiek van authentiek leren in de Basisvorming. Stand van zaken bij docenten Nederlands en Wiskunde. *Pedagogische Studiën*, *76*, 237–257.

*Schools of the Future—Mozambique*. (2019, July 4). Engineers Without Borders. https://www.ewbnl.org/schools-of-the-future/

SLO, Enschede. (n.d.). *Stel een evaluatieplan op* [Overzichtspagina]. SLO. Retrieved 30 March 2020, from https://slo.nl/thema/meer/curriculumontwikkeling/instrumenten/taakhulp/stel-evaluatieplan/

Thijs, A., Fisser, P., & Hoeven, M. van der. (2014). 21e eeuwse vaardigheden in het curriculum van het funderend onderwijs. *Enschede: SLO*, 128.

UNICEF Mozambique. (2016). *Education in the new country programme 2017-2020*.

United Nations Development Programme. (2019). *Human development report 2019: Beyond income, beyond averages, beyond today: inequalities in human development in the 21st century.*

*U.S. Agency for International Development*. (2016, November 8). https://www.usaid.gov/mozambique/education

U.S. Department of Labor. (2006). *The Department of Labor's 2005 Findings on the Worst Forms of Child Labor*. U.S. Department of Labor.

Van den Akker, J. (2004). Curriculum perspectives: An introduction. In *Curriculum landscapes and trends* (pp. 1-10). Springer, Dordrecht.

# APPENDIX

**Appendix A: 21st Century Skills**

| Skill | Explanation |
|---|---|
| Creativity | Being able to think of elaborate on, and analyse new ideas. |
| Critical Thinking | Being able to formulate a personal, substantiated vision or meaning. |
| Problem Solving | Being able to recognize an idea, and constructing a plan to solve the problem |
| Communication | Being able to efficiently and effectively broadcast and receive messages. |
| Collaboration | Being able to realise a goal collectively, while supporting and complement others. |
| Technological literacy | Being able to efficiently, effectively and responsibly use ICT. |
| Social and cultural skills | Being able to effectively live and work with others of different ethnic, cultural and social backgrounds. |
| Self regulation | Being able to realise goal oriented and appropriate behaviour. |

**Appendix B: Mozambican high school curriculum physics**

| Grade | Subject Units |
|---|---|
| 8 | ● Structure of Matter<br>● Kinematics<br>● Dynamics: Newton's Laws<br>● Work and Energy |
| 9 | ● Thermal Phenomena<br>● Solid Statics<br>● Fluid Statics<br>● Geometric Optics |
| 10 | ● Electrical Current<br>● Oscillations and Mechanical Waves<br>● Electromagnetism<br>● Rectilinear Motion with constant acceleration |

| | |
|---|---|
| 11 | ● Mechanical (Kinematic, Static and Dynamic)<br>● Work and Energy. Shock and Collision<br>● Electrostatics<br>● Continuous Electrical Current. Electromagnetism |
| 12 | ● Electromagnetic waves. Black Body Radiation<br>● Atomic Physics<br>● Nuclear Physics<br>● Fluid Mechanics (Hydrodynamics)<br>● Gases. Thermodynamics<br>● Mechanical Oscillations |