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The AudioBrix Toolkit: Developing and evaluating a LEGO brick-based Digital Musical Instrument for STEAM education

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Merlin Waldhör BSc

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Abstract

STEAM (Science, Technology, Engineering, Arts & Mathematics) education combines conventional STEM fields with interdisciplinary arts & humanities, making subjects like music combined with technology more accessible and relatable. Given this context, LEGO is a commonly investigated tool for haptic interaction. Together with computer science, LEGO-based digital music instruments (DMI) provide a promising approach for expressing music in a creative way. However, there is a substantial lack of information on electronic LEGO-based DMIs with a focus on STEAM education. To introduce a STEAM compatible LEGO DMI for straightforward deployment in schools, the national Austrian curricula were analyzed and compared. This analysis of four different curricula included examination of appropriate subjects, topical suitability and respective subject hours. Relevant topics were extracted and summarized in a comparative way. Based on the topical outcomes of the curriculum analysis, an extensive prototyping phase was established. The resulting prototype, called the AudioBrix instrument, was achieved considering technical feasibility, costs and portability within an educational scope. The instrument acts as an Arduino based sequencer and is structured as an assemblable toolkit for students. The final instrument toolkit includes a comprehensive user manual and the required building materials. After the prototyping phase was completed, the assembly and playing of the instrument was evaluated with 21 becoming teachers in two workshops. The workshops were accompanied by a user survey, which led to important functional and educational insights of the overall toolkit. The collected user survey data was analyzed using exploratory data analysis for quantitative and qualitative data. The results of the user survey outline the capabilities for interdisciplinarity and facilitation of problem oriented thinking. In general, all participants were able to operate the instrument. However, some major functional issues were observed, which need to be addressed to prevent possible frustration of students. While didactic difficulties like high time investment and increased teachers effort were mentioned, the interdisciplinary concept, assembly and playing was mainly considered positive. Together with the results from the curricula analysis, subjects in their respective grades were ranked regarding topical alignment, evaluation recommendation and subject availability. Given these details, the usage of the AudioBrix toolkit was assessed from a curricular perspective. Based on these findings, the AudioBrix toolkit is well suited for integration within the Austrian curricula, supporting high STEAM compatibility. However, further functional improvements need to be considered and future research on the AudioBrix toolkit for school-rollout is recommended.

Kurzfassung

MINKT (Mathematik, Informatik, Naturwissenschaften, Kunst und Technik) Bildung erweitert konventionelle MINT-Fächer mit Kunst. Dadurch können Fächer wie Musik und Technik greifbarer und nachvollziehbarer gemacht werden. In diesem Kontext ist LEGO-Spielzeug ein umfangreich untersuchtes Mittel zur haptischen Interaktion. Im Zusammenspiel mit Informatik erlauben LEGO-basierte digitale Musikinstrumente (DMI) einen vielversprechenden Ansatz, um Musik auf kreative Art und Weise auszudrücken. Allerdings mangelt es an Details zu elektronischen LEGO-basierten DMIs mit Fokus auf MINKT-Unterricht. Um ein entsprechendes MINKT-kompatibles LEGO DMI für den einfachen Einsatz in Schulen zu ermöglichen, wurden deshalb die österreichischen Lehrpläne analysiert und verglichen. Die Analyse von vier unterschiedlichen Lehrplänen enthielt dabei die Auswahl passender Fächer, thematische Übereinstimmungen sowie die Verfügbarkeit der Schulfächer. Relevante Themen wurden in einem vergleichenden Prozess aus den Lehrplänen entnommen und zusammengefasst. Basierend auf den Ergebnissen dieser Analyse, wurde eine umfangreiche Prototyping-Phase eingeleitet. Der resultierende Prototyp, genannt AudioBrix, wurde dabei unter Berücksichtigung technischer Umsetzbarkeit, Kosten und Portabilität entwickelt. Das Instrument agiert als Arduino-basierter Sequencer und ist als zusammenbaubares Toolkit für Schüler*innen konzipiert. Das finale Toolkit enthält eine detaillierte Bedienungsanleitung und die notwendigen Baumaterialien. Nach dem Prototyping-Prozess wurde das Instrument von 21 Lehramt-Studierenden in zwei Workshops evaluiert. Die Workshops wurden von einer Nutzerumfrage begleitet, die zu wichtigen Erkenntnissen bezüglich Funktionalität und Didaktik führte. Die erhobenen qualitativen und quantitativen Daten wurden im Rahmen einer explorativen Datenanalyse analysiert. Die Ergebnisse der Umfrage deuten auf hohes Potential für Interdisziplinarität und problemorientiertes Arbeiten hin. Insgesamt konnte das Instrument von allen Teilnehmenden gespielt werden. Für eine Anwendung ohne Frustration bei den Schüler*innen ist jedoch eine Überarbeitung notwendig, da gröbere Mängel der Funktionalität festgestellt wurden. Während didaktische Schwierigkeiten in Hinsicht auf hohen Zeitaufwand oder Aufwand der Lehrkräfte erwähnt wurden, sind das interdisziplinäre Konzept, der Aufbau und das Spielen des Instruments hauptsächlich positiv bewertet worden. Zusammen mit den Ergebnissen aus der Lehrplananalyse wurden die entsprechenden Schulfächer bezüglich thematischer Übereinstimmung, Empfehlung der Workshops und Verfügbarkeit bewertet. Daraufhin wurde eine Einschätzung für die Nutzung des AudioBrix toolkits für die österreichischen Lehrpläne durchgeführt. Das Toolkit ist für eine Integration in den Lehrplan gut geeignet und unterstützt das MINKT Konzept in großem Umfang. Es müssen jedoch weitere funktionale Verbesserungen durchgeführt werden und es wird empfohlen, das Toolkit in Praxiseinsätzen in Schulen zu untersuchen.

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1. Introduction

STEM (short for Science, Technology, Engineering and Math) education is a broadly represented educational field which has gained popularity over the last decades. Many national curricula and education systems are heavily focusing on STEM education. [Zhan et al., 2022] On top of that, arts and humanities have been gradually fused into STEAM education (STEM with Arts) over the last years, filling an important gap for creativity and relatability. [Gavrilas and Kotsis, 2025] Important aspects of STEAM education include problem-oriented thinking, real-world connections and interdisciplinarity. [Chappell et al., 2025] In this thesis, STEAM education is achieved by interlocking computer science, music and electrical engineering as foundational disciplines. Music and technology cannot only be viewed as distinct disciplines but also enable different interconnected elements, including musical engineering, music theory and art integration. [Liu, 2024] Therefore, the commonly known toy brand LEGO can act as a framework for such interdisciplinary education. With LEGO bricks, LEGO robots and externally added electronics, musical interfaces such as digital music instruments have already been investigated in various forms. This includes fully robot-based [Jakobsen et al., 2016, Gold et al., 2025, Lu et al., 2024], solely software-based [Özer and Demirbatir, 2023] and electronics-based [Barbancho et al., 2024, Hödl, 2024] approaches. However, many of these LEGO-based DMIs do not consider educational aspects. Therefore, this work presents a concept for a novel musical interface intended for STEAM education. The instrument is then evaluated regarding its educational benefits and integrability within the Austrian secondary education curriculum.

2. Related Work

2.1. STEAM Education and Music

Given the prevalence of STEAM education, Chappell et al. introduced a STEAM framework which aggregated the following core concepts of STEAM education: Creativity, collaboration, disciplinary inter-relationship, real-world connection, thinking-making-doing and empowered inclusivity.[Chappell et al., 2025] Music and science have been connected in several different STEAM projects. This includes fully digital tools which have been compared in a work from Özer et al.[Özer and Demirbatir, 2023] Their work analyze tools like the EarSketch¹, which enables students to code music within a Python environment.[McCoid et al., 2013] Another popular example is the Google Chrome Music Lab² which offers multiple web-tools to visualize and configure sound in a playful way. Compared to EarSketch, this tool is less complex, but still offers benefits for understanding music from a mathematical perspective.[Mishra, 2021] Another music-coding web-application is Scratch³ which is not restricted to sole music making, but works as a simple programming platform for music, media and games. It acts as a visual block based programming language, avoiding actual writing of code for users.[Maloney et al., 2010]. These interfaces worked fully digital. However, there are also other STEAM prototypes and instruments which combine digital sound creation with physical interfaces. This includes, for example, physical interfaces like the MakeyMakey, which is used to create simple resistance-based interfaces. Besides using MakeyMakey as a simple program controller, Chen et al. demonstrated that it can also be used to integrate music within STEAM education. [Chen and Lo, 2019] Other tangible user interfaces (TUIs) are more complex, including the reacTable which uses symbolic components that are placed on a special table to create and modify sound.[Jordà et al., 2005] Although the reacTable has not specifically been considered in the context of STEAM education, it has been used in several museums and educational institutions for teaching music in a non-traditional way.[Geiger et al., 2016]

2.2. LEGO-Based DMIs and STE(A)M Integration

Due to its advantageous characteristics like haptics or modularity, LEGO has become a well known interactive technique in STEAM education. One popular tool

¹<https://earsketch.gatech.edu/>, last accessed on 13.04.2026

²<https://musiclab.chromeexperiments.com/>, last accessed on 13.04.2026

³<https://scratch.mit.edu/>

2. Related Work

by the LEGO company itself is LEGO Serious Play (LSP)⁴ which uses LEGO for communication and creative thinking. LSP can be used in several learning environments due to its flexibility and adaptability and offers many benefits for acquiring new skills.[Henderson and Shipway, 2026] Another important invention for integration was the introduction of LEGO's robot series called Mindstorms⁵. The modular robot system is used in many projects. According to an investigation of Lee et al., it is the preferred physical computing device related to education (although the study did not address newer Mindstorms version like the Mindstorms EV).[Lee and Kim, 2016] This aligns with the high number of LEGO Mindstorms based DMIs from section 2.2.1. LEGO can also be integrated within education using electronic building kits. Such LEGO compatible electric kits can be purchased online, including *E-Blox*⁶, which uses small metal pin outlets in custom bricks or *Brixo*⁷ which connects bricks with chrome-coated surfaces. While these electronic toolkits can be used for various educational projects with LEGO, they do not support musical integration.

2.2.1. LEGO Mindstorms Based DMIs

Another approach for designing LEGO DMIs includes usage of the previously mentioned Mindstorms series and its components. These DMIs use button, color- or rotary sensors to capture user feedback. For example, Jakobsen et al. introduced the *Hitmachine* which allows creative self-assembled instruments for children in a live setup.[Jakobsen et al., 2016] Gold et al. introduced another DMI, including a newly developed Python API for a raspberry pi together with Mindstorms EV sensors. In this case, the programmable DMI acted as a musical sequencer. The project focused on students programming and intrinsically demonstrated the interdisciplinary potential of LEGO DMIs. [Gold et al., 2025] Shapiro et al. also created a software-focusing DMI sequencer which was based on Google's Blockly⁸ software to allow students to program sounds respectively. In comparison to the work of Gold et al. the DMIs specialized more towards network understanding and multi-device support.[Shapiro et al., 2016] There exist also fully LEGO hardware based DMIs like the *Color Singer*. This DMI by Qiuyu et al. can read predefined colored LEGO note sheets solely using LEGO Mindstorms, its sensors and motors. Although the interaction technique may be limited for this DMI, it depicts the capability of fully Mindstorms based DMIs.[Lu et al., 2024] Equal to the color singer, Sulg et al. introduced a turntable which also only consists out of LEGO components and Mindstorms sensors. However, instead of using square note sheets, it uses colored paper records to store musical notation.[Sulg et al., 2016] Chung et al. also introduced a Mindstorms based DMI which used Mindstorms components to create sound in a Python programmable manner. In this project the DMI was not restricted to generating sound only digitally, but also used digital triggers to mechanically play instruments using Mindstorms motors

⁴<https://www.lego.com/en-de/themes/serious-play/background>, last accessed on 11.04.2026

⁵<https://www.lego.com/de-at/themes/mindstorms/about>, last accessed on 11.04.2026

⁶<https://myeblox.com>, last accessed on 11.04.2026

⁷<https://brixotoyz.com>, last accessed on 11.04.2026

⁸<https://developers.google.com/blockly>, last accessed on 11.04.2026

2.2. LEGO-Based DMIs and STE(A)M Integration

(e.g. hitting a castanet or drum). [Chung et al., 2014] Aukkhosuwana et al. also including external music instruments with Mindstorms motors and sensors. In their work Mindstorms motors were used to create a robotic hand which can play an electronic keyboard. However, in terms of investigating STEAM learning with LEGO, it is a very complex robotic instrument integration, which may only exhibit limited educational advantages. [Aukkhosuwana and Suntiamorntut, 2021]

2.2.2. Visual Recognition Based LEGO DMIs

One way to combine LEGO and music is by creating innovative digital music instruments (DMI). There are several types of DMIs, including visual recognition (VR) based prototypes which capture bricks and translate them into sound. This includes webcam based prototypes like a tangible rhythm sequencer by Gohlke et al. or the *BrickMusicTable* by Waldhör et al. which used OpenCV for visual brick recognition. [Waldhör et al., 2024, Gohlke et al., 2015] A similar, more compact version of VR based brick recognition called *MusicBlocks* was established by Mioretti et al. [Miotti et al., 2022] *MusicBlocks* used a downwards-facing webcam setup that is similar to the concept of Waldhör. In comparison, it was more robust than the *BrickMusicTable* but offered less comprehensive interaction techniques. Oestermeier et al. created another, more complex VR based DMI which used a Samsung tabletop computer to visually detect notes. For this instrument, notes were represented using plates with transparent (no sound) and non-transparent (note) bricks. [Oestermeier et al., 2015]

2.2.3. Electronic DMIs

Beside VR and Robot-Sensor based approaches LEGO DMIs can also be created using raw electronic components like resistors, LED lamps and conductive tapes. Barbancho et al. introduced a novel technique for wiring custom-printed DUPLO bricks together using resistors and springs. So called "pitch-towers" consisting of stacked DUPLO bricks allowed expressing different pitches. This DMI did not use any LEGO Mindstorms components, but was solely based on a raspberry pi for measuring the different resistances. [Barbancho et al., 2024] In 2024, Oliver Hödl published an electrified LEGO piano which used conductive copper tapes with a Arduino Mega board. It provided a fully functional MIDI compatible key layout and was evaluated within a public live performance. [Hödl, 2024] Due to its fine-granular internal wiring, this DMI has a rather complex structure. In comparison to many Mindstorms DMIs, these instruments cannot be created by students in a reasonable manner. Same applies for the DUPLO prototype by Barbancho et al. Not limited to making music, the *Crazy Circuits* toolkits⁹ offer the possibility to create custom LEGO interfaces and robots. Instead of using Mindstorms components, it provides custom made LEGO compatible parts¹⁰ which are connected to an Arduino. By using conductive tapes and other basic components (including LED lamps, buttons etc.) it offers a more low-level building experience. [BrownDogGadgets, nd]

⁹<https://www.browndoggadgets.com/collections/crazy-circuits-all>, last accessed on 11.04.2026

¹⁰<https://github.com/BrownDogGadgets/CrazyCircuits>, last accessed on 11.04.2026

2. *Related Work*

2.3. **Summary and Research Gap**

Given the reviewed literature on LEGO as musical interface for DMIs, there exist multiple prototypes that focus on education of music and computer science. [Jakobsen et al., 2016, Gold et al., 2025, Shapiro et al., 2016, Barbancho et al., 2024, Oestermeier et al., 2015, Chung et al., 2014] Although these projects facilitate specific learning of music or informatics, they do not consider all facets of STEAM education. Other LEGO based instruments do not consider usage in broader education at all. [Liu, 2024, Sulg et al., 2016] Furthermore, related LEGO prototypes and DMIs were rarely designed for low-threshold deployment in schools. Thus, there exists a substantial lack of information on LEGO-based DMIs that implement STEAM education in a compact, toolkit-like structure. In addition, the use of robot-independent electronic LEGO interfaces remains mainly underexplored. [Barbancho et al., 2024]

3. Methodology

For introducing a novel LEGO brick-based digital music instrument in the context of STEAM education, the national Austrian curricula were analyzed to identify potential educational application areas and didactic requirements for a novel DMI. Based on these findings and insights from related DMIs, an iterative prototyping process was conducted. The prototyping phase included established prototyping steps, such as defining prototype objectives, iterative enhancements of design and performance and optimizations regarding cost and time effort.[Camburn et al., 2017] After a sufficiently developed prototype was established, it was evaluated with teacher trainees to get details on the pedagogical impact, prototype functionalities and overall quality. This evaluation was performed as participatory workshops, such that participants were asked to assemble and test the given prototype instrument.[Hu, 2024] The user evaluation was complemented with an online user survey, including quantitative and free-form questions. The results of the user study were analyzed using mixed-methods research, whereby quantitative and qualitative research extended, confirmed and compensated each other.[Caruth, 2013] For both types of data, common techniques of exploratory data analysis (EDA) were applied. This included statistical summaries and visualizations to gain insights on the collected data.[Hussain and Aithal, 2023] Due to the small sample size, no further data transformation was performed on the user survey data. Finally, the results from the user evaluation were compared with the results from the curricula analysis to assess the pedagogical and practical relevance within the Austrian STEAM education. An overview of the methodological process is visible in figure 3.1.

3. Methodology

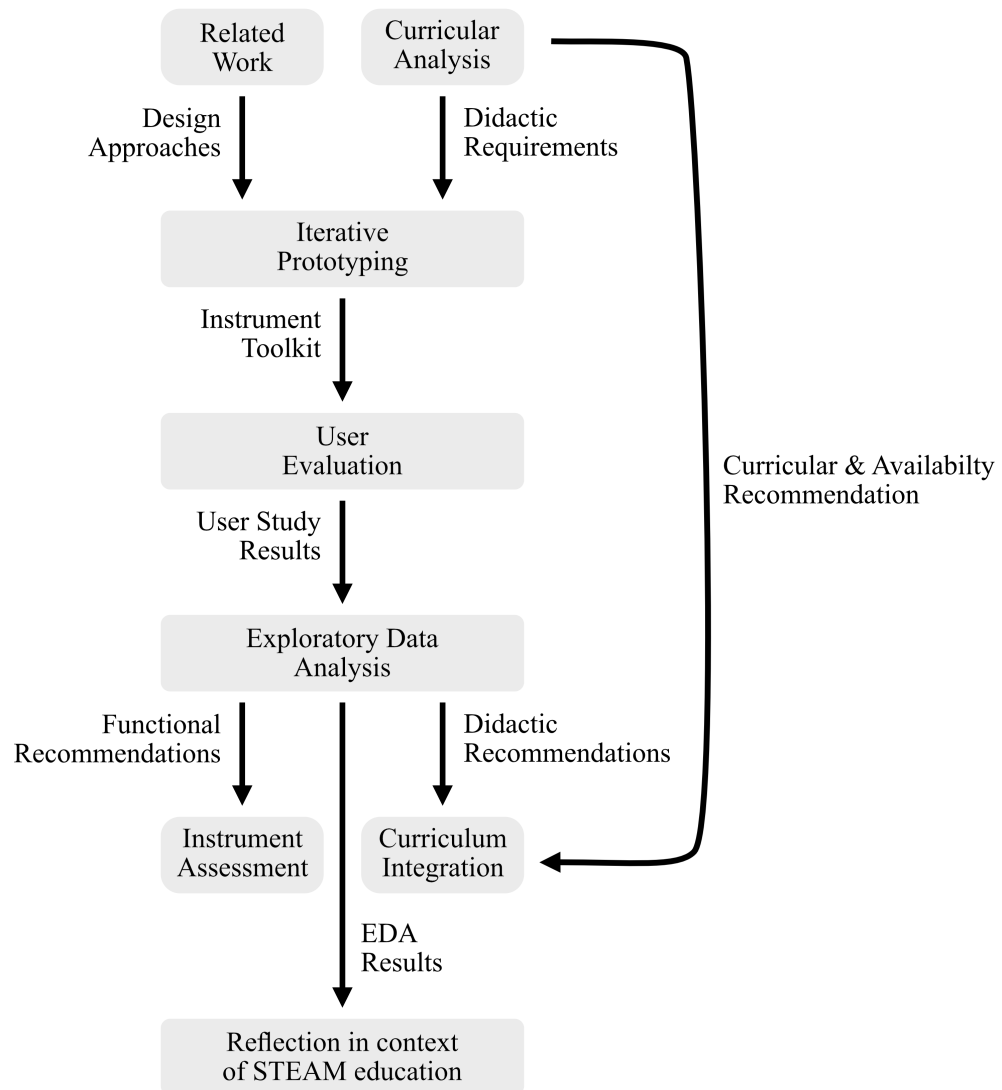


Figure 3.1.: Overview of the methodological process

4. Analysis of Relevant Areas in the National Education System

In this section, relevant Austrian curricula are analyzed regarding subjects, syllabus and subject hours. Subject topics are compared with the matching background topics of the DMI from section 5.3 such as electrical engineering, physical principles of electricity, microcontroller software, new music technologies and new forms of music. According to the degree of complexity of this project, only secondary education will be considered. Within the scope of this work, only non-school-autonomous parts of the curriculum are evaluated. This serves as standardized baseline representation and defines some minimal structural requirements across school types. However, it must be mentioned that many schools in Austria use school-autonomous adaptations of the curricula, leading to deviations of subject distribution and timetables. Thus, this analysis does not aim for a representation of the full diversity of the Austrian school landscape but rather provides a comparative baseline for different schools. As the Austrian education infrastructure is rather extensive, only the most common types of schools will be evaluated. This includes grammar schools (AHS and NMS) as also vocational schools (BHS). Only vocational schools with technical specialization (*Höhere Technische Lehranstalt*, short HTL) will be considered. Two types of HTL specialization, Information Technology and Mechatronics, were selected within the scope of this thesis.

For simplicity, all references to the Austrian curricula are translated from German unless stated otherwise. Curriculum-specific didactic term translations are listed for simple replicability as follows:

- **Scope:** Kompetenzbereich
- **Reference frame:** Thematischer Bezugsrahmen
- **Exemplary content:** Exemplarische Inhalte
- **Supplementary applications:** Ergänzende Anwendungsbereiche
- **Educational Task:** Bildungs- und Lehraufgabe
- **Syllabus:** Lehrstoff

If applicable, the terms containing respective topics are provided. If no specific term, label or area description is applicable the *N/A* abbreviation is used. Only intersections with relevant topics and areas within the subjects syllabus are highlighted. Additional off-topic syllabus content (even within one scope or educational task) is not included in tables or listings of this chapter for reasons of simplicity.

4.1. Allgemeinbildende Höhere Schule (AHS)

The AHS is a general educational grammar school type in Austria. It covers lower and upper secondary grade. In the lower grade, the entry age is 10 years, while the upper grade starts at 14 years of age. At the end of AHS education (eight grade), the higher school certificate (Matura) can be obtained. The Austrian AHS curricula differentiates between Gymnasium, Realgymnasium (Gymnasium with a focus on science) and Realgymnasium with a focus on economics (German: Wirtschaftskundliches Realgymnasium). For AHS the subjects Physics, Informatics, Music and Crafting (German: Technik und Design) will be considered.[Republik Österreich, 2024]

4.1.1. Schedule Integration

Table 4.2 lists the subjects hours per week for AHS Gymnasium, Realgymnasium and Realgymnasium with focus on economics. As the Realgymnasium focuses more on STEM subjects, it includes more subject hours for physics and crafting. The hours per week of elective subjects is shown in table 4.1. There exist two elective subject variants, denoted in the curriculum as *aa* and *bb*: Option *aa* has a fixed schedule for specific subjects (including informatics and music). Option *bb* allows a combination of two elective subjects. The subject crafting is neither available for option *aa* or *bb*. For variant *bb* the subjects physics and music (informatics is only available within variant *aa*) can be chosen as follows:

- Physics or Music in 6th and 7th grade
- Physics or Music in 6th and 8th grade
- Physics or Music in 7th or 8th grade, provided the remaining elective hours are covered by another elective subject in the other grade.

In total, elective subjects sum up to a total of 4 hours in upper grades (except informatics from *aa* with 6 hours) with 2+2 or 4 hour compositions.

Grade	Physics	Informatics	Music
6	2 ^a	2	2 ^a
7	2 ^a	2	2 ^a / 2 ^b
8	2 ^a	2	2 ^a / 2 ^b
Total hours	2 ^a / 4 ^a	6	2 ^a / 4 ^{a,b}

Table 4.1.: Elective subject hours per week (AHS)

^b Only available for students not participating in music as mandatory subject in upper grades (variant *aa*)

^a Flexible schedule distribution for variant *bb*

4.1. Allgemeinbildende Höhere Schule (AHS)

Grade	Physics	Informatics	Music	Crafting
Gymnasium				
1		1 ^a	2	2
2	1	1 ^a	2	2
3	2	1 ^a	2	
4	2	1 ^a	1	
5		2		
6	3		1	
7	2		2 ^b	
8	2		2 ^b	
Realgymnasium				
1		1 ^a	2	2
2	1	1 ^a	2	2
3	2	1 ^a	2	2
4	2	1 ^a	1	2
5	2	2	2	
6	3		1	
7	2		2 ^b	
8	2/3 ^c		2 ^b	
Wirtschaftskundliches Realgymnasium				
1		1 ^a	2	2
2	1	1 ^a	2	2
3	2	1 ^a	2	2
4	2	1 ^a	1	3
5		2	2	
6	3		1	
7	2		2 ^b	
8	2		2 ^b	

Table 4.2.: Mandatory subject hours per week (AHS)

^a Basic digital education acts as informatics in lower grade

^b Students can choose between elective subjects *Music* and *Arts and Design*

^c Depending if physics is selected as main specialization

4. Analysis of Relevant Areas in the National Education System

4.1.2. Topic Integration

Physics

Physics class in lower grade should embed and encourage usage of experiments for skill acquisition. Interdisciplinary questions and incorporation of specialists should be used to improve the student's learning outcomes. The curriculum's section *Knowledge acquisition and experimentation* explicitly mentions observation, measuring and estimating reliability in physics classes. In upper grade, the physics classes should enable students to understand physics as solutions for local and global problems. Teaching students to assess scientific research as a creative process with physical and technical applications is an important goal. Measurement of data, comparison, analysis and estimation of reliability should be included in experiments. Furthermore, it is advised to use modern media and technologies specifically for modeling, measuring, simulation and data analysis. The overall matching topics and areas are listed in table 4.3. In physics class as elective subject, teaching should orientate on the current grade and students personal preferences, facilitating project- and working oriented learning methods.

Grade	Term	Label	Area	Topic and Content
3	N/A	Scope	Electricity and Magnetism	Experiments which involve electricity, resistance, voltage and current.
3	N/A	Scope	Energy	Includes simple circuits, voltage, current and first insights into electronic devices.
6	4	N/A	Electricity Teaching	Impact of electricity, simple circuits, current, voltage and resistance.
6 ^a	4	N/A	Electrical energy	Electric energy, power and batteries.

Table 4.3.: Relevant topics of physics classes (AHS)

^a Only for classes with more than 7 hours in total

Informatics and Basic Digital Education

Informatics as own mandatory subject is only available in upper grades. In lower grade, the subject is called digital basic education (in this work also referenced as DBE). Generally speaking, DBE combines media education with informatics. Digital basic education includes analysis, interaction, modeling, coding and testing of IT systems, software automation and networks. The *didactic principles* orientate on computational- and critical thinking, creativity, communication and collaboration. The scope *production* also includes media publishing, creation of algorithms and coding. In fifth grade, the informatics subject should enable students to design and create with IT on their own. IT classes include cooperative problem-solving within a project-oriented environment. Explorative methods should be used to deepen relevant competences. Further, students

4.1. Allgemeinbildende Höhere Schule (AHS)

should engage in activities of designing and applying information systems. In informatics as elective subject, lessons should include modular and project-like learning methods, including interdisciplinary content. Main focus of the elective subject informatics is deepening and expansion of IT competences. Therefore, teachers and students can reconcile on preferred topics or address specific topical areas exemplarily. Table 4.4 lists all relevant areas for informatics, basic digital education and informatics as elective subject.

Grade	Term	Label	Area	Topic and Content
3	N/A	Scope	Orientation	Includes interdisciplinary applications of engineering within social and cultural aspects.
3	N/A	Scope	Production	Customizing software applications to match personal preferences.
4	N/A	Scope	Production	Creative cooperation using provided media and software applications. Creation of simple programs and web applications to solve a specific issue or task. Documentation of Software.
5	1&2	N/A	IT Systems	Setup of digital terminal devices. Usage of graphical user interfaces and software utilities.
5	1&2	N/A	Practical IT	Understanding terms, concepts, methods and operations of IT. Basics of algorithms and programming.
6 ^a	3	N/A	IT Systems	Technical basics of IT systems, their functionality and collaboration. Setup of computer systems including external devices.
6 ^a	3	N/A	Applied IT	Production and publishing of media including sound.
7 ^a	6	N/A	IT Systems	valuation of terminal devices regarding technical properties and performance. Diagnosis and debugging of simple issues.
8 ^a	7	N/A	IT Systems	Incorporation into new software and justification for chosen software. Evaluation of human-computer interaction and its meaning for the human user.

Table 4.4.: Relevant topics of IT and digital education classes (AHS)

^a Only available as elective subject

4. Analysis of Relevant Areas in the National Education System

Music

In lower grade, music classes include different manifestations of music and musical traditions, music-making, hearing and haptic feeling related to music. Different music genres and performance practices are thematized regarding their innovative potentials. New technologies should be used adequately to support individual and cooperative learn processes. Cooperation with extracurricular education partner can improve the learning process. In upper grade, the music class should deepen and expand the knowledge gained in previous grades. Interdisciplinary and intercultural aspects should be considered. One relevant overall topic labeled as *nature and technology* includes sound and functionality of new media as intersection between nature, technology and arts. Relevant areas are listed in table 4.5. Music as elective subject exhibits the same relevant exemplary contents and reference frame as within the eighth grade and allows students to explore topics aligned with their personal preferences and interests. As elective subject, the music class also focuses on the preparation towards the Matura.

Grade	Term	Label	Area	Topic and Content
1	N/A	Scope	Hearing and Feeling	Development, production and reflection on sound recordings in smaller and larger groups
2	N/A	Scope	Hearing and Feeling	Orientation on digital note sheets and realization of simple harmonic or melodic accompaniment
4	N/A	Scope	Hearing and Feeling	Electric, digital and virtual instruments. Own and predefined compositions in combination with new media technology.
5	1/2	Exemplary content	N/A	The exemplary contents include music, technology and music software.
7	6	Reference frame	N/A	The reference frame lists different types of instrumental music.
8	8	Reference frame	N/A	Expansion, deepening, personal focus areas.
8	8	Exemplary content	N/A	Own music productions without further details.

Table 4.5.: Relevant topics of music classes (AHS)

Crafting

Crafting classes (german *Technik und Design*) are only available in lower grades and introduce project-focussed learning for students. Delight of crafting, curiosity, motivation, self-esteem, self-initiative and frustration tolerance should be facilitated. Students should not work on prepared, fully instructed projects which do not exhibit any process- or researching focused learning. Experimenting kits and educational toolkits are suitable for

4.1. Allgemeinbildende Höhere Schule (AHS)

depicting factual connection towards technology. The relevant topics are shown in table 4.6. The application of microcomputers in first grade is not described further despite the call for usage of different materials and procedures. The provided supplementary applications can be embedded within all lower grades.

Grade	Label	Area	Topic and Content
1	Scope	Reflexion	Microcomputer
2	Scope	Reflexion	Games and Objects
3	Scope	Reflexion	Evaluation of products regarding material, function, form and build quality. Includes electronics, sensors and robots.
N/A	Supplementary Applications	Energy, Electricity and Electronics	Effect of simple electronic components such as diodes, transistors, LED etc.
N/A	Supplementary Applications	Product, Object and Games	Includes media, tools and repairing.

Table 4.6.: Relevant topics of crafting classes (AHS)

4.2. Neue Mittelschule (NMS)

In addition to the AHS grammar school the Neue Mittelschule (NMS) acts as second school type for lower grades. It covers the same age group as the AHS, with students aged 10 to 13 years. After graduating from NMS the further years of compulsory education in Austria can be completed in AHS (see section 4.1), vocational schools and apprenticeships. For NMS the same relevant subjects are available as for AHS. NMS specifies five different subject hour schedules with different focuses. All considered subjects (physics, basic digital education, music and crafting) share the same curriculum and topic intersections as the AHS curriculum specified in section 4.1.2. However, there are small differences for the specified subject hours (see table 4.7).[Republik Österreich, 2025]

Grade	Physics	Basic Digital Education	Music	Crafting
1		1	2	2
2	1	1	2	2
3	2	1	1 / 2 ^{b,c}	1 ^a / 2
4	1 ^a / 2	1	1 / 2 ^c	2

Table 4.7.: Comparison of mandatory subject hours per week for AHS and NMS

^a Applies for schedules with focus "language"

^b Applies for schedules with focus "music, arts and creativity"

^c Applies for schedules without focus

4.3. HTL Information Technology

For upper grades education a Höhere Technische Lehranstalt (HTL) provides domain-specific technic-focused curricula. Similarly to the AHS, the upper grade starts at the age of 14 years. However, instead of a 4 years upper grade, HTLs require 5 years program until the age of 18 years. In term of student age, the first grade in the HTL is similar to the fifth grade in the AHS. There exist 34 different technical domains of which two relevant school types were selected. Regarding the aspect of computer science, the HTL Information Technology was considered suitable. From the according curriculum the subjects Systems Engineering, Media Technology and Science were considered as relevant.[Republik Österreich, 2015a, Republik Österreich, 2016] The curriculum provides two specialization paths (media- and network technology) and one non-specialized path which exhibit different subject hours.

Grade	Systems Engineering *	Media Technology *	Science
Unspecialized path B			
1	3	2 (2)	3
2	5 (1)	2 (1)	2
3	5 (3)	2 (2)	2
4	6 (4)		2
5	10 (6)		
Specialized path B1 for network technology			
1	3	2 (2)	3
2	5 (1)	2 (1)	2
3	5 (3)	2 (2)	2
4			2
5			
Specialized path B2 for media technology			
1	3	2 (2)	3
2	5 (1)	2 (1)	2
3	5 (3)	2 (2)	2
4		8 (5)	2
5		12 (7)	

Table 4.8.: Mandatory subject hours per week (HTL IT)

* Hours in brackets apply for students enrolled in specific tutorials (see [Republik Österreich, 2016], p. 3).

Systems engineering

The subject systems engineering includes areas as electronics for IT, operating systems and industrial information technology. Table 4.9 lists all relevant topical intersections from the relevant electronics and industrial areas of the systems engineering subject.

4. Analysis of Relevant Areas in the National Education System

Grade	Term	Label	Topic and Content
1	1&2	Educational Task	Important principles of electrical engineering, electric measures and units. Understanding and evaluation of simple DC circuits. Basic wiring and passive components.
1	1&2	Syllabus	Electric measures and units. Principles of electrical engineering, DC technology, DC measuring technology, passive components in electrical engineering and basic circuits.
2	3	Educational Task	Area electrical engineering and electronics for information technology (in combination with physical units and phenomena). Description of sequential and DC circuits in digital technology. Description of computer system components.
2	3	Syllabus	Sequential digital technology, direct current technology and connected measuring, basic filter circuits.
2	4	Educational Task	Building up on previous term: Basics of semiconductor engineering and system components, analysis and evaluation of electric circuits.
2	4	Syllabus	Usage of basic circuits in components
4	7	Educational Task	Description of structure, functionality and applications of microcontroller systems in industrial IT.
4	7	Syllabus	Structure and functionality of systems of microcontrollers. Development of typical applications.
5	9	Educational Task	Deployment of microcontroller technology for network- and real-time suitable applications in industrial settings.
5	9	Syllabus	Deepening of microcontroller technology. Development and implementation of systems for specific requirements.

Table 4.9.: Relevant topics of system engineering classes (HTL IT)

Media Technology

The subject media technology includes multimedia applications, web-based applications, graphics and sound. It should prepare students such that they can create, edit and manipulate multiple types of media. The specialization path B2 (specifically for media technology) includes additional syllabus for image- and sound processing.

Grade	Term	Label	Topic and Content
2	4	Educational Task	Description of different in- and output devices for audiovisuals and their properties. Simple audio recordings and suitable external devices for audiovisual application.
2	4	Syllabus	Computer and external devices. Digital audio engineering, setup and application handling.
3	6	Educational Task	Usage of suitable tools for modification of audio and for audio production. Analysis and modification of raw media content.
3	6	Syllabus	Sound processing and optimization
4 ^a	7	Educational Task	Basic principles for sensitive human-computer interaction. Creation of sound-composing for creative, user centered application. Creation, analysis and evaluation of design concepts.
4 ^a	7	Syllabus	Basis of perception and audio design.
5 ^a	8	Educational Task	Analysis and debugging of hard- and software issues. Identification of appropriate state-of-the-art hard- and software for multimedia applications.
5 ^a	8	Syllabus	Deepening of multimedia hard- and software, including speakers, cables and audio jacks. Deepening of audio manipulation.

Table 4.10.: Relevant topics of media technology classes (HTL IT)

^a Only available for educational focus B.2

Science

The mandatory science class shares the same curriculum for all HTL types. [Republik Österreich, 2016] It contains important measures and units of STEM subjects, including physics, chemistry and biology. Table 4.11 shows that only the first grade contains relevant topics.

4. Analysis of Relevant Areas in the National Education System

Grade	Term	Label	Topic and Content
1	1&2	Educational Task	Simple physical experiments, comparison and measuring of values
1	1&2	Syllabus	Definition and measuring of units, resistance, voltage, power, capacity and energy

Table 4.11.: Relevant topics of science classes (HTL IT)

4.4. HTL Mechatronics

The second analyzed HTL specializes on mechatronics. The syllabus focuses on the intersection between electronics, mechanics and information technology. [Republik Österreich, 2015b] For the Mechatronics HTL the following subjects offered reasonable topic overlaps for investigation: Electronic engineering & electronics, Mechatronics systems & automation, Applied informatics & subject-specific IT and the HTL generics science class.

Grade	Electronic engineering & Electronics *	Mechatronics systems & automation	Applied informatics & subject-specific IT *	Science
1			2(2)	3
2	3(1)		2(2)	2
3	4	2	2(1)	2
4	3	3	2(1)	2
5	2	3	2(1)	

Table 4.12.: Mandatory subject hours for per week (HTL Mechatronics)

* Hours in brackets apply for students enrolled in *electronic data processing* tutorial classes

Electronic engineering & electronics

Table 4.13 lists all relevant topical intersections of the subject systems engineering. Main goals of the subject contain basics of electric engineering, electric networks and different types of circuits. Error finding and resolving within electronic components and circuits is also mentioned explicitly.

Mechatronics systems & automation

The subject mechatronics systems and automation includes measuring, units and sensors. The relevant syllabus is presented in table 4.14.

Grade	Term	Label	Topic and Content
2	3	Educational Task	Basic units and principles of electronic engineering.
2	3	Syllabus	Direct current, Ohm's law, power, energy, circuits of resistors.
2	4	Educational Task	Basic units and principles of direct current. Calculation for direct current circuits.
2	4	Syllabus	Direct current resistors.

Table 4.13.: Relevant topics of electronic engineering and electronics classes (HTL Mechatronics)

Grade	Term	Label	Topic and Content
3	5	Educational Task	Measuring of electronic units.
3	5	Syllabus	Measuring voltage, resistance and current.
3	6	Educational Task	Selection of appropriate sensors for measuring electric units.
3	6	Syllabus	Selection and usage of appropriate measurement methods.

Table 4.14.: Relevant topics of mechatronics systems and automation classes (HTL Mechatronics)

4. Analysis of Relevant Areas in the National Education System

Applied informatics & subject-specific IT

The relevant informatics syllabus (see table 4.15) involves microcontrollers within fourth and fifth class. Relevant topics mostly relate to programming, program analysis and testing. Signal processing is also included as a fundamental topic.

Grade	Term	Label	Topic and Content
4	7	Educational Task	Interpretation of analog and digital signals for process systems.
4	7	Syllabus	Analog and digital signal (processing). Structure, commands and external devices of microcontroller.
4	8	Syllabus	Human-computer interaction for data capture & processing
5	9	Educational Task	Analysis, testing and writing of programs for microcontroller.
5	9	Syllabus	Embedded programming for microcontrollers. Realization of simple controls.
5	10	Educational Task	Analysis, testing and writing of programs for microcontroller.
5	10	Syllabus	Interconnected software for process periphery. Software for real-time usage.

Table 4.15.: Relevant topics of the class applied informatics and subject-specific IT (HTL Mechatronics)

Science

As the science subject is a common subject for all HTLs, it shares the same details as the science class mentioned in the section 4.3.

4.5. Summary of Curricular Findings

The Austrian education system accommodates a variety of different school forms, including AHS, NMS and higher technical schools (HTL). For a common baseline, only non-school-autonomous curricula were analyzed. Thus, school-autonomous educational institutions may allow deviations from the outcomes of this analysis.

The analyzed curricula exhibit significant differences within their overall structure and contents. Only the NMS curriculum was rather similar to the AHS curriculum for lower grades. In general, the curricula documents included different layers of topical abstraction and educational labels. Given the structural differences between the curricula, a direct comparison between the schools curricula is not reasonably applicable. However, although the syllabus structure differs, the curricular topics for the respective grades in the different

4.5. Summary of Curricular Findings

schools were successfully extracted and presented in a generic overview.

Regarding relevant subjects, lower grades in AHS and NMS share a similar syllabus for the analyzed subjects, while both investigated HTLs did not share any subjects besides the generic science class. For all investigated school types, subject hour deviations were found according to different subject focuses, topical paths or elective subjects. Nevertheless, the relevant subject hours for the different grades were also successfully extracted.

Concerning the contentual explicitness, all curricula allowed a broad range for interpretation. This makes justification of STEAM-oriented LEGO DMIs in classes considerably reasonable, but may also cause textual ambiguity.

5. Brick-Based DMI Prototyping

Following the analysis of the curricula, a general proof-of-concept study for a new DMI layout was necessary. The instrument was conceived in an electronically-engineered manner, ensuring that the instrument can be recreated rather easily by amateurs (in contrast to many VR- or robot based approaches). The development was based on electronic prototype concepts similar to the work of Barbancho et al. and the *Playel*. [Barbancho et al., 2024, Hödl, 2024] To create such a new DMI the following steps were performed:

1. **Review of existing DMIs:** Before developing new ideas, existing instrument prototypes were compared. Although not exclusively, investigation focused on electronic DMIs as described in section 2.2.3.
2. **Sketching of conceivable technical approaches:** After investigating and comparing technical layouts of existing DMIs, first technical drafts were constructed. This included analysis of LEGO and DUPLO blocks and brainstorming for solutions using different conductive materials.
3. **Development and testing of technical approach:** Before designing a concrete DMI layout, the technical drafts needed to be tested. This mainly focused on establishing stable electric circuits, ensuring that there exist measurable values (i.e. resistances). Due to the requirements defined in section 5.1 this step was time-consuming and error-prone. This step also included a bare-minimum software script development for measuring electric values.
4. **Integration into a hardware DMI layout:** After a determine technical approach for connectivity and preliminary wiring was found, the small-scaled approach was integrated into a DMI layout. This included optimizing work-steps for production, rearranging components for simple recreation and manufacturing of additional necessary components.
5. **Software development and continuous testing:** Based on the previous steps, a suitable and comprehensive software was developed. This included a solid backend application as also a user-friendly front-end user interface (UI). The software development was accompanied by continuous hardware- and software testing.
6. **Additional software features:** After the DMI hardware was assessed stable, new software features (solely digital) were implemented, expanding the software with additional functionalities.

Steps two to five were repeated upon partially failed attempts within prototyping.

5. Brick-Based DMI Prototyping

5.1. Requirements

Within developing possible DMI prototypes, specific restrictions and requirements applied within the scope of this thesis. This included:

- **Technical Feasibility:** The DMI should be designed in such a way, that amateurs or non-engineers are able to rebuild the instrument without major obstacles. This includes material availability and technical practicality.
- **Stability:** The instrument should capture and measure precisely enough to allow a stable note output.
- **Costs:** The material and (if necessary) additional tool costs should lie within a reasonable range. The estimated budget lays between 40€ and 100€.
- **Portability:** The assembled DMI should be suitable for transportation, restricting the overall amount and size of built-in materials.

5.2. Design Progress

The process of designing, prototyping and developing the DMI was performed between February 2025 and December 2025. This section will describe the progression of the prototypes and compare different intermediate stages of development. At the beginning, no specific form of instrument was preferred. However, after some first testing and prototyping (as described in the following sections), the sequencer layout was considered as most appropriate and suitable form of instrument due to its simple structure. The usage of a sequencer layout is generally not considered new, but has already been used for various other DMIs. [Barbancho et al., 2024, Gold et al., 2025, Shapiro et al., 2016, Oestermeier et al., 2015, Miotti et al., 2022, Waldhör et al., 2024]

5.2.1. LEGO Brick-Based Resistance Sequencer

As a general concept, a resistor-based approach using an Arduino Nano Every¹ (with Headers) was selected. The first prototype used LEGO bricks, which are placed next to each other with resistors and conductive copper tapes. At the end- and start bricks, some connecting brick or cable would be attached to get a connected circuit. In the end, each "column" of connected LEGO bricks should represent one note. Putting multiple bricks next to each other in a column would increase the resistance and thus the calculated pitch. For all brick columns, one shared 5V source brick (or similar connecting source) should be used. Each note column needs one separate outgoing cable at the end. Outgoing cables were connected to a breadboard. A full description on the breadboard wiring is available in section 5.3.2. For simplicity, only bricks with a size of 2x2 and 2x4 pins were selected. Respectively to the multiplication factor of note heights, bigger bricks

¹<https://docs.arduino.cc/hardware/nano-every/>

needed built-in resistors with higher Ohm (e.g. a 2x2 brick needed 1kOhm and a 2x4 brick 2kOhm). The first prototype used alligator clamps-based end connectors and is depicted in figure 5.13.

Brick-To-Brick Connections

At first, a sufficiently stable connection between bricks needed to be established. Six different types of connective bricks were evaluated. The first idea (see figure 5.1), using conductive tapes without embedding resistors, was discarded at the beginning because no measurable resistances were exposed. Other approaches involved gluing or placing resistor together with conductive tape inside the LEGO bricks. Additional aluminum foil was used for fixating resistors for specific tests. Resistor placement was done in two different ways: Placing them through drilled holes in the brick (figures 5.2, 5.3 and 5.4) and by taping them within the brick (figures 5.5 and 5.6). Putting the resistors through small drilled holes was found to lead to severe issues in connectivity. Usage of taped wires inside the bricks was easier to manufacture and led to more stable resistance values. Although the electrification of bricks was considered rather easy regarding tools and required preknowledge, the overall electrification of LEGO bricks was laborious and detailed due to the small size of bricks.

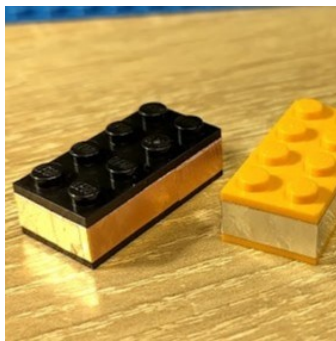


Figure 5.1.:
Side-wise surround tape
without resistor



Figure 5.2.:
Drilled horizontal vis-à-vis
connection

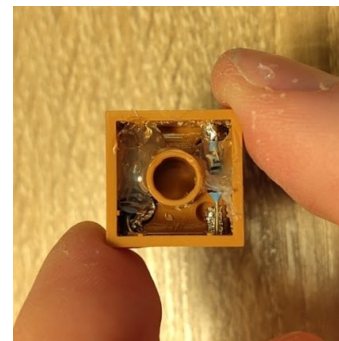


Figure 5.3.:
Double drilled horizontal
vis-à-vis connection

5. Brick-Based DMI Prototyping

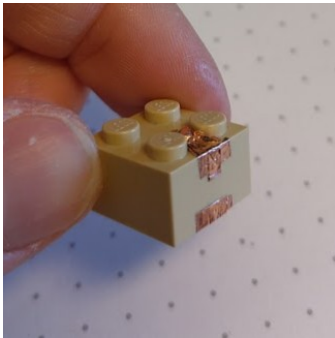


Figure 5.4.:
Drilled vertical
connection

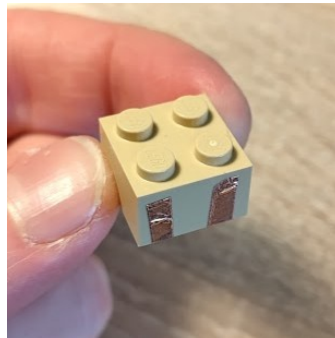


Figure 5.5.:
Taped horizontal
same-side connection



Figure 5.6.:
Taped horizontal vis-à-vis
connection

Brick-To-Arduino Connections

In the next step, start- and endpoint connections to the Arduino needed to be established. Thus, bricks needed to be connected to jumper wires (which fit the Arduino manufactured headers and the breadboards). For this, two types of brick connections were tested: Conductive tape based connections which required alligator clamps to connect (figures 5.7, 5.8 and 5.9) and bricks with jumper cable compatible wire extensions (figures 5.10, 5.11 and figure 5.12). After all connecting brick types have been tested extensively, approaches including wires were found to be too fragile. However, tape based alternatives with alligator clamps were also found to be bulky within usage. Overall, relative to the size of usual LEGO bricks the amount of wires (protruding above the LEGO board) seemed irritating and impractical for (re-)placing bricks. This issue is noticeable in figure 5.13.



Figure 5.7.:
Glued nickel-tape
extension



Figure 5.8.:
Angled glued nickel-tape
extension

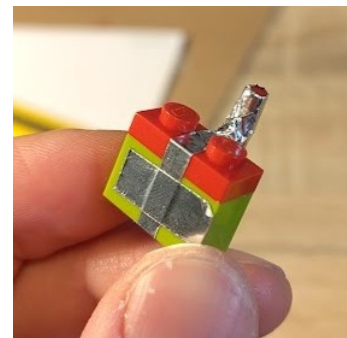


Figure 5.9.:
Tape-only
brick extension

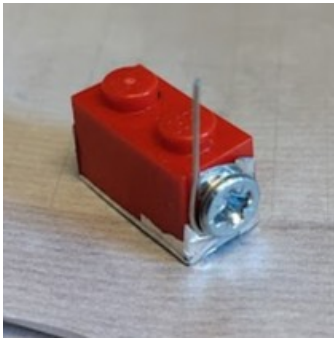


Figure 5.10.:
Side-screwed cable
connection

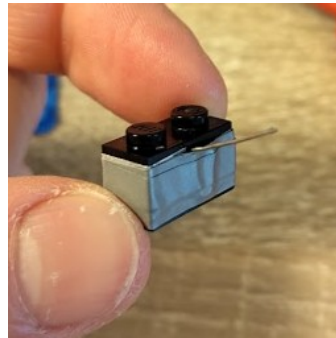


Figure 5.11.:
Taped wire extension

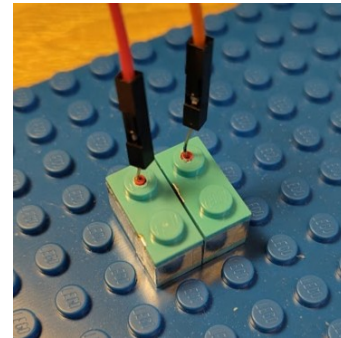


Figure 5.12.:
Top-drilled & inside taped
extension

Interim Findings

Development and prototyping of the first LEGO brick-based sequencer provided important insights in how bricks and the Arduino can be connected. Although the concept as general seemed encouraging, overall resistance values (and consequential note pitches) fluctuated disproportionately much due to the small connecting surfaces. Additionally, because of the small size, the electrification of LEGO bricks required very precise and patient handcraft.

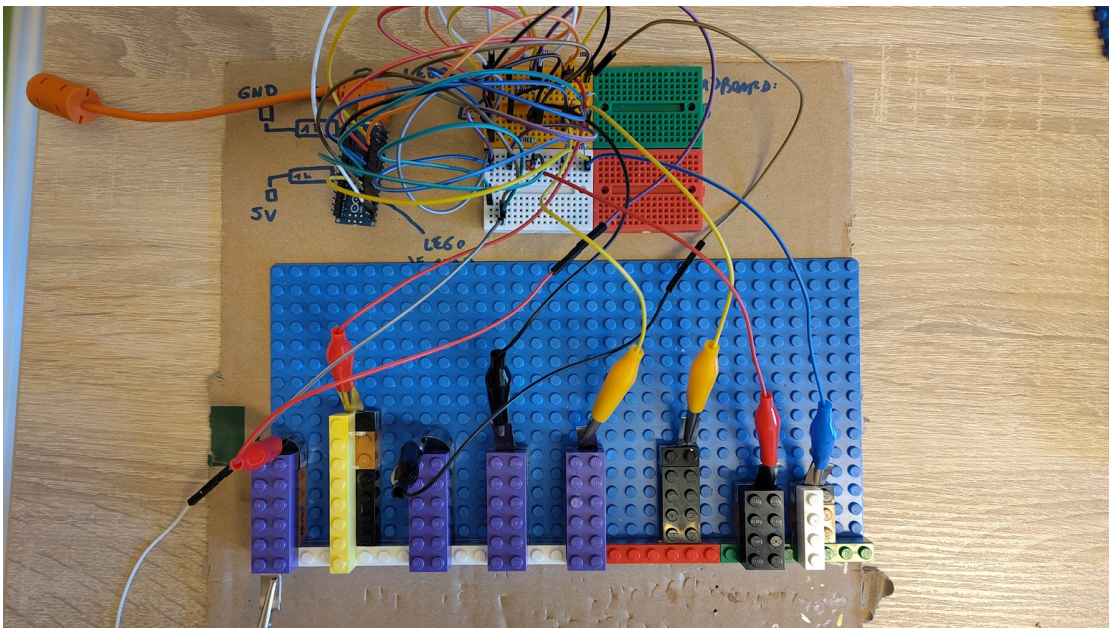


Figure 5.13.: First sequencer prototype using alligator clamps and taped bricks

5. Brick-Based DMI Prototyping

5.2.2. LEGO Tactile-Switch Sequencer

After the first prototype was examined, the prototyping process continued for finding a more stable and functional LEGO based sequencer. In this step, an alternative solution for measuring brick positions was tested. Instead of using resistor-based circuits, a tact switch based setup was created. For this prototype, holes were drilled in the LEGO plate. Eight beats (columns) with each eight pin holes (respective pitch) were prepared beforehand. Bricks were mounted with a small downwards facing screw. Upon placement, the bricks screw protruded through the hole in the LEGO plate. Underneath the LEGO plate, tact switches were mounted which would then be pressed by the bricks screws. This did not only enable more stable results (on/off switch instead of error-prone resistance values), but also allowed playing multiple notes per column. The instrument interface is depicted in figure 5.14. Regarding the software and user interface (UI) the second prototype used a JS and Python based dashboard instead of the previously used solely Python-based UI.

Hardware Setup

Compared to the previous prototype, this attempt did require a much more complex hardware and wiring setup. Usage of breadboards and an Arduino alone was not sufficient due to the large number of tact switches. Specifically, as the Arduino Nano Every only exposes 8 analog pins, the amount of 64 incoming cables needed to be multiplexed beforehand. Therefore, four MCP23017 multiplexers were used. Although sufficient soldering equipment was available, mounting the headers onto the multiplexers took multiple days and was not considered doable by amateurs without further expertise. Corrupt soldering points led to short circuits and heat generation of the multiplexers several times. Thus, this step is generally not recommended without prior knowledge on advanced soldering or without higher class tools. As the tact switches needed to be mounted underneath the LEGO plate, an additional construct was required to hold the ground plate and switches. For this, a custom cut wooden construct was designed. Underneath each hole in the LEGO plate, a slightly bigger hole (matching the tact switch size) was drilled in the upper wooden plate. Underneath, the switches were soldered to a bunch of wiring harnesses, leading to the multiplexers and breadboards. Each tact switch required 2 solder points for the wires. Thus, around 128 cables needed to be mounted. This process took about two weeks until completion. The final wiring construct is visible in figure 5.15.

Interim Findings

Overall, the tact-switch sequencer led to better results regarding stability. Although not all tact switches returned the correct results, the instrument allowed stable playing with the plugged in bricks. However, during prototype development, it became apparent that the instrument violated some of the requirements specified in section 5.1. Especially the requirement for technical feasibility was not met, as amateurs would not be able to create the instrument within a reasonable amount of time.

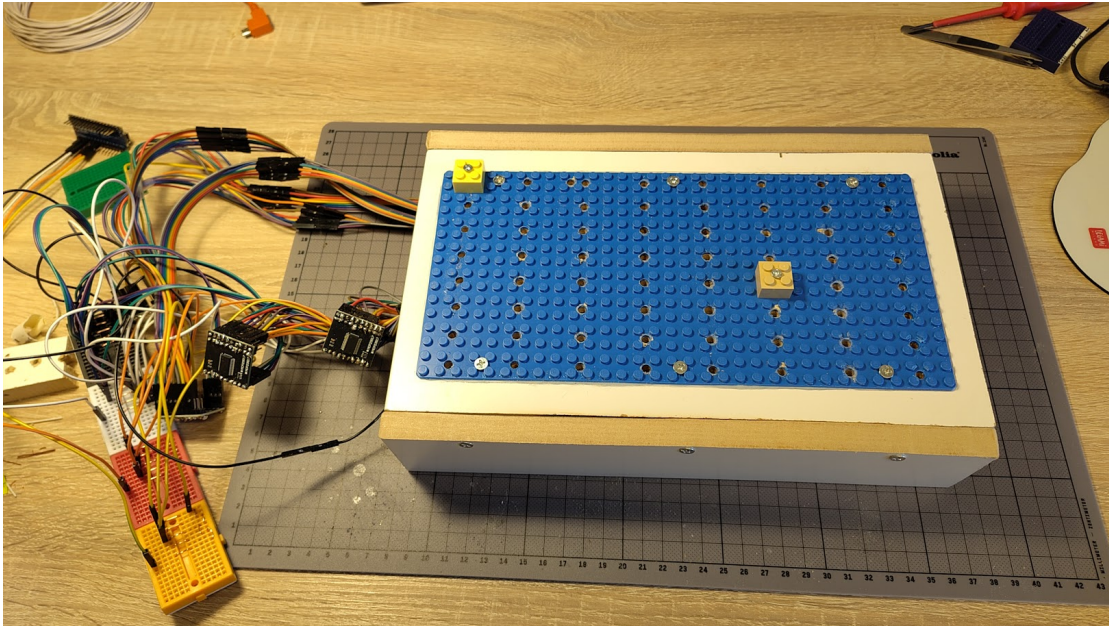


Figure 5.14.: Upper (user) view on the tact switch based prototype with two notes

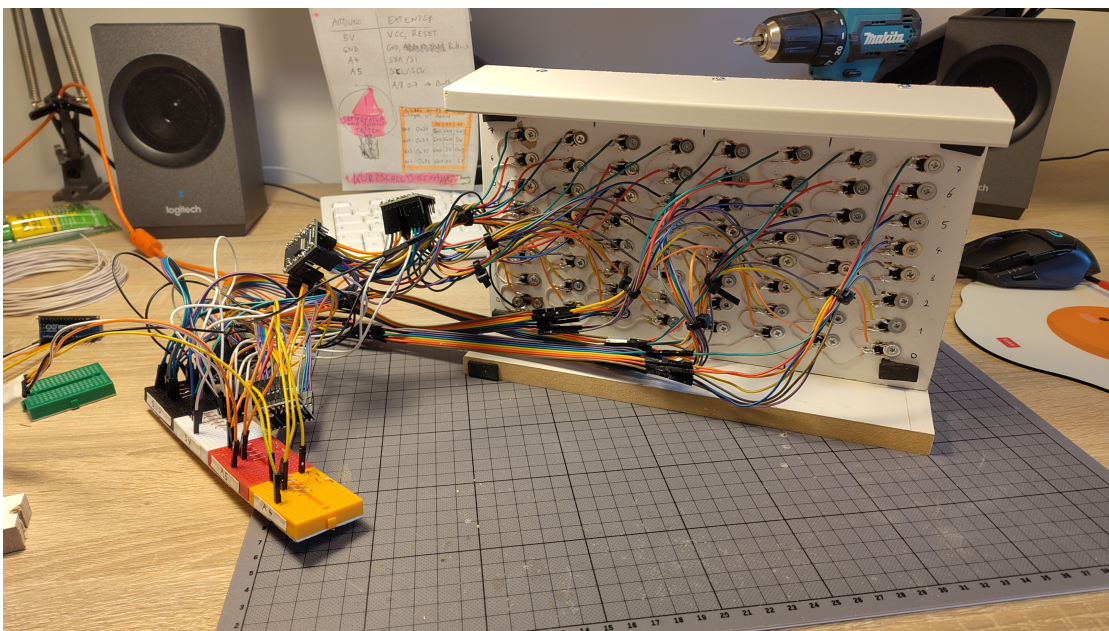


Figure 5.15.: Lower view on the tact switch based prototype

5.3. The AudioBrix Instrument

The AudioBrix instrument is the last prototype and the final stage of this project. While prototyping and testing the previous instrument designs (see section 5.2.1 and 5.2.2) no sufficient outcome was achieved: The first attempt led to a rather simple, but unstable prototype while the second prototype worked stable but was overly complex. Thus, an instrument form was needed that matches the simplicity of the first approach, but also exhibits the stability of the second approach. As LEGO bricks are small and difficult to process, the usage of bigger DUPLO bricks was selected.

DUPLO bricks offer the similar characteristics as common LEGO bricks. However, their bigger size (four times bigger than LEGO bricks) makes it easier to connect and construct a suitable DMI. Furthermore, DUPLO is made for smaller children, leading to a reduced grip strength required to pick up and replace bricks. This makes DUPLO a preferred brick choice for the DMI interface.

5.3.1. Instrument Layout

The final AudioBrix instrument builds on the first resistance-based sequencer. However, it has been refined in multiple ways, making it easier to construct, more robust and more convenient for playing. In total, the instrument consists of multiple types of electrified DUPLO bricks, the necessary wiring and a prepared DUPLO ground plate. Exemplary instruments are shown in figure 5.16. Visualizations from this section are taken from the user manual (see appendix A.1). In the following, the instrument layout and technical background is described.

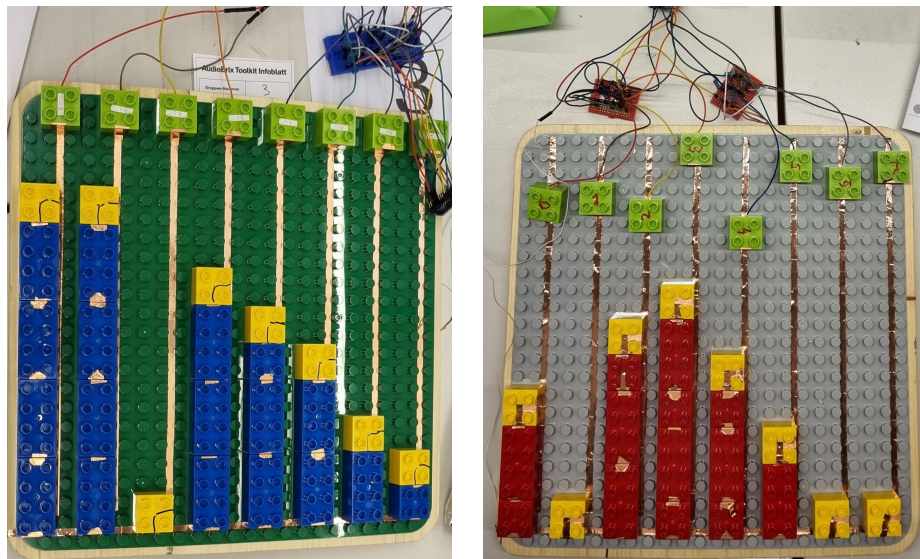


Figure 5.16.: Assembled AudioBrix instruments from the workshop in section 6

Ground Plate

The ground plate is a 24x24 pin sized plastic plate. Due to the malleable properties of the ground plate, the plate curves slightly when bricks are placed. To avoid this, the plastic plate was glued to an additional wooden plate using epoxy glue. On top of the ground plate, nine separate stripes of conductive copper tape were put on the plastic plate. One vertical stripe acted as the 5V power lane while the other eight stripes were used for collecting the column (beat) resistance values. At the edge of the vertically placed 5V power lane a small screw was mounted, touching the 5V power lane. To connect the screw with the Arduino, a copper cable was squeezed between screw and conductive tape.

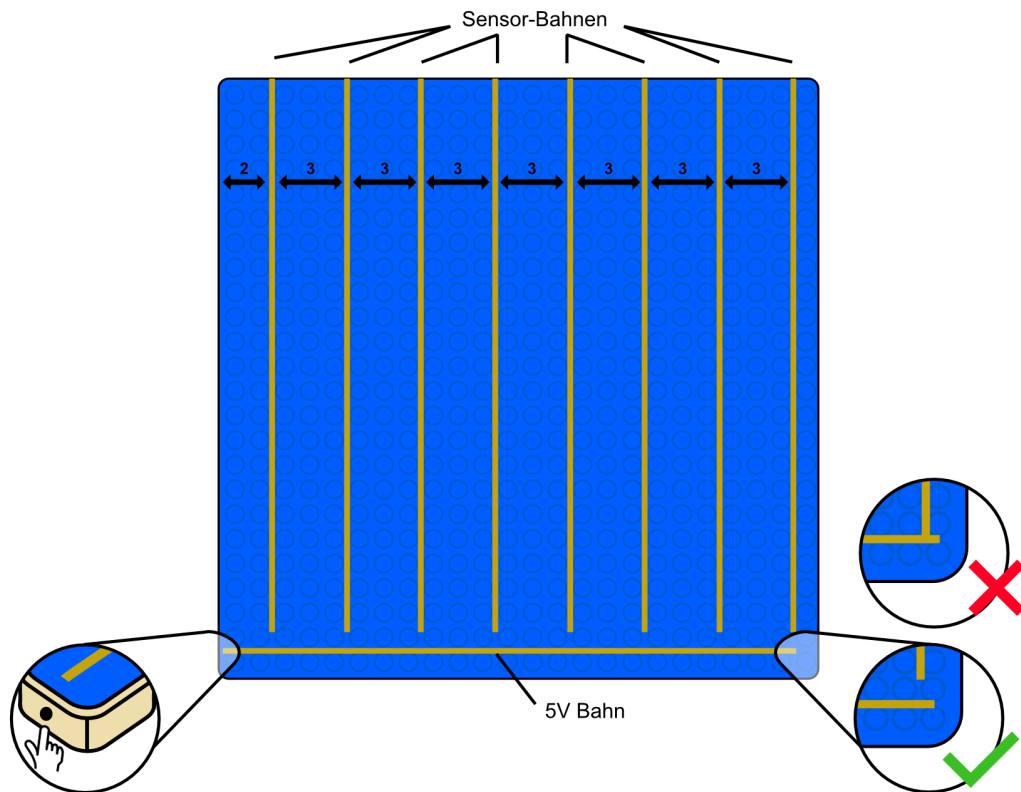


Figure 5.17.: Visualization of the electrified ground plate

5. Brick-Based DMI Prototyping

Electrified Bricks

There exist three different types of electrified bricks which are depicted in figures 5.18, 5.18 and 5.20.

1. **Note Bricks:** Most bricks required to play the instrument are *Note Bricks*. Inside of these bricks (which can be 2x2 or 2x4 pins sized) a corresponding $1k\Omega$ or $2k\Omega$ resistor is placed. At brick creation, aluminum foil is pressed into the bricks to fixate the resistors and increase conductivity. The outer and inner sides of the bricks are connected over the bricks bottom edge using conductive tapes. Placing multiple note bricks next to each other causes an overall increased resistance at the end of the column.
2. **Bridge Bricks:** All bricks within one column (beat) must be placed such that the right edge touches the conductive stripe (for simplicity it is called *sensor lane*) on the ground plate. This allows a separation of the conductive tapes of the note bricks from the sensor lanes. Thus, to connect the circuit without skipping resistors, so called *Bridge Bricks* are used. These bricks do not contain any resistors or other wiring. They only connect one side of the note brick to the bottom side of the sensor lane.
3. **Sensor Bricks:** At the end of each sensor lane, a *Sensor Brick* is placed. It contains aluminum foil and conductive tape similar to the note bricks on one side. On the other side, a male jumper wire is put through a drilled hole. The jumper wire is then pushed into the aluminum foil and fixated using hot glue. This creates a connection between jumper cable and tape surface. The jumper cable of the sensor brick is then connected to the breadboard.



Figure 5.18.:
Note brick
containing a resistor

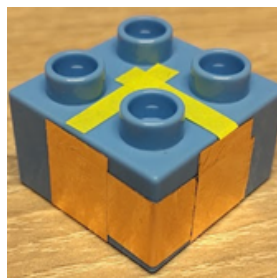


Figure 5.19.:
Bridge brick with
direction annotation



Figure 5.20.:
Sensor brick with
inserted jumper cable

5.3.2. Breadboard Wiring

To connect the sensor bricks to the Arduino, multiple voltage dividers are required. Each voltage divider connects the cable to the sensor brick, a jumper cable to the matching Arduino analog pin and a cable leading to the Arduino's GND. Each voltage divider requires one $2k\Omega$ reference resistor. To avoid losing track of the current voltage dividers, the eight required voltage dividers (one for each beat/sensor brick) are separated onto two interconnected breadboards. The wiring plan is depicted in figure 5.21.

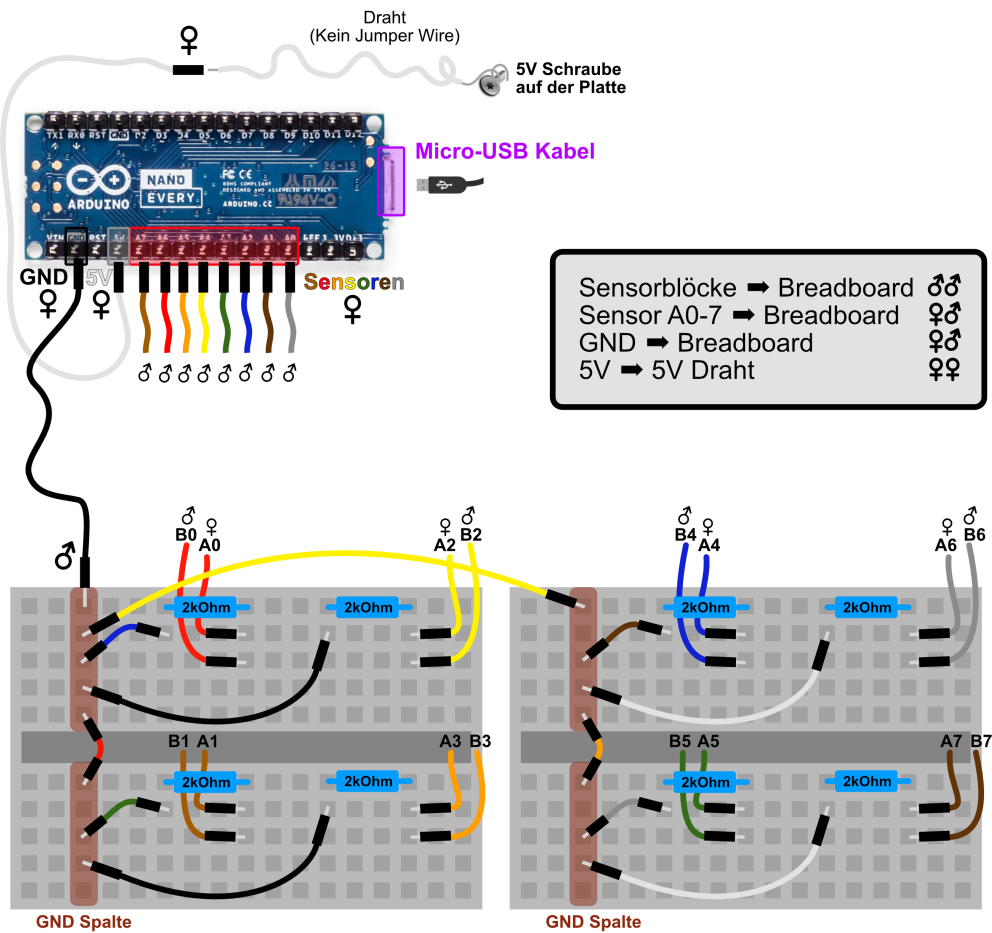


Figure 5.21.: Visualization of the breadboard wiring

5. Brick-Based DMI Prototyping

5.3.3. Required Materials

The Arduino Instrument follows a lightweight construction concept. Its corpus mainly consists out of simple materials. To assemble the AudioBrix instrument, the materials from table 5.1 are required. The total costs were calculated based on the order of materials for the workshops from section 6. The overall price of one toolkit unit depends on the overall quantity of ordered toolkit materials. Thus, the purchasing price could be lower in production.

Description	Amount	Total Cost
Wooden plate	1	7.2 €
DUPLO plate	1	9.83 €
Felt pad	4	0.32 €
Epoxy glue	N/A*	2.72 €
Clear coat	N/A*	2.12 €
Copper Tape (Broad)	290 cm	1.78 €
Copper Tape (Thin)	320 cm	1.33 €
Arduino Nano Every	1	15.7 €
DUPLO bricks	40	11.6 €
Breadboards	2	4.69 €
Screw	1	0.03 €
Micro USB cable	1	2.3 €
Wire	40 cm	0.09 €
Resistors 1k Ω	7	1.04 €
Resistors 2k Ω	33	4.16 €
Aluminum foil	2.5 m	0.17 €
Jumper wires	40	3 €
Sum		65.07 €

Table 5.1.: Listing of material and costs of the AudioBrix instrument

* Depends on available units and artisanal properties

5.3.4. Software

The required software for the DMI is a Python based application. First prototypes were solely based on Python for back- and frontend. Later prototypes (including the final AudioBrix Software) used Python and FastAPI as backend with JavaScript as frontend application. The application repository is available online.² At last, the software handled:

- Capturing and rounding of resistance values
- Mapping resistance values to notes
- Playing of the sequencer loop
- Visualization of notes as note sheet and brick table
- Changing MIDI instrument sound and speed of playing
- Skipping beats for unstable note columns
- Log and error presentation

The main dashboard is shown in figure 5.22, depicting the visualization of notes and the user interface. The user interface is currently only available in German. The application is highly customizable, including the following settings (excerpt):

- Settings for Arduino connection, including port and baudrate
- Limits for note beats and maximum pitch (which should correspond to the ground plates size)
- Configuration of external OSC-compatible applications (e.g. SonicPi³ or other DAWs) for bypassing the internal sound engine
- Configuration of the brick table visualization

The Arduino IDE⁴ was used for programming the Arduino. The functionality of the Arduino code was minimized to put most of the configuration into application settings. However, changing the baud rate still requires adapting and re-uploading the Arduino sketch (see listing 5.1). The Arduino Script solely measures and calculates the resistance values and sends them as JSON messages to the AudioBrix application.

²<https://github.com/waldhoer/majorbrix>, last accessed on 17.04.2026

³<https://sonic-pi.net>, last accessed on 17.04.2026

⁴<https://www.arduino.cc/en/software>, last accessed on 17.04.2026

5. Brick-Based DMI Prototyping

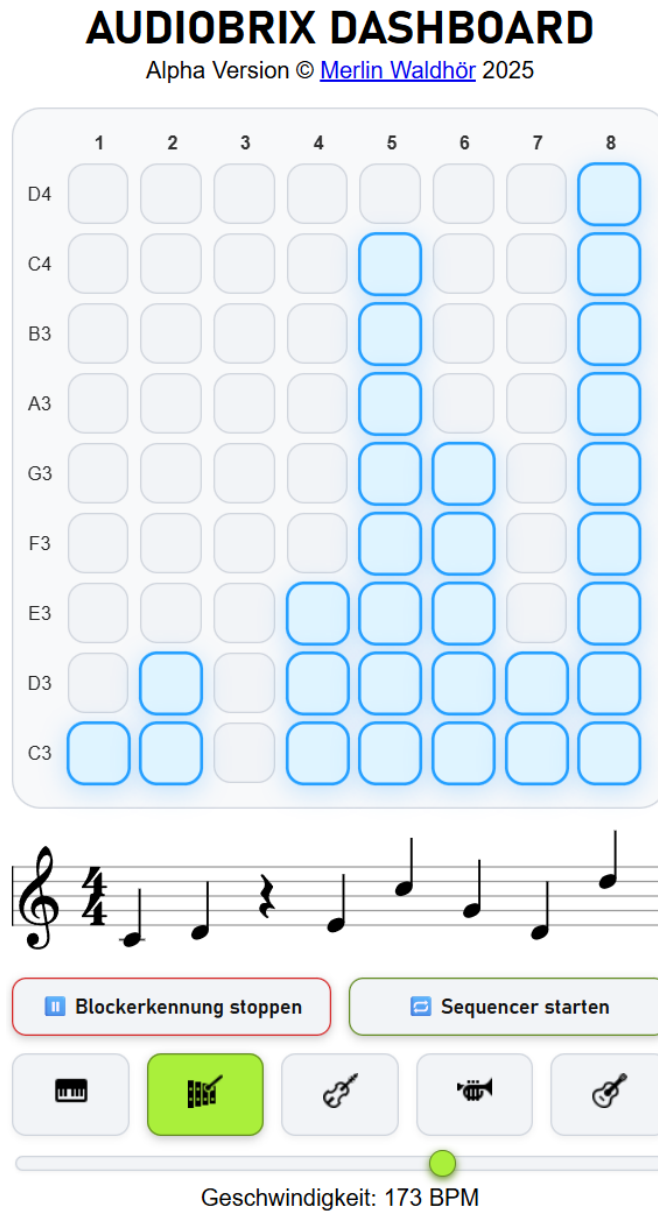


Figure 5.22.: Main dashboard of the AudioBrix application

```

1 void setup() {
2   Serial.begin(115200); // must match the AudioBrix settings
3 }
4
5 #define START_VOLTAGE 5.0
6
7 const int sensorPins[] = {A0, A1, A2, A3, A4, A5, A6, A7};
8 const int numSensors = sizeof(sensorPins) / sizeof(sensorPins[0]);
9
10 const float knownResistor = 10.0; // Reference resistor
11
12 void loop() {
13   String result = "[";
14   for (int i = 0; i < numSensors; i++) {
15     int sensorPin = sensorPins[i];
16     int sensorValue = analogRead(sensorPin);
17     float voltage = sensorValue * (START_VOLTAGE / 1023.0);
18     float resistance = (voltage > 0) ? (knownResistor * (START_VOLTAGE -
19       voltage)) / voltage : 0;
20
21     result = result + "{ \"Volt\": " + String(voltage, 4) +
22       ", \"Resistance\": " + String(resistance, 2) +
23       ", \"Sensor\": " + String(i) + String((i==numSensors-1) ?
24       \"}\" : \",\");
25   }
26   Serial.print(result+"];");
27   delay(150);
28 }

```

Listing 5.1: AudioBrix Arduino sketch

5.4. AudioBrix as Toolkit

The AudioBrix instrument was designed for easy and autonomous assembly in schools. To embed the instruments corpus and concept as educational tool, the AudioBrix toolkit accommodates:

- Packaging and organization of material
- Auxiliary materials
- Instructions on necessary work tools

In figure 5.23, the compact design of the AudioBrix toolkit is presented. Within the scope of this thesis, a shared packaging box was used for transporting multiple toolkits. However, for a potential rollout in schools, separate boxes should be considered to avoid confusion during classroom distribution. For each toolkit, multiple materials need to be separated into appropriate amounts (e.g. tapes and foil need to be cut into required sizes). Bricks should be grouped such that bridge, sensor- and note bricks differ in color. Additionally, the color of the ground plate should differ from the color of the bricks.

5. Brick-Based DMI Prototyping

Besides the included instrument materials, the toolkit requires basic tools such as scissors, hot-glue guns, (optionally) gloves and permanent markers. In general, the required tools are commonly available in schools or can be brought by students without extra costs.



Figure 5.23.: Multiple AudioBrix toolkits in a shared packaging

6. Evaluation with Future Teachers

To examine the prototypes functionality, educational potential and overall toolkit quality, a user evaluation with student teachers was performed. The evaluation aimed not only to assess the pedagogical impact, but also led to new insights on how the instrument and toolkit could be improved in the future. This included feedback regarding the assembly process, clarity of the user manual, didactic suitability, material selection and software functionality.

6.1. Procedure and Analysis

A user study was conducted as workshops on two dates in January 2026 within the course "Design Thinking"¹ at the Faculty of Computer Science at the University of Vienna. For both workshops, one similar looking seminar room was used. 21 lectureship students, of which also non-computer science students were included, participated in the workshop. For each date of the user study, the participants worked together in groups of 3 to 4 students. For both dates, there were three groups of three students and three groups of four students. All group members remained the same across the two workshops, except for one group in which one participant from the first session was replaced by a different participant in the second session. Each group had one big table for working together. Required tools and materials were provided for all groups. On both dates, background music was played (which was also asked by a student) for a pleasant working experience. For both workshops, anonymised photographic documentation was performed in compliance with the participants approval. Figure 6.1 shows the participants in the working environment of the workshop.

The detailed procedure of the two workshop dates took place as follows:

- **Day 1:** The first workshop was performed on Friday, 16.01.2026 and took 3 hours. Beforehand, required materials and the seminar room were prepared. At the beginning, an introduction into the topic of STEAM education, digital music instruments and the structure of the user study was given by the supervisors. Afterwards, the toolkit materials were distributed for the groups. On the first day, students completed the electrification of the ground plate and the different bricks (see section 5.3.1). At the end of the workshop, all separate toolkits were stored in the faculties office building.

¹<https://ufind.univie.ac.at/en/course.html?lv=051972&semester=2025W>, last accessed on 21.05.2026

6. Evaluation with Future Teachers

- **Day 2:** The second workshop was performed one week later on Friday, 23.01.2026 and took 2.5 hours. Although students were already familiar with the topic, the next steps of the assembly were recapitulated at the beginning of the second session. On this date, the students were asked to complete the wiring, software setup and playing of the instrument. Afterwards, an anonymised online user survey was performed on-site.

The results of the workshop were gathered from

- Written supervisors observations
- Verbal feedback from participants
- Written feedback from participants in user manuals
- Quantitative data from the user survey (empirical)
- Qualitative data from the user survey (free text)

Within the survey data analysis, empirical questions and free-text questions were separated. One participant aborted during the survey and did not complete all required questions. Due to the small sample size, partially completed responses were kept whenever possible, while only invalid or incomplete answers for specific questions were excluded from further analysis.

The qualitative data was analyzed using the QDA-Miner² tool and was refined in an iterative coding and category refinement process. Afterwards, an exploratory data analysis (EDA) was conducted for both quantitative and qualitative data. For the quantitative data, descriptive statistical values, including mean values and standard deviations, were calculated. Bar charts were used to identify trends, outliers or potential correlations within the data. Furthermore, a possible correlation between the demographic details on musical and engineering skills and empirical data was assessed within the EDA. Observations, hand-written notes in the user manuals and verbal responses were used to contextualize and complement the survey data. The collected findings were used to illustrate specific results from the user survey and creative ideas regarding the instrument concept. Redundant outcomes which did not provide additional insights for the previously analyzed survey data were not assessed further.

²<https://provalisresearch.com/products/qualitative-data-analysis-software/freeware/>, last accessed on 21.05.2026



Figure 6.1.: Participants working on the instruments (second day)

6.2. Results

6.2.1. Instrument Manufacturing

The participants worked on the instrument based on the instructions from the AudioBrix user manual. While the overall feedback on the user manual was positive, some participants declared parts of the user manual as confusing. Specifically, the block- and color coding inconsistency (i.e. page 14 and 22 in appendix A.1) was criticized for making the assembly and wiring confusing. This feedback was also brought to the supervisors by the participants and marked within some user manuals. Still, the user manual was perceived very supportive by 57% of the students and useful by 33%. Regarding the technical debugging, some participants mentioned missing details in the FAQ section. The accumulated feedback on the user manual is shown in figure 6.2.

Overall, the participants enjoyed the crafting and assembling of the instrument. The working environment and team work was considered relaxed and pleasant. This was not only confirmed by the survey results as depicted in figure 6.3, but also mentioned verbally by some participants. The handicrafts and assembly of the AudioBrix instrument itself was perceived rather easy by 62% of the participants. Still, 35% of the participants mentioned that the assembly of the instrument was very sensitive or laborious.

Although there were technical issues as mentioned in section 6.2.2, participants appreciated the debugging, troubleshooting and experimenting with the instrument (see "Instrument building & playing" in figure 6.3). Experimentation with the instrument outside the scope of the user manual was also mentioned as interesting by some participants. An exemplary experimentation of students is visible in figure 6.4. Regarding the necessary materials and available tools, both workshop days took place without major issues.

6. Evaluation with Future Teachers

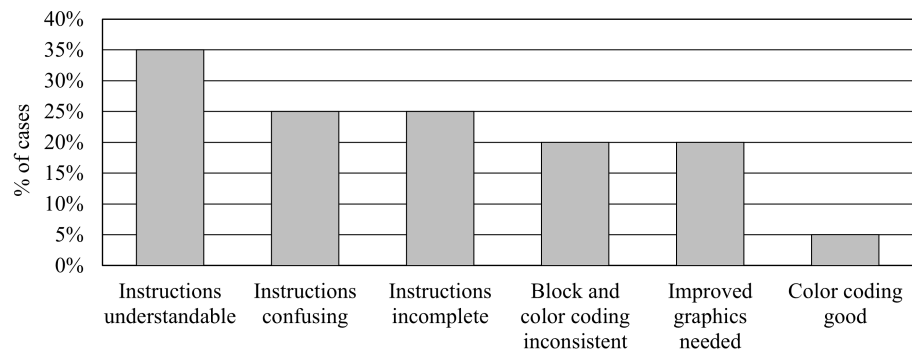


Figure 6.2.: Percentage of cases where auxiliary material is mentioned in free text forms

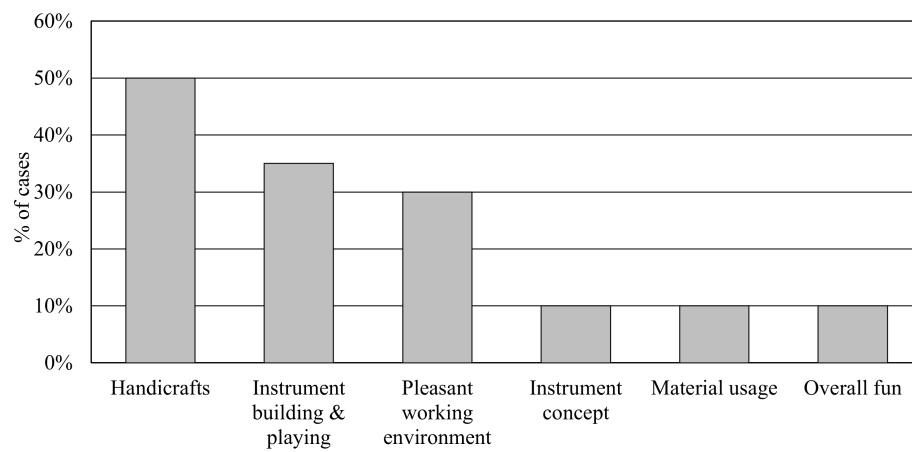


Figure 6.3.: Percentage of cases on what the workshop participants liked the most

However, some groups were missing additional toolkit materials and specific tools were requested from the supervisors multiple times. Figure 6.5 shows the respective survey feedback on materials and tools. In detail, three groups required additional conductive tape for assembling the note bricks and four groups needed some additional resistors. Missing materials were compensated from the additional and replacement materials by the supervisors. Additionally, some students proposed alternative materials like differently colored breadboards or thicker copper tapes in the user survey. Although some groups needs for tools overlapped in time, required tools (which were not available per group) rotated through the room without issues. For one group, there also occurred problems due to a defective cable. This led to some intermediate frustration, but was fixed by an alternatively provided Arduino and USB cable.

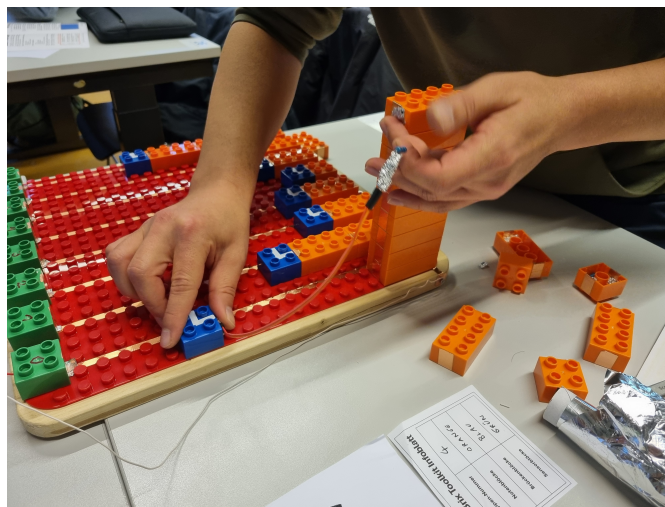


Figure 6.4.: Students experimenting with the instrument

The workshop schedule was followed as planned, and the intended time span of approximately three hours per session was not exceeded. On the first day participants read the user manual, prepared the bricks, and assembled the base plate. In total, the groups worked on the project for between 1.5 and 2 hours, excluding introductory talks and organizational instructions. On the second day participants engaged in wiring, debugging, and playing the instrument. The wiring of the breadboard took between 15 and 35 minutes per group, followed by approximately one hour of troubleshooting and instrument playing. Then, the groups worked on troubleshooting and instrument playing for one hour. In total, the working time on the second date laid between 1:15 and 1:35 hours. Although some participant described working time as too short in the user survey, none of the participants work seemed rushed or stressed. This also matches the survey outcome of a pleasant working environment in figure 6.3. For both dates, a total workshop time of 3 hours per date was used, which included introduction, instructing talks and the conduct of the user survey.

6. Evaluation with Future Teachers

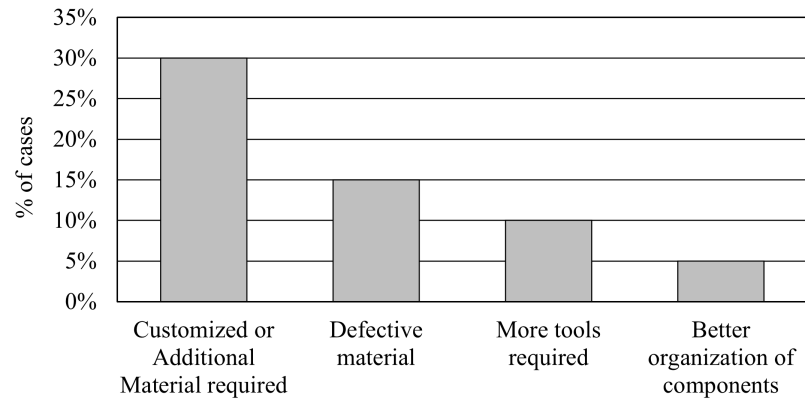


Figure 6.5.: Percentage of cases on feedback for materials and tools

6.2.2. Instrument Functionality

Overall, all participants were able to play the self-made AudioBrix instruments. 66% of the participants rated their built instrument as successful, while 33% rated it as partially successful. None of the built instruments exhibited a complete failure. However, there were severe problems regarding contact quality between the bricks on the second date. This was caused by a bulge of the wooden ground plate which occurred during the week between the workshop appointments. The wood curvature (visible in image 6.6) was likely due to a sudden temperature and humidity change of the storage place between the two workshop dates. The curved plates led to a smaller touching area between the bricks conductive tapes, leading to major connectivity issues. Within all qualitative data, this particular issue was mentioned in 85% of cases. To counteract, students worked with additional aluminum foil and conductive tapes between the bricks to enhance the conductivity. Although all groups shared the same connectivity problem, the groups worked and refined immediate solutions for the short-term issue independently. For debugging contact issues, some students proposed the idea for an additional ammeter-like tool for testing the connection of bricks.

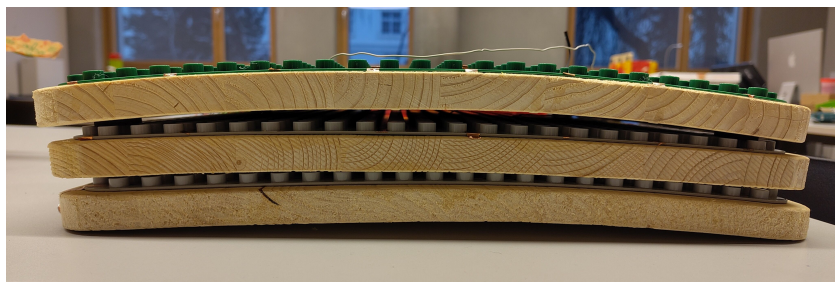


Figure 6.6.: Curvature of the wooden plates on the second workshop day

The connectivity issues led to frustration of some participants. The overall stability rating of the instruments while playing was mainly considered rather unstable (43%). Still, 24% of the participants rated their instruments as very stable (which could possibly correlate to one or two groups that had instruments that performed relatively well). Figure 6.7 depicts the distribution of stability responses from the participants. Despite some minor bugs for auto-detecting the necessary Arduino ports upon software setup, no software errors were reported by the participants. Some participants criticized a virus warning when starting the application on windows. However, this was already foreseeable and mentioned in the user manual.

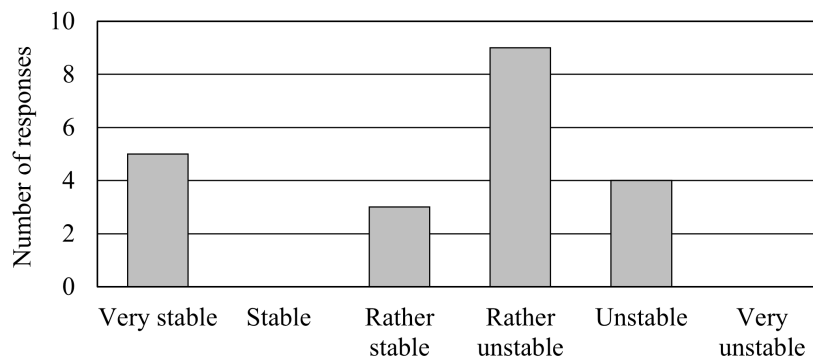


Figure 6.7.: Ratings of the instrument playing stability

6.2.3. Instrument Concept

One participant mentioned possible expansions of the instrument concept like additional LED lamps to signalize the currently played beat on the board. Another student proposed ideas for enabling chord like or multi-layered notes playback using an adapted software. Combining multiple instruments for enabling students to play together at the end of the assembly was also mentioned as additional functionality. Regarding the technical setup, one student (who likely had an extensive knowledge in engineering) criticized that connections in and between bricks should be soldered and electronic boards should be used instead of loose breadboards. Overall, students appeared interested in the instrument concept.

6.2.4. Educational Aspects

There has been a variety of responses from the participants regarding the instruments possibilities and problems for using the instrument in education. One important finding was a interdisciplinary subject integration. For this, important outcomes included the estimated appropriate school grades, possible subjects and interdisciplinary subject combinations. According to the user survey, the instrument is rather not suitable for the first to third lower secondary grade. Most participants proposed a usage within fourth

6. Evaluation with Future Teachers

lower grade to fourth (or higher) upper secondary class. Figure 6.8 shows a peak of votes for usage in the first upper secondary grade (*1 US*) with 76% approval.

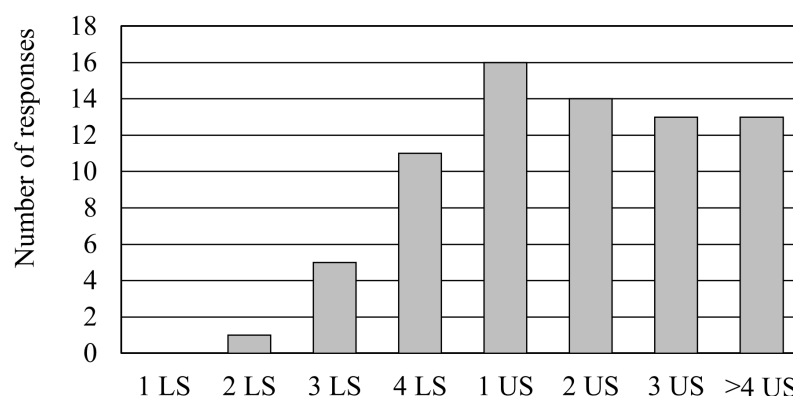


Figure 6.8.: Appropriate school grades according to the participants

Regarding subject integration the participants could specify the subject as free form text to ask for all different types of subjects. The aggregated subject recommendations are shown in figure 6.9. The most appropriate subjects rated by the participants are informatics (only available in upper secondary grade, see chapter 4) with 70% and music with 65% of cases. Handicrafts (50%), digital basic education and physics (each 30%) were also proposed as suitable subjects. As potential for interdisciplinarity with other subjects, music was highlighted by 40% of the participants, followed by informatics (20%). Although informatics was voted for at most, it was mentioned that the fifth grade may not be as suitable because of its crowded syllabus.

The participants mentioned that the teachers effort for embedding and using the AudioBrix instrument within school lessons is rather high and difficult for only one teacher per class. 60% of the participants reported the teachers effort as rather high or high. Also, a high time commitment was criticized by 40% of the participants. Participants reported that the integration within (i.e.) informatics schedule is rather difficult. Figure 6.10 shows the most mentioned didactic issues of the instrument. 45% of the participants stated that the instrument is likely to cause frustration among students upon failure. Students specifically mentioned the contact problems and the need for very sensitive or laborious crafting as reasons for a likely frustration.

The project is considered well-suitable for team work, as it is rated as very good (25%), good (45%) and rather good (20%). However, it was mentioned that there could be difficulties for integrating the project with inhomogeneous groups of students that own different prior knowledge.

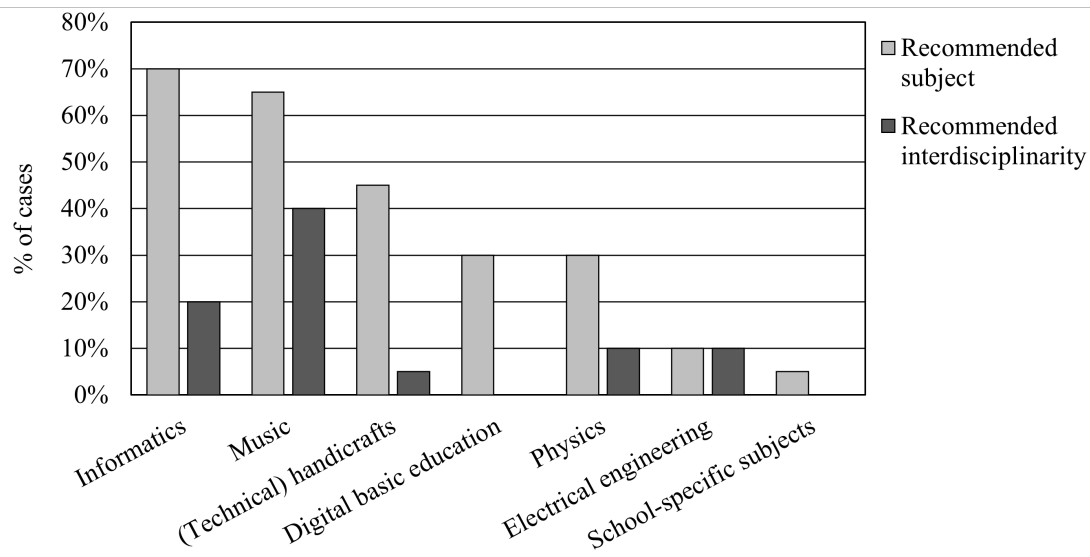


Figure 6.9.: Topically appropriate subjects according to the participants

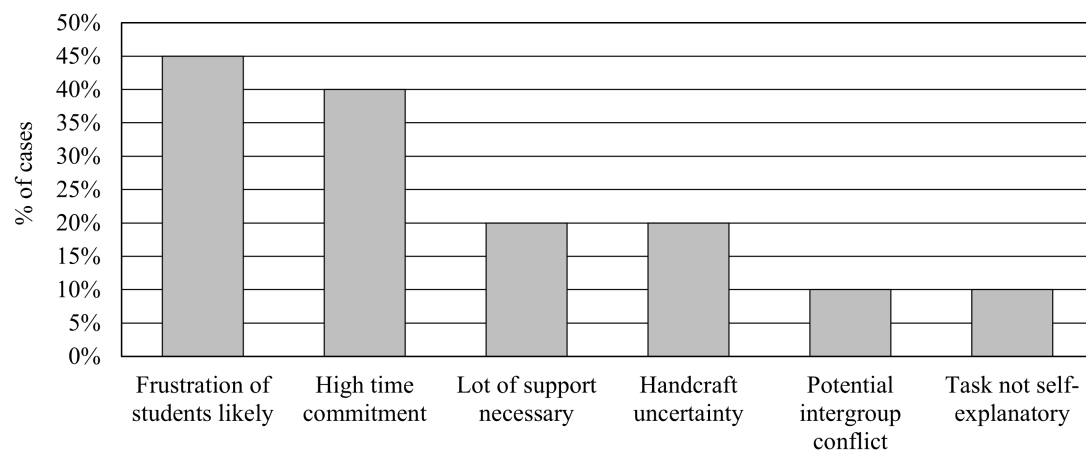


Figure 6.10.: Didactic problems according to the participants

6.2.5. Demographics

Most participants had already collected teaching experience between one to three years (including internships). 30% of the participants did not collect any teaching experience yet. A majority of the participants reported high levels of music experience, such as having learned an instrument. Regarding electronic engineering skills, most participants stated that they are rather inexperienced (see figure 6.11). Each 40% of the participants were aged between 20-24 years and 25-29 years. No significant correlation between the participants musical- or engineering skills and the quantitative data was observed.

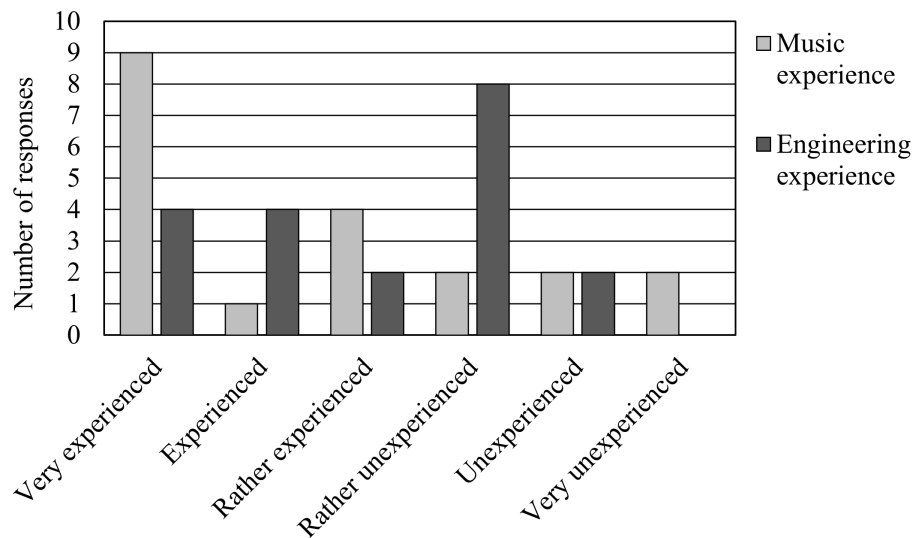


Figure 6.11.: Distribution of the participants music experience

7. Discussion

In the following, the outcomes of the curricula analysis, prototyping phase and user study are reflected. To address the question on how to create an electrical STEAM-oriented LEGO DMI, educational and functional properties are discussed. First, the prototype phase is recapitulated from a technical and didactic perspective, highlighting important prototyping decisions and insights of the workshop. Then, the toolkit suitability within the Austrian curricula is addressed. Finally, the instrument and its usage is reflected regarding the STEAM framework of Chappell et al. [Chappell et al., 2025]

7.1. Toolkit Reflection

7.1.1. Prototyping Based Reflection

Overall, a novel DMI concept was developed in the prototyping process. Multiple aspects of the instruments were examined, including the most important properties defined in section 5.1. The first prototyping on the LEGO based DMI from section 5.2.1 did not only introduce a basic framework for the final prototype, but also exhibited valuable details on how to electrify and connect bricks using conductive tapes and resistors. The concept, which was derived from the work of Barbancho et al., seemed encouraging regarding the simplicity of the technical layout.[Barbancho et al., 2024] The prototyping outcomes of different end-brick wiring (towards Arduino and breadboards) suggests that cables should not be positioned directly at the end of the brick columns due to entanglement of wires over the LEGO board. At last, the instability due to the small conductive surfaces between the bricks impaired the functionality of the first prototype, making it rather unplayable. Thus, the first prototype was considered easy in concept, but too unstable for real usage.

The second button-based prototype offered a more stable approach than the resistance based instrument and introduced another possibility for capturing positions of LEGO bricks. Compared to the first prototype, the preparation, assembly and wiring of the tact switch-based instrument took disproportionately long and was rather difficult. Especially the soldering of the multiplexers headers and tact switches seemed tedious. In the end, the requirement for easy technical feasibility was not satisfied. Regarding the software components, the switch from a purely Python-based UI to a JS-based UI improved the software usability. Although the prototype still acted as a sequencer, it allowed playing multiple notes per beat (i.e. chords and harmonies), which was not possible with the resistance based approach.

7. Discussion

The final stage of the brick-based prototyping process, the AudioBrix instrument, refined the concept of the first LEGO resistance based approach. Electrification of bigger DUPLO bricks was considered much easier and the overall stability performed better due to the increased size of conductive surfaces between the bricks. The usage of conductive ground lanes instead of letting cables hover over the board made the playing experience straightforward and well-structured. Although the instrument is bigger due to the ground plate, the instrument is easily portable, similar to the first prototype. Table 7.1 summarizes important parts of the prototyping stages regarding the requirements of section 5.1.

Prototype	Technical Feasibility	Stability	Costs	Portability
LEGO brick-based resistance sequencer	Simple layout, but overly precise and laborious assembly required	Very unstable	In budget	Very small and well portable
LEGO tact switch-based sequencer	Very complex wiring and time-consuming soldering required	Stable	In budget	Fragile, needs securing of wiring for transport
AudioBrix DMI (DUPLO brick-based resistance sequencer)	Simple layout and rather easy assembly	Rather stable	In budget	Big, but well portable

Table 7.1.: Comparison of prototypes regarding the requirements from section 5.1

7.1.2. Evaluation Based Reflection

Independently of the prototyping outcomes, the evaluation led to very important insights regarding usability, testing and educational usage of the AudioBrix DMI. All attendees were able to play the self-assembled instrument at least partially. However, many technical and educational problems mentioned by the participants correlate directly or indirectly to the issue of strongly curved ground plates. This led to a rather decreased stability of the instrument and caused frustration of some participants. This frustration was also mentioned as main issue (see figure 6.10) from a didactic point of view. It is likely that the replacement of the wooden plates would resolve this issue. As a result, the curvature problem required the students to troubleshoot and debug connectivity problems on their own, which was considered interesting by some participants. Some participants also experimented on their own, separate from the user manual, which indicates that the AudioBrix toolkit allows autonomous problem-oriented working. Regarding the auxiliary materials, the toolkit can be considered overall suitable for educational deployment. However, minor adjustments of the user manual and toolkit composition should be considered for simplifying the assembly further.

The building, playing and inspecting of the instrument concept generally appeared

interesting and was embraced by the participants. The handicraft and group-work was considered pleasurable which suggests that usage within education could also be interesting and humorous for students. The evaluating participants mentioned a rather high time commitment for the project and that a lot of support of students could be necessary. In total the groups worked between 2,75 and 3,5 hours on the project. In terms of lessons (usually 50 minutes per hour) this would map to roughly 3-4 hours working time. As the workshops also had some introductory talks and explanations, one or two additional school hours are recommended to allow didactic integration and a time buffer in case of further delays (adding up to a total of 4-6 school lessons). Although a high time commitment was mentioned, the overall required workshop time did not exceed the expected time frame. According to the ratings of the teacher trainees, the AudioBrix toolkit is suitable for classes between 4th lower secondary and 4th (or higher) upper secondary grade. The students rated the toolkit most applicable for the first upper secondary grade.

Regarding subject integration, informatics and music classes are recommended the most, making it the most appropriate subjects before (technical) handicrafts. Digital basic education and physics were also considered useful for integration, but were only recommended by a third of the responses. It must be noted that the informatics term could potentially be misleading as some students could have included the class digital basic education within this term while others separated the two terms. Some students also provided details on interdisciplinary subjects that could be considered additionally. Almost half of the participants stated that the music class could be used therefore.

7.2. Curriculum Integration

Given the results and previous discussion on the educational insights on the AudioBrix toolkit, an integration within the national curriculum is discussed in this section. For the different school types, the results of the evaluation and its discussion will be opposed to the national curricula syllabus and content. For AHS and NMS class-grade matrix comparisons are introduced to identify most suitable subjects and grades. Tables 7.2 and 7.4 summarize and compare the findings on suitable topics from chapter 4 with the subject-recommendations from the user evaluation. To enable comparability between school grades and subjects, the curricula topics were grouped and evaluated based on their topical alignment with the AudioBrix application field. The topical alignment was categorized in roughly fitting, well-fitting and very well-fitting given the amount of suitable keywords, contentual alignment and topical room for interpretation. Given the subject-specific recommendations from the evaluation (see figure 6.9), the rated subjects were categorized into previously mentioned labels by dividing the percentage values into three equal intervals. A grade was considered overall recommended if it was mentioned in over 50% of the responses (see figure 6.8).

Finally, a suitability ranking for AudioBrix usage is introduced given different subjects and grades for each analyzed school type. These rankings are based on the amount of

7. Discussion

suitable topics, subject availability, subject hours and recommended subjects and school grades. However, they do not imply a strict exclusion for other grades or subjects. Due to the contentual flexibility of Austrian curricula, alternative implementations can be considered equally valid. These rankings therefore provide a reasonable prioritization based on the findings of this thesis rather than distinct classifications. Highest ranked subjects are considered most suitable. Furthermore, it must be emphasized that lower ranked subjects are still considerably suitable. The suitability ranking only considers subjects within the normal class schedule. Alternative time frames (e.g. project weeks or consolidations of multiple lessons) could possibly cause different rankings.

For both investigated HTL school types, the evaluation based subject recommendation does not apply for the subject ranking as only few of the evaluation results included details on higher technical schools. Additionally, the grade recommendation is omitted for HTLs, as all grades in upper secondary are considered recommended. This leads to a subject suitability ranking with reduced complexity. Only topical alignment, hours per week and availability are considered.

7.2.1. AHS Integration

Table 7.2 compares the investigated subjects and respective grades of AHS. For a simple overview, IT and digital basic education (DBE) are summarized in this table. Due to the flexible nature of elective subjects, only informatics with a fixed schedule (see table 4.1) is represented in the comparative table for a consistent overview. However, the investigated elective physics and music classes could also be used to embed usage of the AudioBrix toolkit. This mainly depends on the students and teachers preferences and mutual agreements on lesson structure, as elective subjects are highly flexible and student-orientated. All elective subjects have two subject hours per week, qualifying them as feasible. While the suitability ranking (table 7.3) seems apparently structured, the last ranked music class would topically align similarly to the second ranked music subject. However, due to the limited subject hours per week, the grade was down-voted respectively.

7.2. Curriculum Integration

Grade	Physics	IT/DBE	Music	Crafting
1				
2				
3				*
4				*
5	*		*	
6		*		
7		*	*	
8		*	*	

Topical advice
 Evaluation advice
 Roughly fitting
 Well-fitting
 Very well-fitting
 Grade overall not recommended

Table 7.2.: Comparison of topical and evaluation recommendations for AHS

* Availability depends on school type and elective subject

Rank	Subject	Grade	Topics excerpt	Subject eligibility	Grade eligibility	Hours per week	Availability
1	Informatics	6	Production of sound, setup of IT systems, external devices	Very good	Yes	2	Elective Subject
2	Music	5	Electric, digital & virtual instruments, new media technology	Very good	Yes	2	Excluding Gymnasium
3	Physics	6	Electricity, circuits, current, voltage and resistance	Mediocre	Yes	3	For all
4	Crafting	3	Electronics, sensors and robots	Good	No	2	Excluding Gymnasium
5	Physics	3	Simple circuits, voltage, electronic devices & resistance	Mediocre	No	2	For all
6	Music	4	Music technology and software	Very good	Yes	1	For all

Table 7.3.: Subject suitability ranking (AHS)

7. Discussion

7.2.2. NMS Integration

As the NMS shares a similar structure to the previously mentioned AHS, the general outcome is rather equal to the previous recommendations. Table 7.4 compares the relevant outcomes for the analyzed subjects given the topical and evaluation results. However, as informatics as subject is not available in NMS, digital basic education classes are contained in the ranking from table 7.5 to include information technology education in lower grades curriculum. Similar to the previous ranking, subjects with only one hour per week are ranked lower. Overall, the recommended grade impacts the ranking less than for AHS as the NMS generally only serves lower grades.

Grade	Physics	DBE	Music	Crafting
1				
2				
3			*	*
4	*			

Topical advice
 Evaluation advice
 Roughly fitting
 Well-fitting
 Very well-fitting
 Grade overall not recommended

Table 7.4.: Comparison of topical and evaluation recommendations for NMS

* Subject hours depend on schedule focus

Rank	Subject	Grade	Topics excerpt	Subject eligibility	Grade eligibility	Hours per week	Availability
1	Crafting	3	Electronics, sensors and robots	Good	No	2	Depending on focus
2	Physics	3	Simple circuits, voltage, electronic devices & resistance	Mediocre	No	2	For all
3	Music	4	Music technology and software	Very good	Yes	1	For all
4	Digital Basic Education	4	Interdisciplinary applications of engineering, customizing and documenting software	Good	Yes	1	For all
5	Digital Basic Education	3	Creative cooperation using provided media & software, creation of simple programs	Good	No	1	For all

Table 7.5.: Subject suitability ranking (NMS)

7.2.3. HTL IT Integration

Table 7.6 shows the overall topical alignment of the three inspected subjects. The derived suitability ranking from table 7.7 of the information technology HTL is not only affected by the topical alignment but also the differing subject hours. Specifically, the first three ranks offer a rather comprehensive time quota and precisely matching topics. The generic science class is also considered suitable for AudioBrix integration, but does not show a similar precisely fitting syllabus to be contained in the recommendation ranking.

Upper Grade	Systems Engineering	Media Technology	Science
1	Very well-fitting		Well-fitting
2	Roughly fitting	Very well-fitting	
3		Very well-fitting	
4	Very well-fitting *	Very well-fitting *	
5	Very well-fitting *	Well-fitting *	

 Roughly fitting
 Well-fitting
 Very well-fitting

Table 7.6.: Comparison of topical recommendations for HTL IT

* Subject hours depend on schedule focus

7. Discussion

Rank	Subject	Grade	Topics excerpt	Hours per week*	Availability
1	Media Technology	4	HCI, creation of sound-composing for creative user centered application. Creation, analysis and evaluation of design concepts, audio design	8	Available for path B2
2	Systems Engineering	5	Deployment of microcontroller technology for network- and real-time suitable applications	10	Available for path B
3	Systems Engineering	4	Structure, functionality and applications of microcontroller systems, development of typical applications	6	Available for path B
4	Systems Engineering	1	Principles of electrical engineering, electric measures and units, DC technology, basic circuits	3	For all
5	Media Technology	3	Usage of suitable tools for modification of audio, analysis and modification of raw media, sound processing and optimization	2	For all
6	Media Technology	2	In- and output devices for audiovisuals and their properties, computer and external devices, digital audio engineering, setup and application handling	2	For all

Table 7.7.: Subject suitability ranking (HTL IT)

* Excluding subject hours for students enrolled in specific tutorials for reasons of simplicity

7.2.4. HTL Mechatronics Integration

For the mechatronics specialized HTL the overall amount of suitable subject grades is smaller than for the previously discussed HTL IT. Thus, the more generic science class is also included within the suitability ranking from table 7.9. The subjects with rank 2, 4 and 5 all share similar topical areas within electronics and physical measures. However, the second grades electronic engineering & electronics class is ranked higher due to the increased subject hours per week. The first ranked subject offers an ideal integration regarding human computer interaction and microcontrollers and was thus prioritized. Overall, all subjects offer a high topical alignment while the overall amount of generally suitable grades is less than for HTL IT.

Upper Grade	Electronic engineering & electronics	Mechatronics systems & automation	Applied informatics & subject-specific IT	Science
1				
2				
3				
4				
5				

 Roughly fitting
  Well-fitting
  Very well-fitting

Table 7.8.: Comparison of topical recommendations for HTL Mechatronics

Rank	Subject	Grade	Topics excerpt	Hours per week*	Availability
1	Applied informatics & subject-specific IT	4	Analog and digital signals, external devices, microcontroller, HCI for data capture	2	For all
2	Electronic Engineering & Electronics	2	Basic units, DC, ohm's law, power, energy, circuits of resistors	3	For all
3	Applied informatics & subject-specific IT	5	Analysis, testing and writing of programs of microcontrollers, interconnected software for process periphery, software for real-time usage	2	For all
4	Science	1	Physical experiments, comparison and measuring of values, units including resistance, voltage, power and capacity	2	For all
5	Mechatronics Systems & Automation	3	Measuring of electronic units, voltage, resistance and current. Sensors and methods for measuring	2	For all

Table 7.9.: Subject suitability ranking (HTL Mechatronics)

* Excluding subject hours for students enrolled in specific tutorials for reasons of simplicity

7.3. Reflection in the context of STEAM education

After discussing the toolkit and curriculum integrability, the results of this thesis are highlighted in terms of its application field in STEAM education. The AudioBrix toolkit and instrument showcased a novel implementation of musical STEAM education. Within the evaluation, participants intrinsically worked on the instruments in a problem-oriented and experimental way. In the following, the fulfillment of the five core concepts of the framework by Chappell et al. considering the results of this thesis are summarized [Chappell et al., 2025]:

1. **Creativity:** Creativity is required in multiple steps of building and playing the AudioBrix DMI. The instrument playing and designing of a melody facilitates creativity while the problem-solving and troubleshooting also requires creative thinking. The unsupervised working process of the evaluation (see day two in section 6) revealed the creative problem-oriented working potential.
2. **Collaboration:** The AudioBrix toolkit enables multi-layered collaboration while playing and building. The most self-explaining collaboration is given by the interactive group work which connects the work of multiple students. Additionally, there is also collaboration between groups, including passing through toolkits and materials. On top of that, groups may observe each others and exchange tips or information. Teachers do not only associate the building and playing process but also collaborate directly with the students (e.g. upon problems or success).
3. **Disciplinary inter-relationship:** The interdisciplinary of the given instrument connects multiple different educational branches. While the building process mainly attributes to the disciplines of physics and electrical engineering, the underlying concept and instrument playing introduces a graspable approach of the music subject. At last, the sound generation and configuration of the instrument include informatics as important subject-connecting discipline.
4. **Involving Real-world connections:** Usage and creation of the AudioBrix instrument allow insights into (small-scaled) microcontroller based applications and enables understanding of commonly-used measuring techniques. Regarding music, the instrument introduces real-world note patterns, note sheets and sequencers as form of digital instruments. The provided software also shows how software is used to read and control external devices such as microcontrollers.
5. **Thinking-Making-Doing:** The previously mentioned problem-oriented creative thinking contributes to the thinking-making-doing requirement of Chappells framework. Students are encouraged to experiment, analyze, rethink and investigate on the given instrument, its setup and issues.
6. **Inclusion, personalization, empowerment:** The instruments barriers regarding foreknowledge and required skills are kept low to provide broad inclusivity.

7.3. Reflection in the context of STEAM education

Additionally, the instrument should encourage students with no or minor knowledge on engineering new perspectives in the area of electrical engineering. The mixture of basic job steps (e.g. taping bricks) and possibly unknown processes like wiring combines well-known handicraft and novel procedures. Similar to other self-explaining instruments (such as keyboards or drums) the AudioBrix instrument enables students to quickly understand note heights and beat patterns.

Summarizing, the introduced DMI toolkit aligns with typical properties of STEAM education, confirming the AudioBrix toolkit as fully STEAM-compatible concept.

8. Conclusion

With the AudioBrix instrument and toolkit, a novel approach for a LEGO-based digital music instrument within STEAM education has been introduced and demonstrated thoroughly. While designing and creating a new Arduino- and brick-based sequencer, new insights were gained regarding technical feasibility, stability, costs and portability. The developed AudioBrix instrument uses resistors with conductive tapes to electrify DUPLO bricks on a conductive taped ground plate. To connect the bricks with each other, the ground board and the breadboard wiring, three different types of electrified bricks were established. A custom Python and JS-based application was created for translating received signals into sound, managing playback and allowing necessary configuration.

The final instrument combines electronic engineering, music and informatics as interdisciplinary connector for educational settings. After prototyping, the instrument was structured as self-assembly toolkit and evaluated with becoming teachers in two workshop dates. Although there were some obstacles regarding the instrument stability in the evaluation, the DMI was playable for all participants. The results of the conducted user survey led to encouraging outlooks of the project, but also indicated potential for improvements.

The analysis of the Austrian curricula of AHS, NMS and two types of HTLs indicates that the integration of AudioBrix usage in different subjects is legitimate and reasonable. Although no explicitly most suitable subject could be identified due to the interpretable nature of the Austrian curricula, suitability-based rankings were created for the investigated school types.

8.1. Future Work

While the basic concept and functionality of the AudioBrix toolkit were successfully achieved, an ongoing refinement of the project is desired. Next steps would focus on feature implementation, bug fixing and improvements of the toolkit, based on the results of the user evaluation. This includes important enhancements of the user manual, removal of software issues, rethinking on the ground plate material and fine-tuning of the provided toolkit material amounts. Furthermore, usage of the toolkit could be tested and evaluated for the analyzed school types in on-site-experiments with students and teachers. Overall, the AudioBrix concept allows multi-faceted development and expansion. Usage can be investigated further in the scope of STEAM education, but could also be adapted for live-performance settings.

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Acronyms

AHS Allgemeinbildende Höhere Schule. ix, 9–17, 22, 23, 53–56, 63

BHS Berufsbildende Höhere Schulen. 9

DAW Digital Audio Workstation. 37

DBE Digital Basic Education. 12, 54, 55

DMI Digital Music Instrument. iii, vii, 1, 3–7, 9, 23, 25, 26, 32, 37, 51, 52, 60, 61, 63

EDA Exploratory Data Analysis. 7, 42

FAQ Frequently Asked Questions. 43

HCI Human Computer Interaction. 58, 59

HTL Höhere Technische Lehranstalt. ix, 9, 17, 19–23, 54, 57–59, 63

LSP LEGO Serious Play. 4

N/A Not Applicable. 9, 12–15, 36

NMS Neue Mittelschule. ix, 9, 16, 22, 23, 53, 56, 63

OSC Open Sound Control. 37

STEAM Science, Technology, Engineering, Arts & Mathematics. iii, 6, 23

STEM Science, Technology, Engineering & Mathematics. iii

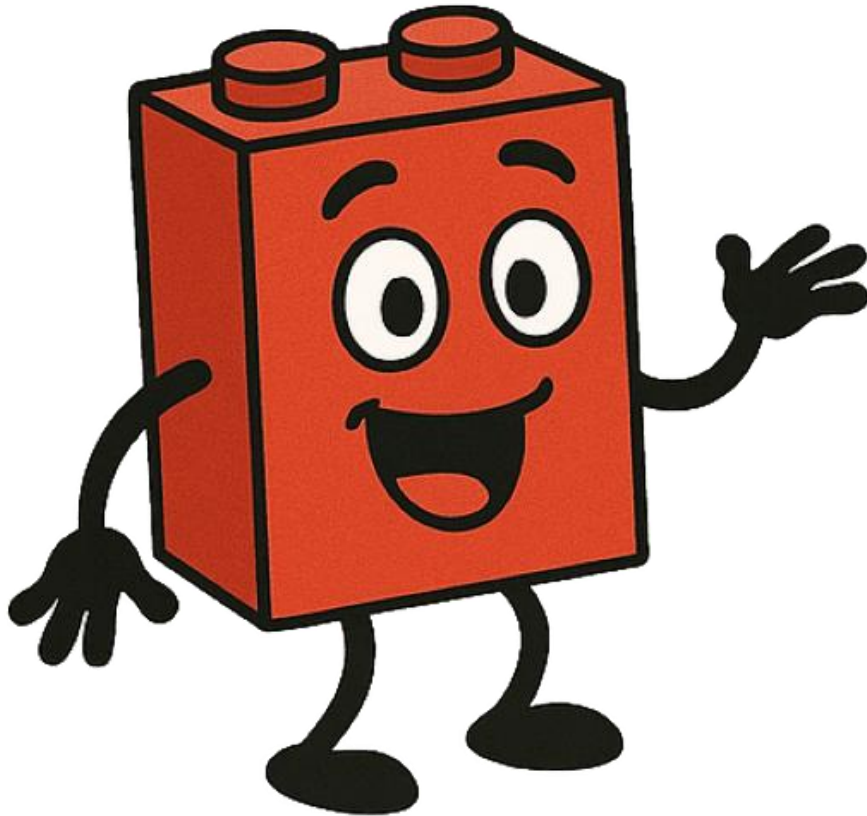
TUI Tangible User Interface. 3

UI User Interface. 25, 30, 51

A. Appendix

A.1. AudioBrix Benutzerhandbuch

AUDIOBRIX



BENUTZER- HANDBUCH



universität
wien

Masterpraktikum P2 – Merlin Waldhör
Betreuer: Dr. Oliver Hödl

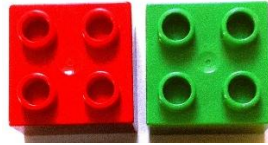
INHALTS- VERZEICHNIS

Inhalt	3
Hallo!	4
Bauen wir Musik!	5
Sequencer Design	6
Wie geht das?	7
Elektrifizierung	8
Technischer Aufbau	9
Grundplatte	10
Blockübersicht	11
Brückenblöcke	12
Sensorblöcke	13
Notenblöcke	15
Stromzufuhr	18
Elektronik	19
Verkabelung	21
Schritt-Für-Schritt Verkabelung	23
Software	28
Einrichtung	30
Dashboard	32
Häufige Fragen	34
Zur Software	34
Zur Verkabelung	36

INHALT



Arduino Nano Every



Diverse Blöcke



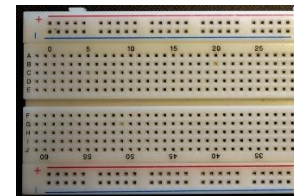
Aluminium Folie



Widerstände



**Leitendes Klebeband
(Breit + Schmal)**



Breadboards



USB Micro Kabel



Jumper Kabel

Inhalt	Anzahl
Grundplatte mit Holzunterkonstruktion	1
Kupferband Breit	1
Kupferband Schmal	1
Arduino Nano Every	1
2x2 Spielblöcke	> 7
2x2 Spielblöcke gebohrt	8
2x4 Spielblöcke	> 25
Mini Breadboards	2
Schraube 10mm M3	1
Micro USB Kabel	1
Kabel ~40cm	1
Widerstände 1k Ohm	>7
Widerstände 2k Ohm	>33
Alufolie	1
Jumper Wires MM	20
Jumper Wires FM	20

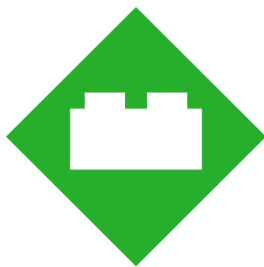
Stelle sicher, dass zu Beginn alle angegebenen Einzelteile vorhanden sind.

HALLO!

Herzlich Willkommen zur Anleitung vom AudioBrix Bausatz! In diesem Tutorial wirst du neue Dinge über Elektronik, Informatik und Musik lernen.

Dieses Handbuch wird dich durch den Aufbau, die Verkabelung und das Spielen des AudioBrix Sequencers leiten. Am Ende dieser Anleitung kannst du deine eigenen Musikstücke komponieren und mittels Duplo Blöcken Musik machen.

Bitte beachte, dass der AudioBrix Bausatz in zwei Versionen verfügbar ist. Stelle sicher, dass du die Anleitung entsprechend deiner Version verwendest.



AudioBrix Relaxed Edition:

Dieser Bausatz ist mit einem grünen Symbol markiert und enthält bereits fertig zusammengebaute Teile. Du musst hier lediglich die Verkabelung durchführen.



AudioBrix Explorer Edition:

Dieser Bausatz ist mit einem roten Symbol markiert. Damit du das Instrument spielen kannst, musst du zuerst das Spielmaterial zusammenbauen.



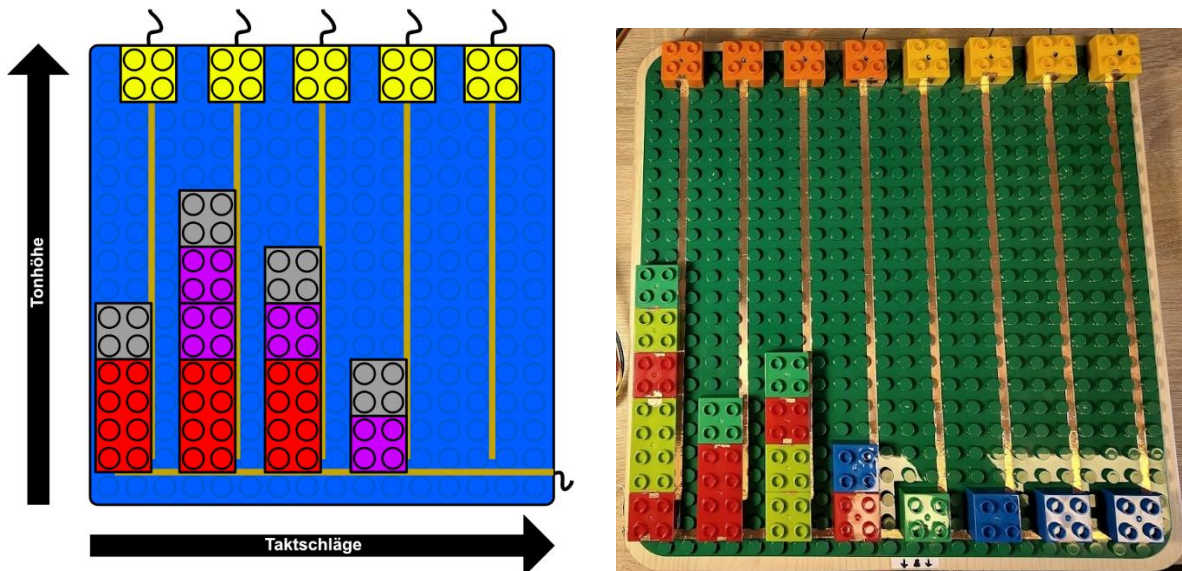
**Die Explorer Edition benötigt Arbeitswerkzeug.
Arbeite niemals unbeaufsichtigt.**

Diese AudioBrix Bausatz Anleitung dient ausschließlich für Bildungszwecke. Veröffentlichung ist untersagt. Die AudioBrix Figur wurde mittels KI illustriert.

BAUEN WIR MUSIK!

Mit dem AudioBrix Bausatz erschaffen wir ein Instrument aus Duplo Blöcken, mit denen wir Musik zum Leben erwecken können.

Bevor es wirklich los geht, machen wir uns mal einen groben Überblick über das Instrument. Hier siehst du zwei Darstellungen: Eine vereinfachte Visualisierung (links) und das echte Instrument (rechts).



Das Instrument funktioniert wie ein Sequenzer. Ein **Sequenzer** spielt die Noten von links nach rechts in einer Schleife ab.

Stell dir das wie ein Notenblatt vor, das wiederholt abgespielt wird. Jede Note wird durch einen oder mehrere Bausteine pro Spalte dargestellt.

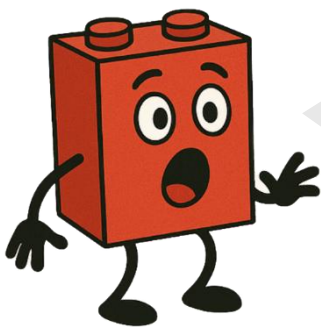
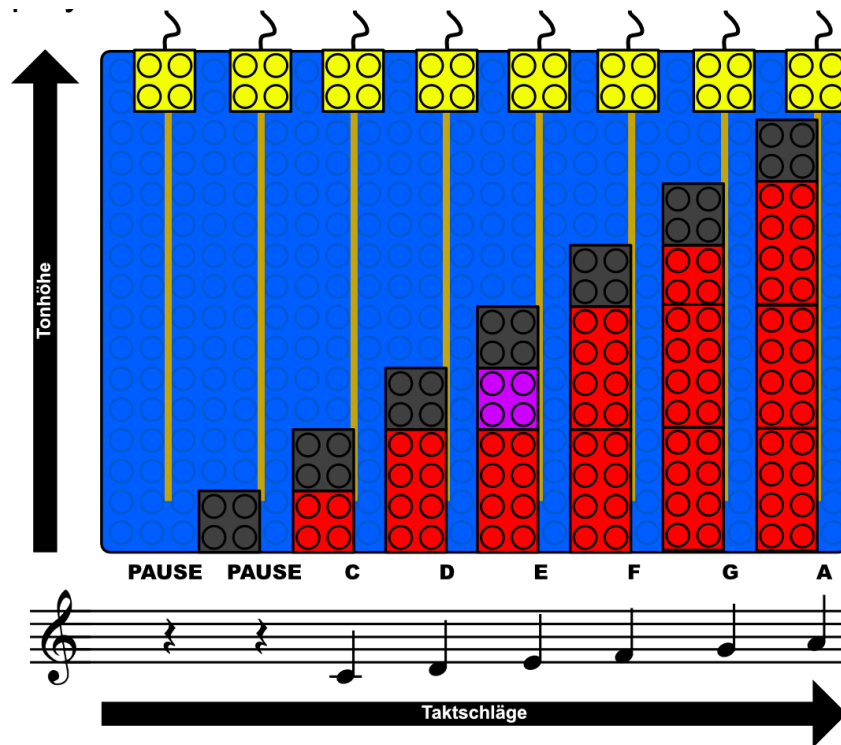
Je mehr Bausteine in einer Spalte platziert werden, desto höher ist die Note. Weniger Bausteine bedeuten also z.B. tiefere Töne. („Notenhöhe“). Wir werden dazu später noch mehr erfahren.

SEQUENCER DESIGN

Damit wir wirklich spielen können, müssen wir zuerst verstehen wie das Instrument Noten und Taktschläge repräsentiert.

Wir können dazu klassische Noten aus der Musik ganz einfach auf den AudioBrix Sequencer übertragen. Im unteren Bild siehst du die Darstellung von Noten auf dem AudioBrix Instrument.

Wenn keine (Noten-)Blöcke in einer Spalte platziert sind, gilt das als Pause.

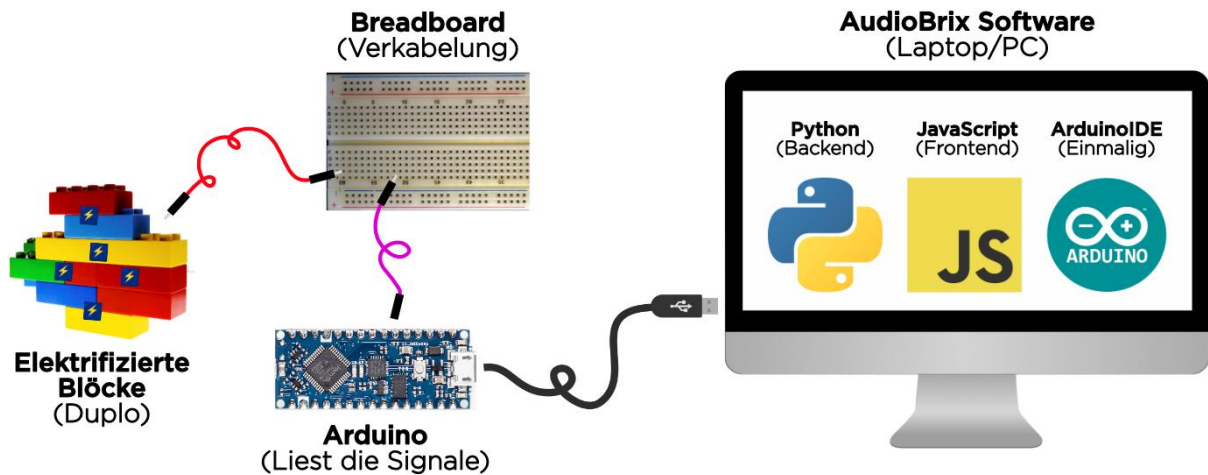


Plus Eins!?

Um eine Note hörbar zu machen brauchen wir für jede Spalte (Taktschlag) einen zusätzlichen Block. Dieser wird hier dunkelgrau dargestellt. Dieser Block stellt keine zusätzliche Notenhöhe dar – Wir werden später in der Elektrifizierung sehen warum!

WIE GEHT DAS?

Sehen wir uns kurz den technischen Aufbau an, bevor wir uns das Instrument weiter ansehen:



Elektrifizierte Blöcke:

Dazu gehören die modifizierten Blöcke und Grundplatte. Die Blöcke schließen einen Stromkreis, die dann messbare Widerstände erzeugen.

Breadboard:

Auf dieser Steckplatte findet der Großteil der Verkabelung statt.

Arduino:

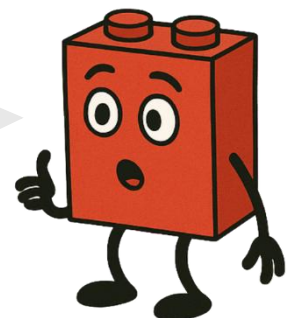
Der Arduino ist ein Entwicklungsboard mit Sensoren – Er liest die Signale von den Blöcken und sendet diese Signale an den Computer.

AudioBrix Software:

Am Computer läuft die AudioBrix Software. Diese basiert auf den Programmiersprachen Python und JavaScript. Sie übernimmt die Kommunikation mit dem Arduino, wandelt die Signale in Noten um und kümmert sich um das Abspielen der Noten.

Online-Videoanleitungen

Auf dev.waldhoer.org/audiobrix gibt es diverse Tutorials für das Zusammenbauen und hilfreiche Tricks – Schau gerne rein wenn du wo festhängst!





ELEKTRIFIZIERUNG

Genug gelesen – Lass uns loslegen! Das Kernstück des Instruments muss zunächst gebaut werden: Die Blöcke und Grundplatte!

In den nächsten Schritten werden wir die Grundplatte vorbereiten und die Blöcke anfertigen. Nachdem wir alle Blöcke fertig haben, werden wir mit der Verkabelung fortfahren.

Lege dir für die Elektrifizierung folgende Sachen bereit:

- Aluminiumfolie
- Widerstände
- Leitfähiges Klebeband

Zusätzlich benötigst du:

- Schere
- Arbeitsunterlage
- Heißklebepistole
- Handschuhe
- Kleines Lineal oder Geodreieck

Mach dir genug Platz auf deinem Tisch, damit du ordentlich arbeiten kannst und nichts verlierst.

Teile dein Arbeitsmaterial und die Arbeitsschritte auf, falls du mit anderen zusammenarbeitest – So seid ihr schneller fertig!

Beachte beim handwerklichen Arbeiten diese Informationen:



Verletzungsgefahr! Verwende Handschuhe, wenn du mit der Heißklebepistole arbeitest.



Arbeite nie unbeaufsichtigt! Während der Arbeiten muss sich immer eine Aufsichtsperson in der Nähe befinden.



Verwende eine Arbeitsunterlage und stelle sicher, dass deine Arbeitsfläche groß genug ist.



Arbeiten mit Strom: Der Arduino arbeitet mit 5V Strom. Für Menschen ist das ungefährlich. Mehr Infos s. Seite 36.



TECHNISCHER AUFBAU

Für den Aufbau des Instruments brauchen wir zunächst:

- **Grundplatte** mit neun leitenden Bahnen
- **Notenblöcke**, die mit Widerständen ausgestattet sind
- **Brückenblöcke**, die Notenblöcke mit den Bahnen verbinden
- **Sensorblöcke** am Ende jeder Bahn

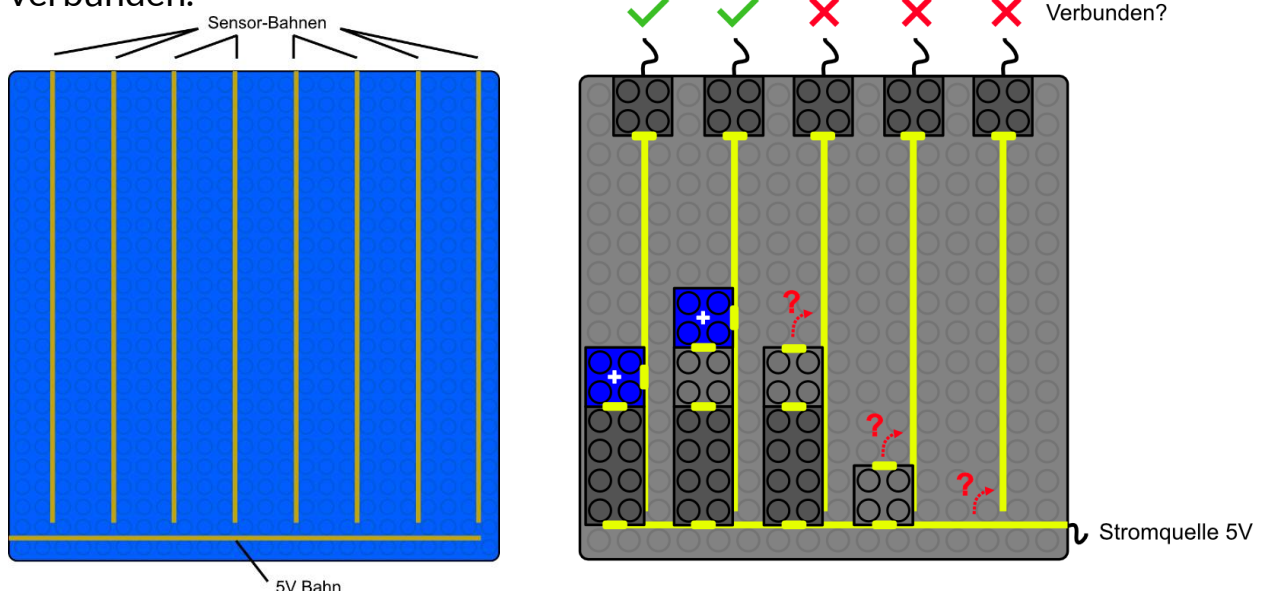
Sehen wir uns einmal die Grundplatte an. Diese hat verschiedene leitende Klebestreifen (Wir nennen diese „**Bahnen**“).

- Die untere, quer verlaufende Bahn ist die **Stromversorgung**. Durch diese Bahn werden alle Notenblöcke mit 5 Volt Strom versorgt.
- Die vertikal verlaufenden Bahnen sind die **Sensor-Bahnen**. Sie laufen jeweils zu einem Endstück (Sensorblock), der die Sensorbahn mit der Verkabelung verbindet.

Die Sensor-Bahnen sind nicht direkt mit der Stromquelle verbunden. Wir wollen hier nämlich **Widerstände (in Form von Notenblöcken)** dazwischenschalten.

Die Notenblöcke werden einen Pin links neben den Sensor-Bahnen platziert (So dass die Kanten der Notenblöcke die Bahn berühren – Nicht mittig auf der Bahn). Das ist wichtig, denn der Strom würde sonst den kürzesten Weg nehmen und die Notenblöcke überspringen.

Nach dem letzten Notenblock (dem obersten in jeder Spalte) platzieren wir deswegen einen verbindenden Block (Brückenblock). Dieser ist im Bild rechts blau dargestellt. Ohne Brückenblock ist der Sensor nicht verbunden.





GRUNDPLATTE

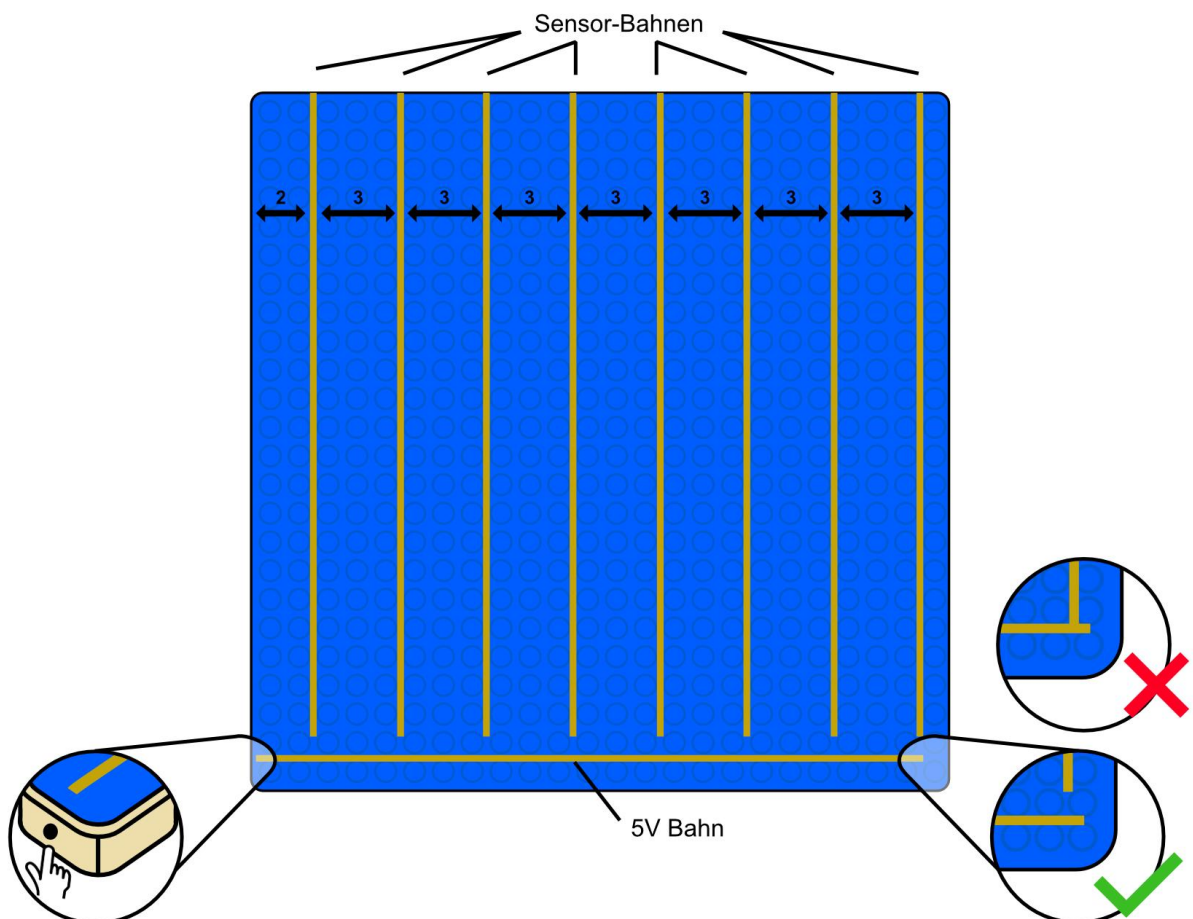
Zunächst müssen wir die Grundplatte vorbereiten. Diese Platte muss zunächst mit leitfähigem Klebeband ausgestattet werden.

Insgesamt benötigen wir neun lange **schmale** Klebestreifen.

- Es gibt eine 5 Volt-Bahn, die vertikal verläuft
- Es gibt acht Sensor-Bahnen, die horizontal verlaufen

Schneide entsprechend **9 lange schmale Klebestreifen** ab und klebe diese wie am Bild auf die Grundplatte. Bringe die Streifen dabei so an, dass die 5 Volt-Bahn auf der Höhe vom vorgebohrten Loch ist.

Stelle sicher, dass die Abstände richtig sind und sich keine Klebebänder berühren.



Jeder Klebestreifen sollte vorsichtig angebracht werden, sodass keine Risse oder gröbere Kratzer am Klebestreifen vorhanden sind.



BLOCKÜBERSICHT

Im nächsten Schritt müssen wir die Blöcke elektrifizieren.

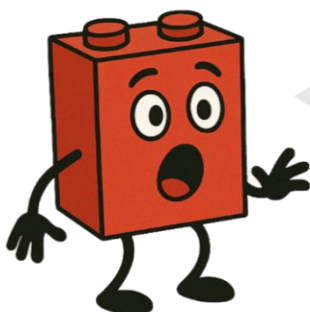
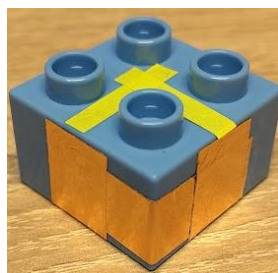
Es gibt drei Arten von Blöcken, die wir in unterschiedlichen Stückzahlen herstellen müssen. **Jede Blockart hat eine eigene Farbe.** Die richtigen Blockfarben sind in deinem Toolkit angegeben.

- **8 x Brückenblöcke:** s. Seite 12
- **8 x Sensorblöcke:** s. Seite 13
- **Notenblöcke:** s. Seite 15
 - ~8 x Kleine Notenblöcke (2x2)
 - ~25 x Große Notenblöcke (2x4)

Gehe für die Blöcke wie folgt vor. Teile dabei die Schritte mit deinen Gruppenkollegen auf – Damit geht alles schneller! 🕒

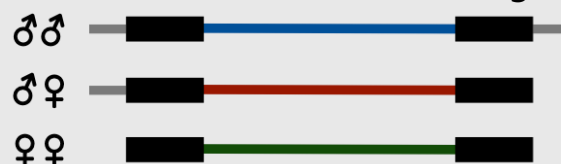
1. Bastle die 8 Brückenblöcke
2. Bastle die 8 Sensorblöcke (Heißklebepistole notwendig)
3. Bastle die Notenblöcke aus den übrig gebliebenen Blöcken. Damit du gut spielen kannst empfehlen wir 25 große und 8 kleine Blöcke. Beachte Beim Bearbeiten jedenfalls, dass **8x 2kOhm** Widerstände für die Verkabelung übrigbleiben.

***Tipp:** Wenn die Zeit knapp wird, kannst du einige Notenblöcke auslassen.*



Jumper-Kabel Arten

Es gibt drei verschiedene Arten von Anschlüssen. Sie werden mittels ♀ und ♂ dargestellt:





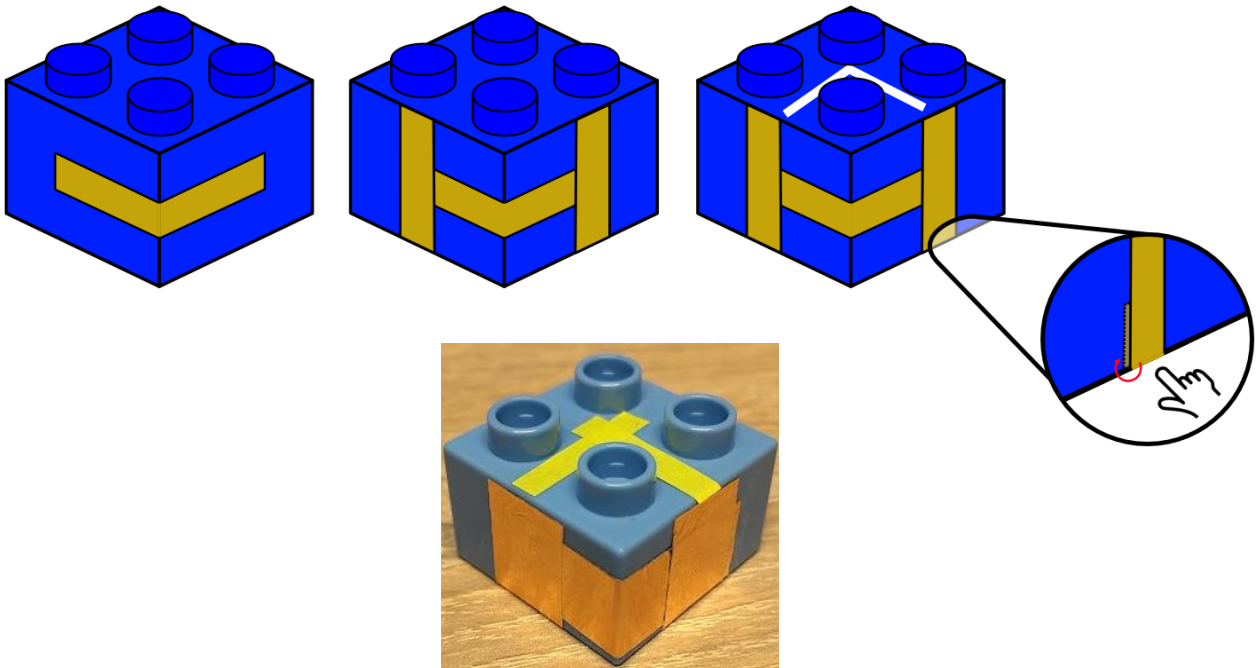
BRÜCKENBLÖCKE

Damit die Notenblöcke mit den Sensorbahnen verbunden werden können müssen wir die Brückenblöcke vorbereiten.

Die Brückenblöcke sind sehr einfach konstruiert. Sie haben keine Widerstände, sondern verwenden nur leitendes Klebeband, um die Stromkreise zu schließen.

Es werden 8 x Brückenblöcke benötigt. Gehe dabei wie folgt vor:

1. Schneide ein ~4 cm langes und zwei ~2,5 cm lange **breite** Klebebänder ab und löse sie vom Schutzfilm.
2. Klebe die drei Klebestreifen auf den Block. Beginne mit dem längeren, waagrechten Streifen und klebe danach die zwei Kürzeren.
Stelle sicher, dass die leitenden Klebestreifen über die Kante des Blockes gehen.
3. Klebe zwei kleine Papier-Klebestreifen auf die Oberseite des Blocks, um den Brückenblock einfacher zu erkennen. (Optional)



So sieht das dann beispielsweise aus 😊



SENSORBLÖCKE

Wir benötigen **8 x Sensorblöcke**, die das Stromsignal von jeder Sensor-Bahn zum Arduino verbinden. **Jeder Sensorblock ist vorgebohrt.**

Gehe für jeden Sensorblock wie folgt vor:

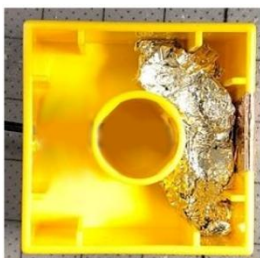
1. Nimm dir einen der vorgebohrten Sensorblöcke.



2. Klebe einen leitenden **breiten** Klebestreifen auf die **nicht durchbohrte** Seite von innen nach außen. Achte darauf, dass das Klebeband im Inneren etwa bis zum „Plastikboden“ reicht.

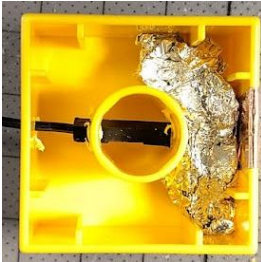


3. Reiße dir etwa 20x10 cm großes Aluminium ab und presse daraus ein Aluminium-„Kipferl“. Füge dieses Kipferl auf der Seite vom Klebestreifen im Block ein. Das Aluminium muss den Klebestreifen berühren. (Eine detaillierte Anleitung, wie Aluminium-Einlagen funktionieren findest du auf [Seite 16](#))





4. Stecke nun ein ♂♂ (männlich-männlich) Jumper-Kabel mit dem Stift durch das Loch bis ins Aluminium. **Verwende dafür nur Kabel mit den Farben aus der Abbildung in Schritt 5.** Verwende jede Farbe dabei nur ein Mal. *Tipp: Mit einem kleinen Lineal oder Geodreieck kann der Pin noch besser in das Aluminium gepresst werden.*



5. Beschrifte den Sensorblock oben mit einem Marker mit der richtigen Nummer. Also der Sensorblock mit rotem Kabel etwa „0“ oder der Sensorblock mit blauem Kabel „4“. Beachte, dass **B7 in dunkelbraun oder lila** geliefert wird.



6. Fixiere das Kabel im Block mit Heißklebepistole an den Öffnungen, so dass das Kabel gut stabilisiert ist.



**Verletzungsgefahr:
Benutze Handschuhe!**



**Arbeite niemals
unbeaufsichtigt!**



**Arbeite auf einer
Arbeitsunterlage!**



NOTENBLÖCKE

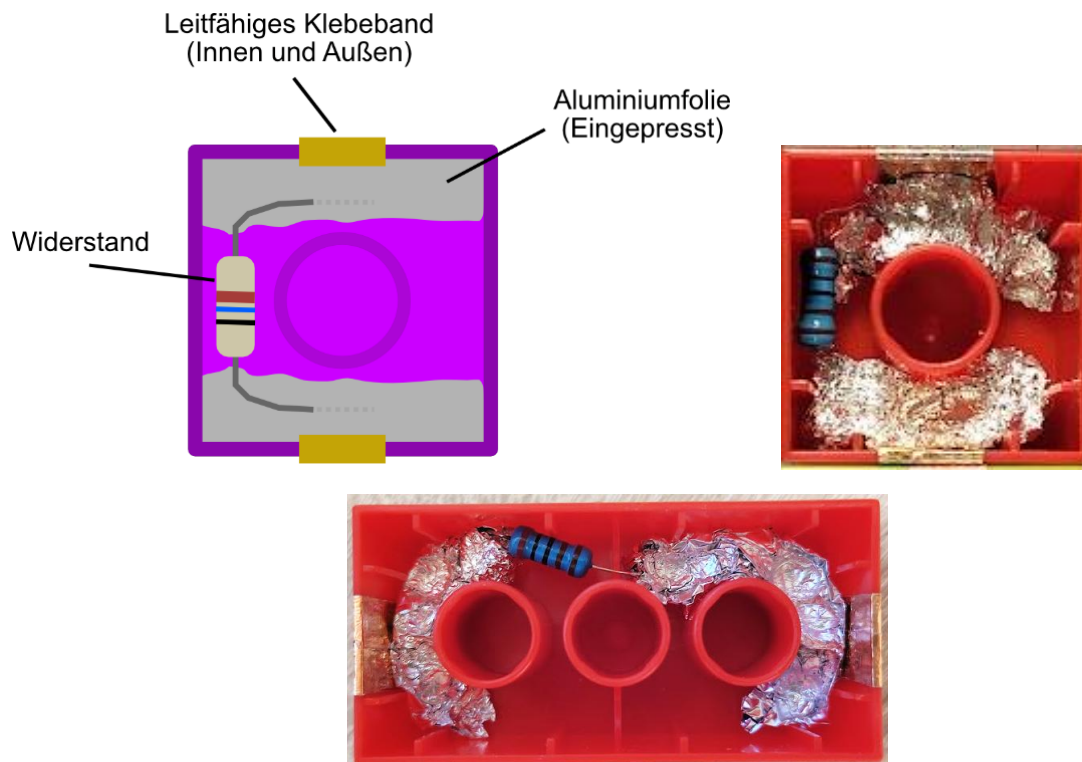
Die Platte ist bereit: Jetzt kommen die Notenblöcke ins Spiel. Wir haben zwei verschiedene Größen verfügbar: 2x2 und 2x4 große Blöcke.

Je nach Größe des Blocks muss ein unterschiedlicher Widerstand eingebaut werden:

- 2x2 Block: 1k Ω (1000 Ohm)
- 2x4 Block: 2k Ω (2000 Ohm)

Ziel ist es, den Widerstand mittels Alufolie an das leitfähige Klebeband zu fixieren, so dass das Klebeband einen durchgängigen elektrischen Fluss erlaubt.

Ein fertiger Notenblock sieht so aus (Ansicht von unten):

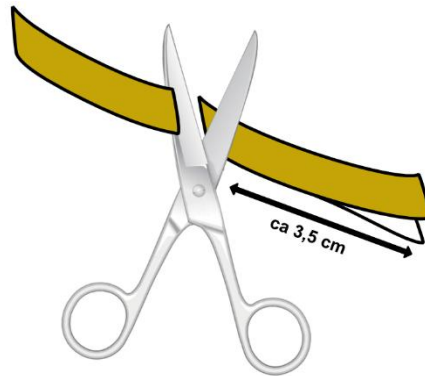


Befolge die Schritte auf den folgenden Seiten in der gegebenen Reihenfolge, um einen Notenblock anzufertigen. Wiederhole die Schritte bis du alle (oder einige) Notenblöcke fertig hast.

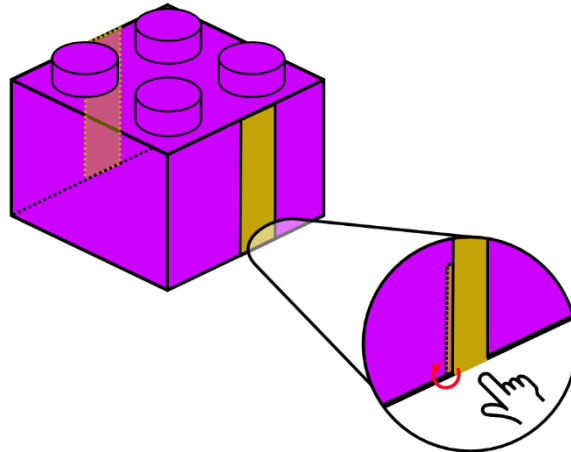
Die Anleitung gilt für 2x2 und 4x2 Blöcke. Wähle immer den entsprechend richtigen Widerstand und richtige „Alu-Kipferl-Größe“! 😊



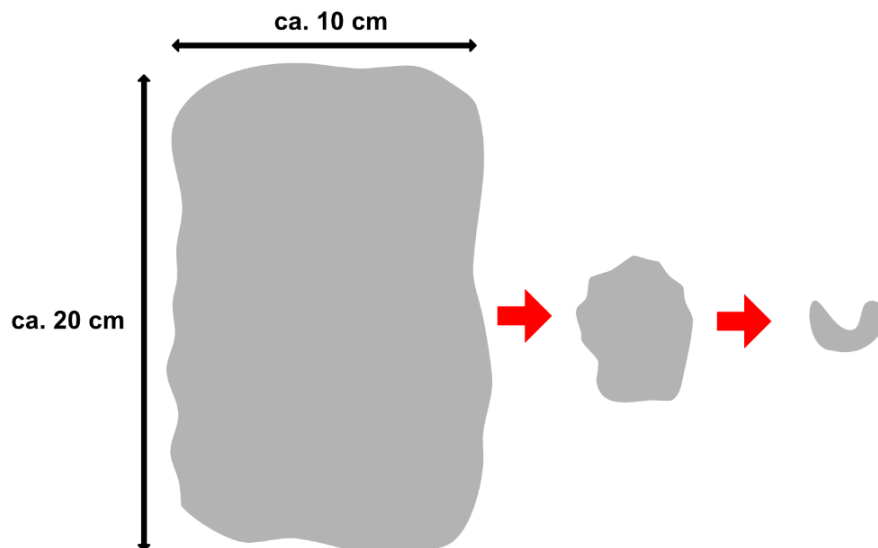
1. Schneide **zwei** etwa 3,5 cm breiten Klebestreifen ab und löse sie vom Schutzfilm.



2. Klebe zwei (auf der je gegenüberliegenden Seite) **breite** Klebestreifen von der Außenseite über die Kante auf die Innenseite. Achte darauf, dass die Folie im Inneren nicht zu kurz ist.

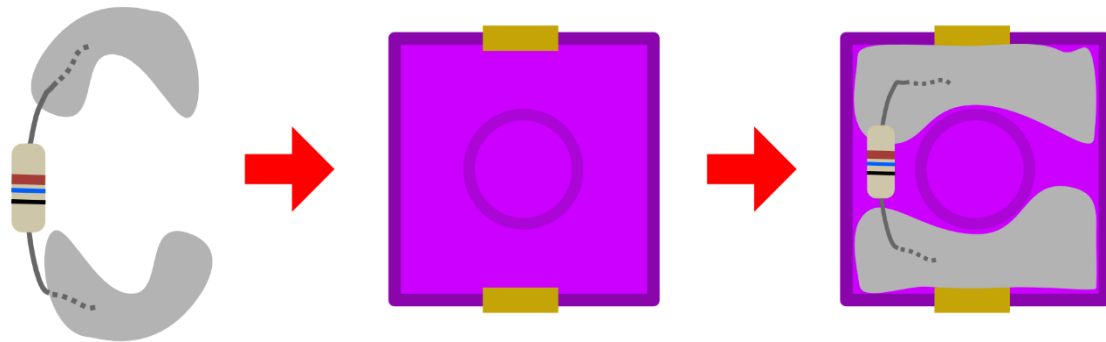


3. Mache **zwei** Aluminium- „Kipferl“ und forme sie so, dass sie jeweils zwischen dem mittleren Plastikkreis und der Innenwand des Blocks passen. Verwende dafür (*etwa*) 10 x 20 cm Aluminiumfolie.

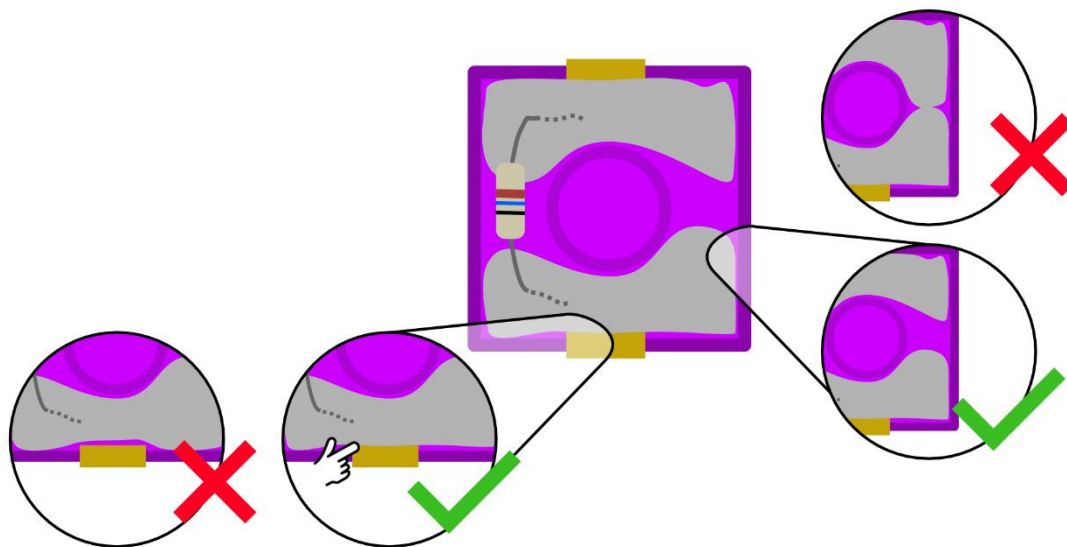




4. Stecke den Widerstand in beide Aluminiumbällchen und setze das Aluminium-Widerstand Konstrukt in den Block ein. Du kannst für diesen Schritt einen dünnen Stift verwenden, um das Alu-Kipferl in den Block zu drücken.



5. Stelle sicher, dass der Widerstand gut sitzt, das Aluminium das leitende Klebeband berührt und alles gut in den Block eingepresst ist. Die zwei Aluminiumbällchen dürfen sich nicht berühren¹.



¹ Wenn sich die Aluminium-Kipferl berühren, wird der Widerstand übersprungen – Denn Strom nimmt immer den kürzesten Weg. Dadurch würde der Notenblock keine messbaren Ergebnisse liefern 😬



STROMZUFUHR

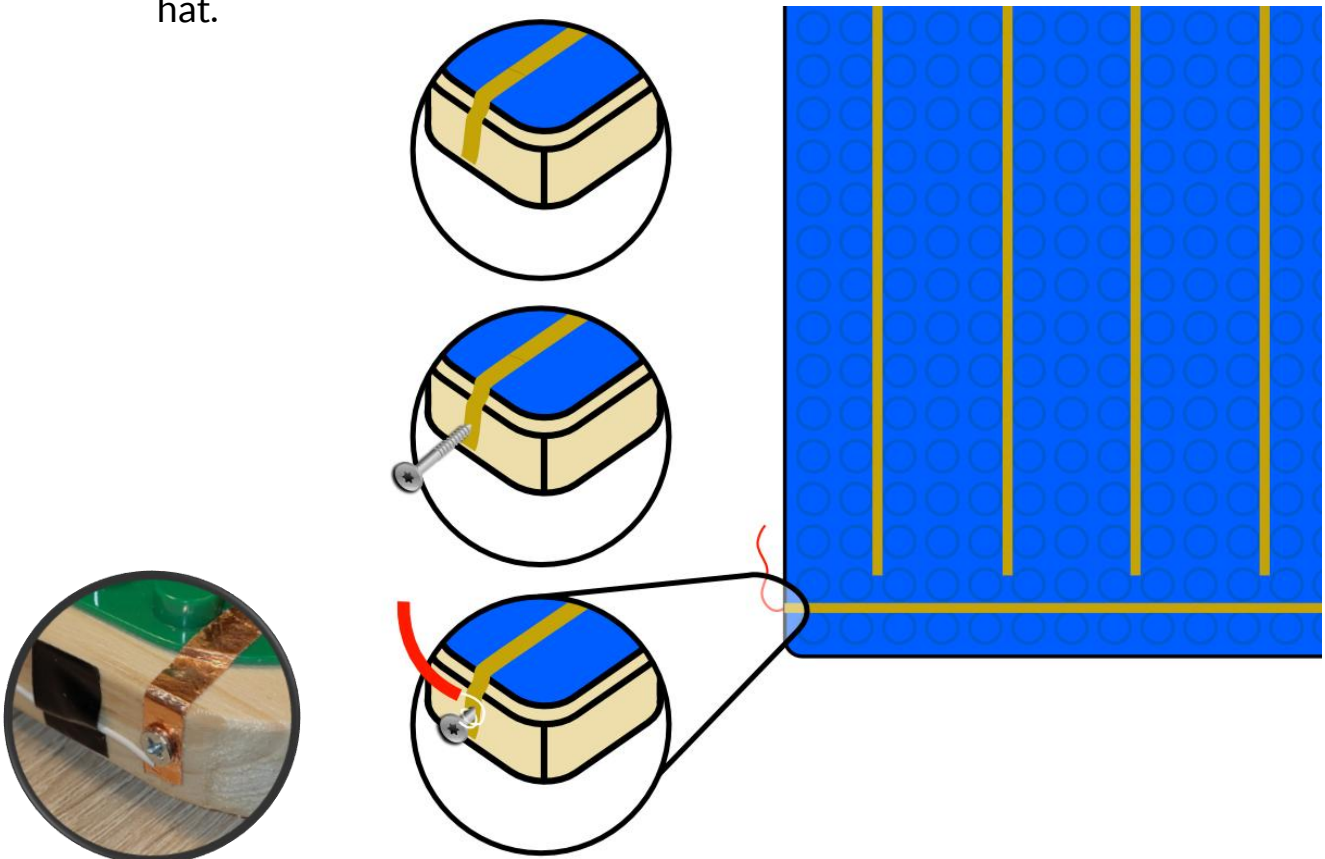
Wir haben jetzt bereits alle notwendigen Blöcke fertig gebaut. Super!

Im letzten Schritt müssen wir nur noch das Kabel der Stromzufuhr an unsere 5 Volt-Bahn (quer verlaufend) verbinden. Dafür benötigen wir keinen eigenen Block, sondern können direkt ein Kabel an das schmale leitende Klebeband anbringen.

Führe diese Schritte bei einem der vorgebohrten Löcher der Platte durch. (Es kann das Loch Links oder Rechts verwendet werden)

Gehe wie folgt vor:

- Klebe ein kleines Stück leitendes **schmales** Klebeband über die Kante des Brettes und verbinde somit die 5V-Bahn und das Loch. Das Loch wird hier vom Klebeband überdeckt.
- Schraube die beigelegte Schraube in das Loch, so dass etwa 2-3mm Abstand vorhanden ist.
- Wickle nun das Stromkabel (abisoliertes Ende) um den Kopf der Schraube. Nachdem du das Kabel ein, zwei Mal gewickelt hast kannst du die Schraube die restlichen 1-2mm einschrauben. Stelle hier sicher, dass das Kabel gut sitzt und Kontakt mit dem Klebeband hat.





ELEKTRONIK

Nach dem Bauen kommt das große Verkabeln. Bevor wir zum Verkabeln beginnen müssen wir uns aber noch die physikalischen Grundlagen kurz ansehen.

Der Arduino Microcontroller hat viele Ansteckplätze, wir benötigen aber nur ein paar davon. Das sind:

- **5V:** Das ist unsere Stromquelle, die mit der 5V-Bahn verbunden wird und somit alle Notenblöcke mit Strom versorgt.
- **GND:** Das ist der Nullpunkt. Zu diesem Endpunkt fließt der Strom hin.
- **A0 – A7:** Das sind die einzelnen Sensoren, die mit den Sensor-Bahnen verbunden werden.

Klingt so weit verständlich. Können wir das einfach schon so anschließen?

Nein, ganz so einfach ist das leider nicht. Die Sensoren A0-A7 sind **Spannungsmesser**, der Widerstand wird durch die Spannung zwischen ihnen und GND berechnet. Solche Spannungsmesser haben einen sehr hohen Widerstand → Also fließt über den Sensor selbst quasi kein Strom.

Deshalb müssen wir einen sogenannten **Spannungsteiler** (eng. Voltage Divider) einsetzen. Ein solcher Teiler besteht immer aus mehreren Widerständen. Zumindest einen Widerstand haben wir schon: Die Notenblöcke². Zusätzlich brauchen wir dann noch einen **Referenzwiderstand**. Jeder Stromkreis (Also für alle Sensoren) braucht einen solchen Widerstand, der für alle Sensoren die gleichen Ohm hat.

Daraus folgt der vereinfachte Zusammenbau für jeden Sensor:

5V → Notenblöcke (R_x) → Sensor (A_x) → Referenzwiderstand (R_1) → GND

² Ausgenommen bei Pausen ohne Brückenblock, hier fließt generell kein Strom.



Mit dieser Zusammensetzung können wir nun die Spannung für jeden Sensor berechnen:

$$V_{Raus} = V_{Rein} \cdot \frac{R_x}{R_1 + R_x}$$

Und mit etwas Umformen können wir dadurch den Widerstand berechnen:

$$R_x = R_1 \cdot \frac{V_{Raus}}{V_{Rein} - V_{Raus}}$$

Mit jeweils:

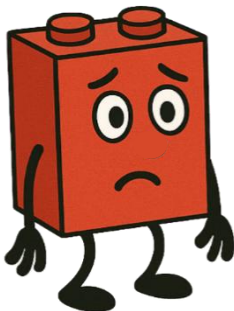
R_x – Widerstand durch Notenblöcke

R_1 – Fixer Referenzwiderstand

V_{Raus} – Spannung zwischen R_x und R_1 relativ zu GND

V_{Rein} – Das sind die 5V vom Arduino

Wir verwenden in unseren Blöcken $1k\Omega$ und $2k\Omega$ Widerstände. Entsprechend verwenden wir auch ähnlich dimensionierte Referenzwiderstände. Ein guter Trade-Off ist hier ein **$2k\Omega$ Widerstand**. Diese werden wir dann später im Schaltplan einbauen, damit wir unseren Spannungsteiler fertig bauen können.



Kein Grund zur Sorge!

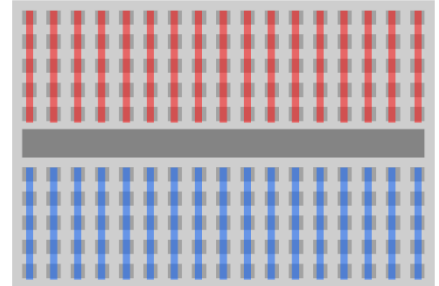
Solltest du jetzt bereits verzweifelt den Taschenrechner ausgepackt haben: Keine Sorge, wir müssen davon nichts per Hand berechnen. Die AudioBrix Software berechnet uns den Widerstand automatisch 😊



VERKABELUNG

Wir verkabeln die zuvor besprochenen Spannungsteiler mit einem **Breadboard** und Jumper-Kabel. Breadboards sind leere Platten mit Löchern, in die Jumper- Kabel und Widerstände gesteckt werden können.

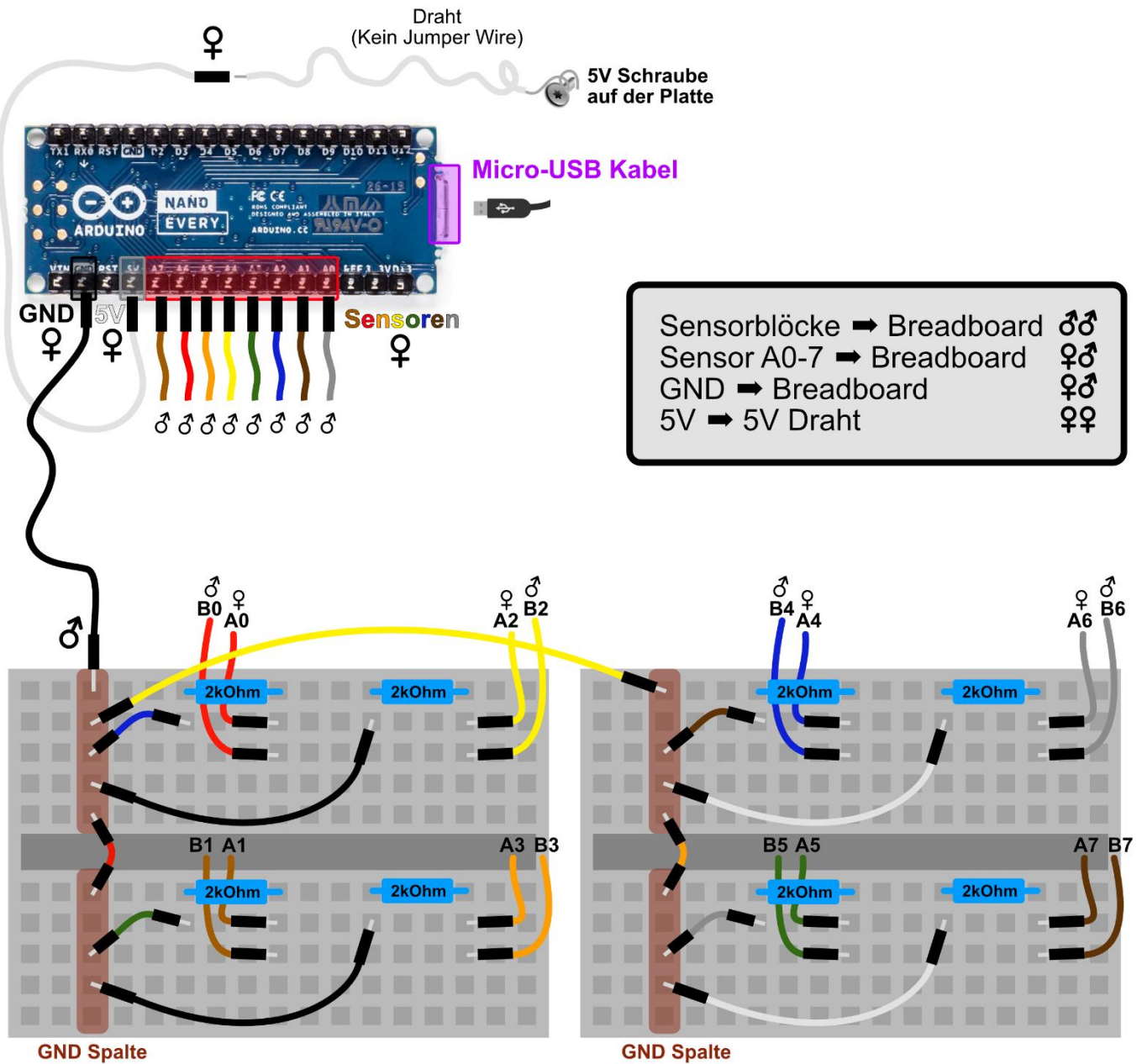
Die Löcher sind in eine Richtung verbunden. Im rechten Bild sind alle Löcher innerhalb der roten und blauen Linien miteinander verbunden. In die andere Richtung (quer) sind sie nicht verbunden. Ebenso sind die Spalten mit einem langen Balken durchtrennt.



Für jede Notenbahn:

- Wird ein Referenzwiderstand ($2k\Omega$) zwischen zwei Spalten im Breadboard gesteckt.
- An einem Ende des Referenzwiderstands wird das Kabel vom Sensor-Block (B...) und das Kabel zum Arduino Sensor (A...) gesteckt.
- Am anderen Ende des Referenzwiderstandes wird ein Kabel zu einer GND-Reihe platziert.
- Verwende die Farben so wie in der detaillierten Verkabeln-Ansicht auf der nächsten Seite.

Auf den nächsten Seiten findest du den detaillierten Schaltplan sowie eine detaillierte Schritt-Für-Schritt Anleitung.



Beachte beim Verkabeln:

- Die richtigen Farben³
- Die richtigen Kabel-Arten (weiblich: ♀ und männlich: ♂)
- Die Reihenfolge der Sensoren (A0-A7) und der Sensorblock-Kabel (B0-B7)
- 2kOhm Widerstände für das Breadboard (oben [blau](#) dargestellt)

³ Das 5V-Kabel (♀♀) kann farblich abweichen.



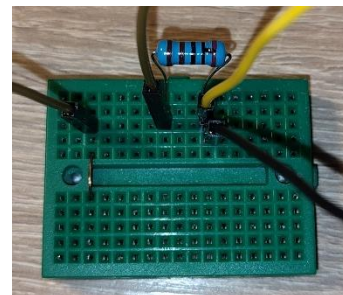
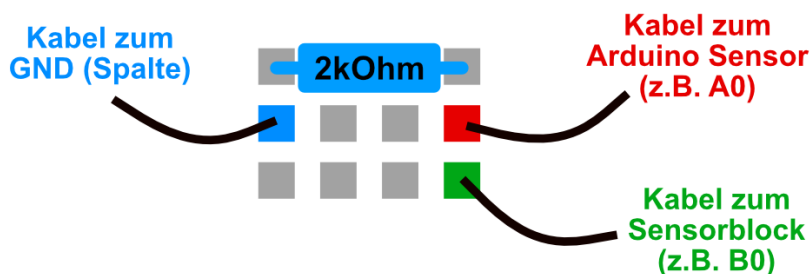
SCHRITT-FÜR-SCHRITT VERKABELUNG

Wie bereits erwähnt benötigen wir **acht Spannungsteiler**.
Sehen wir uns dafür mal einen einzelnen Spannungsteiler an:

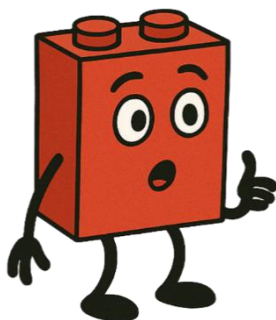
- An einem Ende des 2kOhm Widerstandes sind das Kabel zum Arduino-Sensor-Pin (A0 – A7), sowie ein Kabel zum entsprechenden Sensorblock (schematisch B0-B7) angesteckt.

Der Sensorblock (B0) vom ersten Taktschlag gehört zu A0, der zweite Taktschlag/Sensorblock zu A1 und so weiter.

- Auf der anderen Seite des Widerstandes geht ein Kabel zu einer GND-Spalte. Diese GND-Spalten verbindet alle „Ausgänge“ der Spannungsteiler mit dem Arduino.



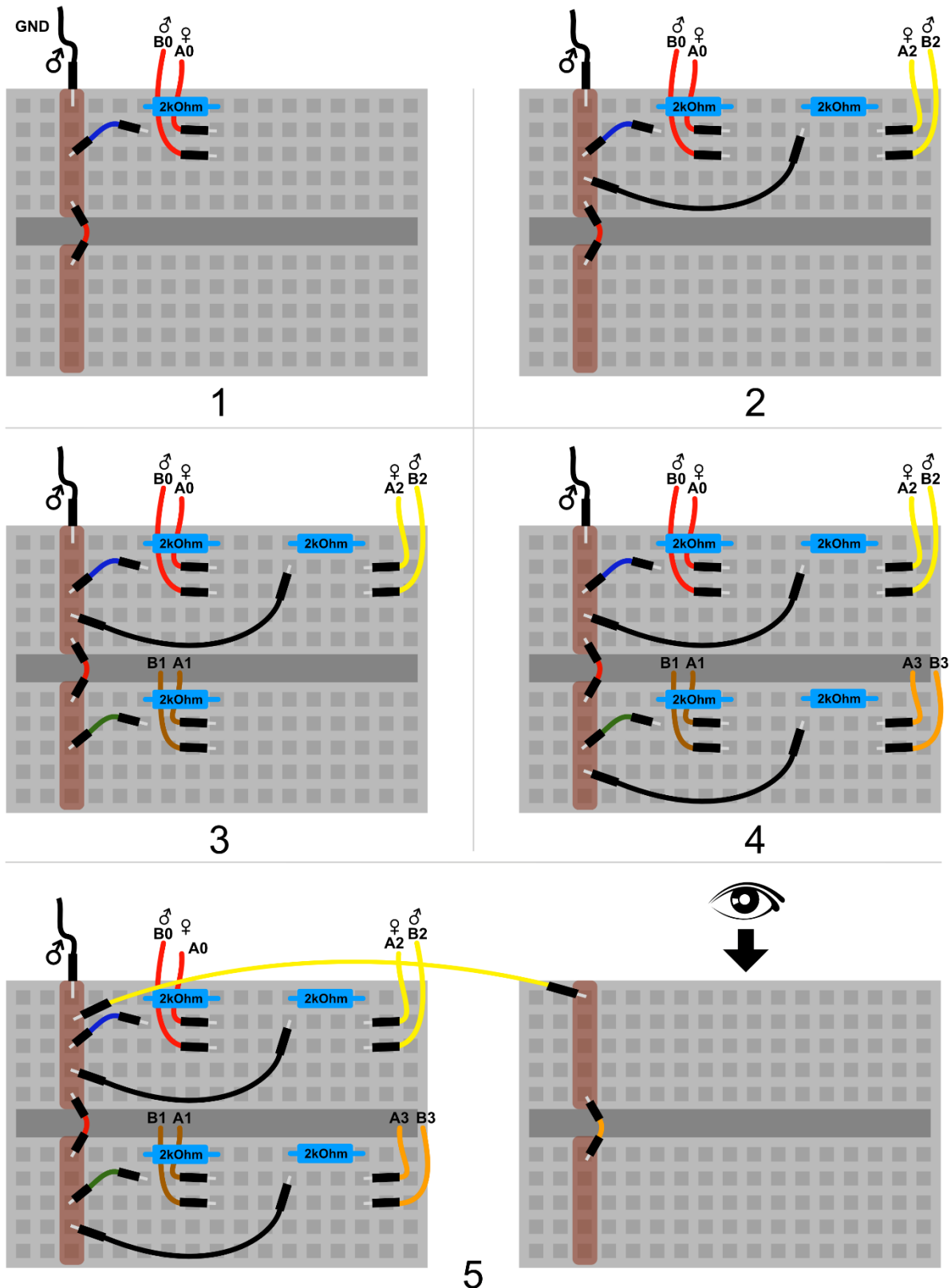
Ziel ist es, acht Spannungsteiler auf zwei kleinen Breadboards zu platzieren. Es müssen also pro Breadboard vier Spannungsteiler platziert werden.



Wir beginnen beim Zählen von Null!

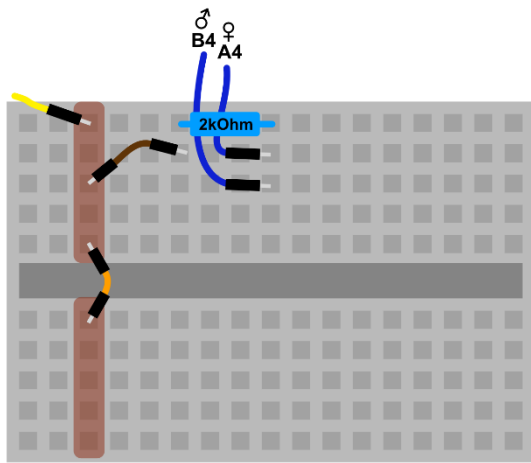
Die Sensor-Pins fangen bei 0 an. Entsprechend beginnen wir auch bei den Sensorblöcken bei 0.

In der Informatik wird bereits seit 1967 immer ab Null gezählt. Wenn wir also Taktschläge 1 bis 8 meinen, heißt das in der Informatik 0 bis 7.

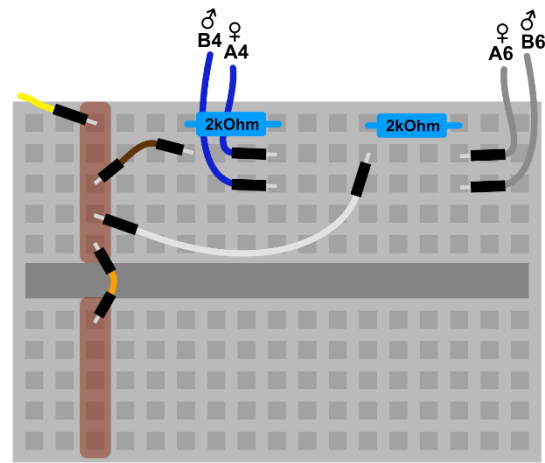


*B0-B7 steht jeweils für die Kabel zu den Sensorblöcken
A0-A7 steht jeweils für die Kabel zu den Arduino Sensor Pins*

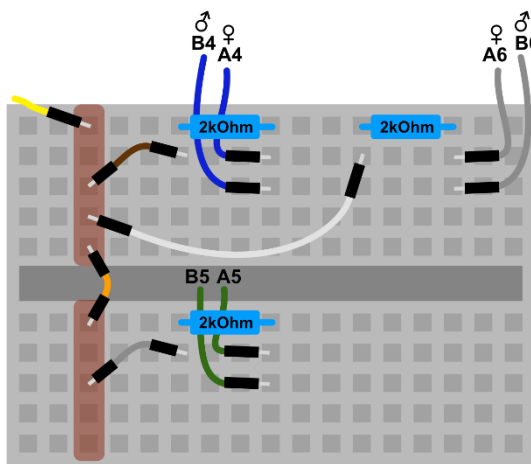
(Die genaue Position der Spannungsteiler darf etwas abweichen, allerdings müssen die Kabel/Widerstände immer entsprechend in der Spalte passen.)



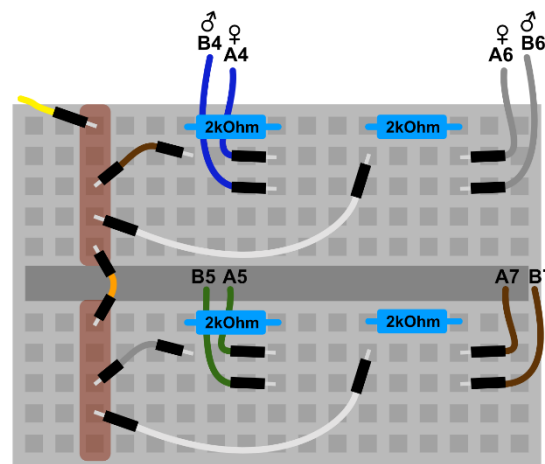
6



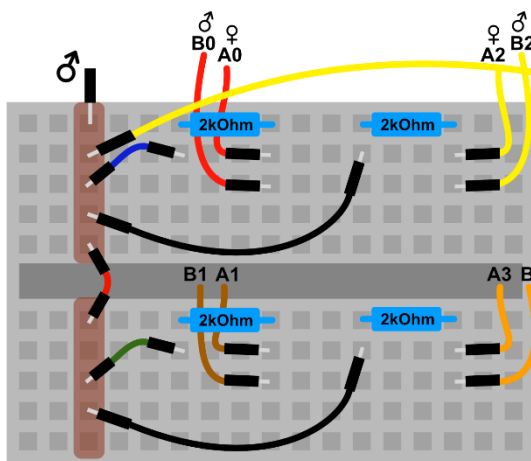
7



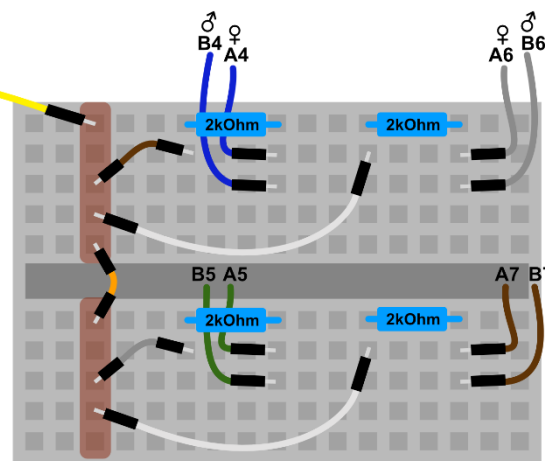
8



9



GND Spalte



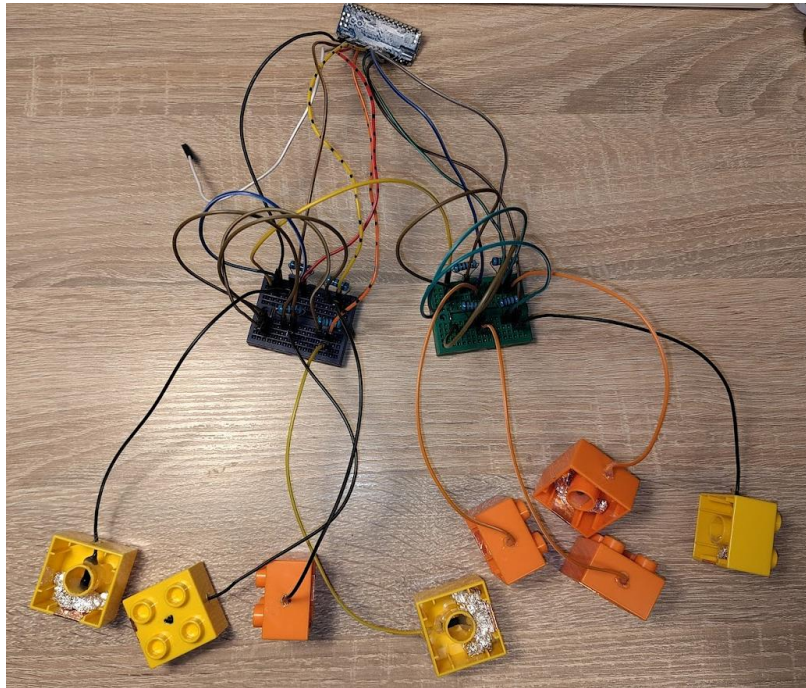
GND Spalte

10

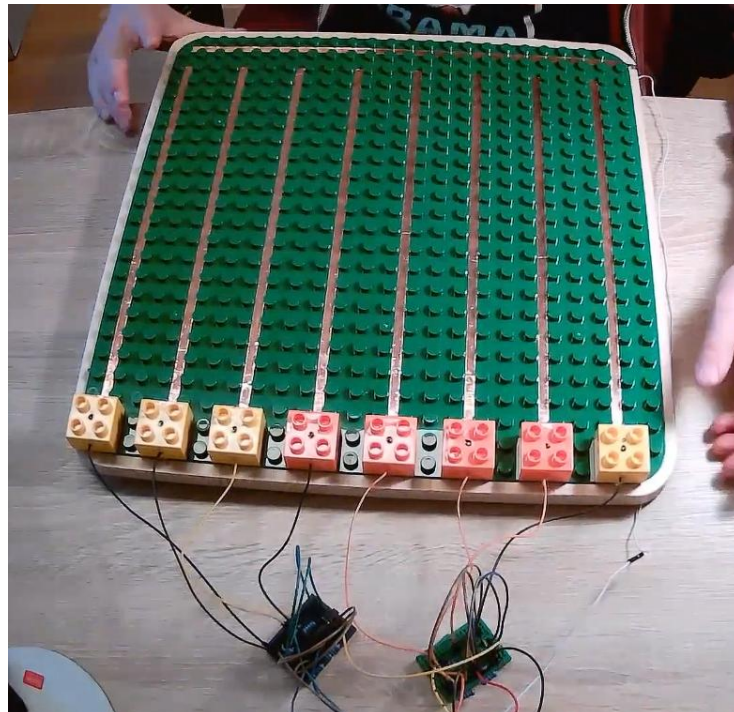
*B0-B7 steht jeweils für die Kabel zu den Sensorblöcken
A0-A7 steht jeweils für die Kabel zu den Arduino Sensor Pins*



Die fertige Verkabelung sieht dann etwa so aus⁴:



Stecke nun die Blöcke in der richtigen (farbbasierten) Reihenfolge auf die Sensorbahnen von links (0) bis rechts (7). Das sieht dann so aus:

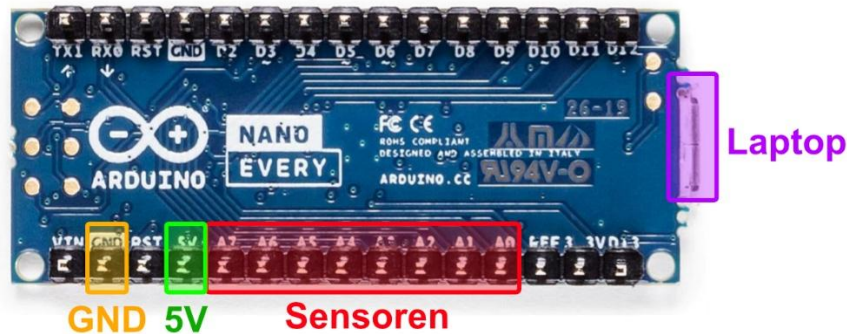


⁴ Bei dieser Darstellung weichen die Farbcodes von der zuvor besprochenen Anleitung ab. Stattdessen wurden hier die Blöcke mit (B) 0-8 beschriftet. Halte dich dennoch wie in der Anleitung gezeigt an die Farbkodierung.



Die im Schaltplan gezeichneten Ausgänge (5V, GND und die Sensoren) müssen am Arduino angesteckt werden. Auf der Rückseite des Arduino (dort, wo die Jumper-Kabel angesteckt werden) sind kleine Texte, die zeigen, wo welcher Anschluss ist.

Die für uns relevanten Pins sind:



Nachdem wir alle notwendigen Kabel verbunden haben, kann der Arduino mit dem Laptop verbunden werden. Nutze das Mikro-USB Kabel, um den Arduino an einen USB-Port am Laptop zu stecken.

Vergiss nicht, dass Stromkabel der Grundplatte (welches an der Schraube fixiert ist), mit dem 5V-Kabel des Arduinos zu verbinden – Ansonsten läuft hier gar nichts! 😊

Wenn der Arduino verbunden ist, blinkt das Lämpchen auf der Vorderseite orange.



SOFTWARE

Unser Instrument ist vollbracht – Gute Arbeit! Jetzt fehlt nur noch die Verbindung über die AudioBrix Software. Damit wir die Software auf unserem Rechner verwenden können müssen die folgenden Schritte durchgeführt werden. Es gibt dafür zwei Varianten.

Variante 1: Anwendung mittels .exe öffnen (Empfohlen)

1. Lade die AudioBrix Software herunter:
 - Öffne dev.waldhoer.org/audiobrix in deinem Browser
 - Gib dabei folgendes Passwort an: **Brick-Brix-1365**
2. Extrahiere den ZIP-Ordner [repo.zip](#) und öffne den enthaltenen Ordner [waldhoer-majorbrix... > dist](#).
3. Öffne die darin enthaltene [main.exe](#) Datei mit einem Doppelklick.

Achtung: Es ist möglich, dass Virenprogramme die Anwendung fälschlicherweise als gefährlich markieren. Fahre bei dieser Warnung dennoch fort.

Es wird ein Terminal geöffnet. Schließe dieses Fenster nicht.

4. Öffne deinen Browser und öffne [localhost:8000](#) in der Adresszeile

Falls es beim Starten der Anwendung zu Problemen kommt oder Fehlermeldungen in der Konsole auftreten, probiere Variante 2 auf der folgenden Seite.



Variante 2: Anwendung mittels Python starten:

5. Lade die AudioBrix Software herunter:
 - Öffne dev.waldhoer.org/audiobrix in deinem Browser
 - Gib dabei folgendes Passwort an: [Brick-Brix-1365](#)
6. Extrahiere den ZIP-Ordner [repo.zip](#) und öffne den enthaltenen Ordner, der eine [install.bat](#) oder [install.sh](#) Datei enthält.
7. Lade dir die Programmiersprache Python von der offiziellen Python Seite (www.python.org/downloads) herunter und führe die Schritte des Installations-Assistenten durch.
8. Gehe zurück zum Ordner und führe folgendes aus:
 - **Windows:** Doppelklick auf [install.bat](#)
 - **MacOS:** Doppelklick auf [install.sh](#)Die Installation der notwendigen Libraries erfolgt danach automatisch.
9. Um die Software zu starten, navigiere in den [dashboard](#) Ordner und mache einen Doppelklick auf [main.py](#).

Es wird ein Terminal geöffnet. Schließe dieses Fenster nicht.

10. Öffne deinen Browser und öffne localhost:8000 in der Adresszeile



EINRICHTUNG

Beim ersten Starten der Anwendung müssen noch Kleinigkeiten eingestellt werden, damit das Instrument funktioniert.

Das Setup wird automatisch bei erster Öffnung gestartet.

Wähle hier den passenden Anschluss, an dem der Arduino verbunden ist. Unser Systemtest empfiehlt diesen Anschluss:

COM3 - Arduino NANO Every (COM3)

★ COM3 - Arduino NANO Every (COM3) ★

Wähle hier den passenden MIDI-Anschluss. In der Regel funktioniert Anschluss 0. Sollte 0 oder 1 nicht funktionieren, installiere bitte [VirtualMIDISynth](#). Unser systemtest empfiehlt diesen Anschluss:

0 - Microsoft GS Wavetable Synth 0

★ 0 - Microsoft GS Wavetable Synth 0 ★

Du kannst diese Einstellungen jederzeit ändern, sollte etwas nicht funktionieren.

Einstellungen Speichern und Fortfahren

Stelle diese zwei Parameter ein und klicke auf „Speichern und Fortfahren“. Es folgt ein kleines Tutorial und schon geht's los! 😊



Falls der Sequencer oder die Blockerkennung nicht funktioniert müssen wir die Eigenschaften [arduino_port](#) und [midi_device_id](#) weiter konfigurieren. Die Software schlägt automatisch die verfügbaren Optionen vor.

- **Arduino Port:** Das AudioBrix Programm erkennt i.d.R. den richtigen Anschluss und zeigt dir die Empfehlung an. Beispiel: „COM3“
- **MIDI Device:** Probiere es am besten zuerst mit dem **MIDI-Synthesizer 0** oder der vorgeschlagenen ID. Falls es später beim Starten des Sequencers zu Problemen kommt, probiere noch eine andere ID. Sollte es dann immer noch nicht funktionieren, installiere das kostenlose MIDI-Tool [VirtualMIDISynth](https://coolsoft.altervista.org/virtualmidisynth) (coolsoft.altervista.org/virtualmidisynth). Dieses wird dir dann in den Einstellungen ebenfalls angezeigt – Benutze entsprechend diese ID.

↻ Systemtest durchführen und Empfehlungen anzeigen

Einstellung	Beschreibung	Standard	Wert
arduino_port	Der USB Port an dem der Arduino verbunden ist. Empfohlene Einstellung(en): COM3 - Arduino NANO Every (COM3) Insgesamt Verfügbar: COM3 - Arduino NANO Every (COM3)	COM3	COM3
arduino_baudrate	Die Übertragungsrate (Abtastgeschwindigkeit) des Arduinos.	115200	115200
midi_device_id	Die Geräte ID vom MIDI Device. Sollte 0 oder 1 nicht funktionieren, muss ggf. MIDI Software installiert werden. Empfohlene Einstellung(en): 0 - VirtualMIDISynth #1 0 1 - Microsoft GS Wavetable Synth 1 Insgesamt Verfügbar: 0 - VirtualMIDISynth #1 0 1 - Microsoft GS Wavetable Synth 1	0	0

Andere Einstellungen können ebenfalls auf dieser Seite eingerichtet werden. Aber Achtung: Änderungen können Fehler verhorrufen!

Klicke nach den Änderungen auf „**Einstellungen Speichern**“ und kehre damit zum Spielbereich zurück.



DASHBOARD

Das Dashboard ist unser Spielbereich. Hier können wir

- Die erkannten Noten sehen und hören
- Die Blockerkennung starten / stoppen
- Den Sequencer starten / stoppen
- Musikinstrument wechseln
- Geschwindigkeit wechseln
- Details vom Programmablauf anzeigen
- Taktschläge stummschalten

AUDIOBRIX DASHBOARD

Alpha Version © [Merlin Waldhör](#) 2025

The screenshot shows the AudioBrix Dashboard interface. At the top is a grid of 8 columns (labeled 1-8) and 8 rows (labeled C4, B3, A3, G3, F3, E3, D3, C3). Several cells in the grid are highlighted with blue borders, representing notes. To the right of the grid is a label 'Taktschläge' with a line pointing to the grid. Below the grid is a label 'Notenhöhe' with a line pointing to the row labels. To the right of the grid is a label 'Blockansicht' with a line pointing to the grid. Below the grid is a musical staff with a treble clef and a 4/4 time signature, showing a sequence of notes. Below the staff are two buttons: 'Blockerkennung stoppen' (with a red border) and 'Sequencer starten' (with a green border). To the left of these buttons is a label 'Blockerkennung de/aktivieren' with a line pointing to the 'Blockerkennung stoppen' button. To the right of these buttons is a label 'Sequencer de/aktivieren' with a line pointing to the 'Sequencer starten' button. Below these buttons are five instrument icons: a keyboard, a drum set, a guitar, a trumpet, and a violin. To the left of these icons is a label 'Instrumenten auswahl' with a line pointing to the keyboard icon. Below the instrument icons is a slider control with a green knob. Below the slider is a label 'Geschwindigkeitsregler' with a line pointing to the slider. Below the slider is a label 'Geschwindigkeit: 133 BPM' with a line pointing to the text.

Taktschläge

Notenhöhe

Blockansicht

Notenansicht

Blockerkennung de/aktivieren

Sequencer de/aktivieren

Instrumenten auswahl

Geschwindigkeitsregler

Geschwindigkeit: 133 BPM



- **Blockansicht:**
Die obere Tabellen-artige Ansicht zeigt die momentan gelegten Notenblöcke an. Drücke auf einen der Taktschläge am oberen Rand (1 bis 8), um einen Taktschlag stummzuschalten. Stummgeschaltete Spalten werden rot dargestellt.
- **Notenansicht:**
Die Notenansicht zeigt die Noten als musikalische Notation an.
- **Blockerkennung:**
Ist die Blockerkennung aktiviert, werden die Widerstände gemessen und Notenwerte berechnet. Wenn die Blockerkennung ausgeschaltet ist, werden keine Aktualisierungen (→ wenn die Blöcke neu gelegt werden) angezeigt.
- **Sequencer:**
Ist der Sequencer aktiviert, so werden die Noten in der Schleife abgespielt. Ist er deaktiviert werden keine Noten abgespielt.
- **Instrument:**
Es kann zwischen mehreren Klängen gewählt werden. Um einen Klang zu wählen, klicke auf eines der Symbole (Klavier, Xylophon, Streicher, Trompete, Gitarre)
- **Geschwindigkeit:**
Die Abspiel-Geschwindigkeit kann mit dem Regler eingestellt werden. Die Geschwindigkeit wird in BPM („beats per minute“) angegeben. Sie betrifft nur den Sequencer.
- **Detaillierte Ausgabe:**
Es können immer wieder Fehler auftreten. In diesem Fall macht es Sinn, die detaillierte Log-Konsole einzublenden. Dort werden oft hilfreiche Informationen preisgegeben. Häufige Probleme werden im Kapitel „Häufige Fragen“ beantwortet.

HÄUFIGE FRAGEN

ZUR SOFTWARE

- **Ich sehe eine **Warnung**, was bedeutet das für mich?**
Bei Software im Allgemeinen unterscheidet man zwischen verschiedenen Nachrichten-Arten. Eine **Warnung** kann hier auf Unregelmäßigkeiten hinweisen, die zu einem Problem führen **können**. Das muss allerdings nicht der Fall sein. Wahrscheinlicher ist es, dass ein **Fehler** – also ein tatsächliches Problem im Programmablauf – gemeinsam mit einer Warnung erscheint. Hierbei können uns Warnungen helfen, das Problem zu erkennen.
- **Ich habe bereits MIDI Device 1 und 0 probiert, aber der Sequencer startet immer noch nicht.**
Auf Windows ist es (leider) nicht ungewöhnlich, dass der Standard-MIDI Anbieter nicht funktioniert. In diesem Fall benötigen wir ein zusätzliches MIDI-Tool, um das Instrument zu verwenden.

[VirtualMIDISynth](#) ist ein solches Tool, welches gratis installiert werden kann. Nach der Installation wird das MIDI-Gerät dann in den Einstellungen blau vorgeschlagen. Wähle die angezeigte Nummer und probiere es erneut!
- **Der Sequencer läuft, aber ich höre nichts. Warum?**
Das tritt auf, wenn etwa VirtualMIDISynth installiert wurde, aber kein SoundFont darin aktiviert ist. Öffne dafür die VirtualMIDISynth Einstellungen und klicke auf „SoundFonts“. Lade ein beliebiges SoundFont von der Website herunter:
<https://coolsoft.altervista.org/en/virtualmidisynth#soundfonts> und füge dieses mit dem „+“ Knopf hinzu.

- **Das Dashboard funktioniert nicht oder hängt, was soll ich machen?**
Manchmal kann es zu Fehlern im Dashboard kommen. Lade die Seite im Webbrowser neu (meistens F5-Taste) und versuche es erneut. Sollte das Problem bestehen, versuche das Programm neu zu starten in dem du das Terminal schließt und mittels main.exe neu öffnest.
- **Warnungen und Fehler sind manchmal englisch. Warum?**
Das liegt daran, dass interne Programmabläufe- und Probleme meistens in Englisch angezeigt werden. Häufige Probleme haben wir übersetzt – Aber das geht leider nicht für alle Fehler 😞
- **Ich habe einen Fehler im Programm entdeckt, der nicht von mir verursacht wurde – An wen kann ich mich melden?**
Das Programm ist in kontinuierlicher Entwicklung. Melde deine Probleme gerne per Mail zu [REDACTED] Sende bitte die Datei „events.log“ im „log“ Ordner gleich dazu, damit eine sinnvolle Auswertung geschehen kann.

ZUR VERKABELUNG

- **Ist das Arbeiten mit Strom gefährlich?**

Grundsätzlich birgt das Arbeiten mit Strom immer Gefahren. In unserem Fall können wir uns allerdings beruhigen: Der Arduino arbeitet mit einer viel zu geringen Leistung, als dass der menschliche Körper dadurch betroffen werden könnte – Es fließt quasi kein Strom über den Körper.

Dennoch ist das Arbeiten mit Stromkreisen – etwa bei Steckdosen zuhause – lebensgefährlich und sollte immer durch Fachpersonal durchgeführt werden. Frage das Lehrpersonal, solltest du dir hier unsicher sein.

- **Die erkannten Notenblöcke schwanken sehr, wie kann ich das beheben?**

Gelegentlich kommt es immer wieder zu kleineren Schwankungen der Widerstandswerte – Das ist ganz normal. Sollte jedoch bei gewissen Blöcken immer wieder ein abweichendes Ergebnis auftreten, empfiehlt es sich zusätzliches leitendes Klebeband auf die leitenden Seiten zu kleben. Dadurch wird der Kontakt zum nächsten Block womöglich verbessert. Kontrolliere auch ob das Innenleben des Blocks richtig sitzt und keine Teile lose sind.

Solltest du dir sicher sein, dass die Blöcke gut verbunden sind und es dennoch zu Schwankungen kommt, überprüfe auch deine Verkabelung. Beim Breadboard können Widerstände oder Kabel leicht aus der Fassung rutschen – Dadurch kann es zu Fehlern kommen.

- **Mein Arduino Nano leuchtet durchgehend, nicht blinkend. Was tun?**

In diesem Fall liegt wahrscheinlich ein Defekt im Arduino Ablauf vor. Drücke den weißen Knopf am Arduino kurz, um den Microcontroller neu zu starten.

- **Was passiert bei einer Fehlschaltung? Was sind die Risiken?**
Auch beim Arbeiten mit dem Arduino ist es möglich Fehler zu begehen. Der für uns problematischste Fall ist der elektronische Kurzschluss, also dass Strom ohne Widerstand vom 5V zum GND fließt. Meistens bemerkt der Computer, dass beim Stromfluss etwas nicht stimmt und koppelt das Gerät automatisch und blitzschnell ab. Allerdings ist das nicht garantiert. Achte deshalb immer auf die richtige Verkabelung, um Arduino und Computer zu schützen! 🤪
- **Mein Arduino wird heiß, was tun?**
Stecke das Gerät umgehend vom Computer ab! Lass das Gerät abkühlen und prüfe deine Schaltung – Es liegt ein ernstzunehmender Kurzschluss vor. Kontrolliere die Schaltung und frage dein Lehrpersonal nach Unterstützung.

Entwickler, Autor und Illustrator: Merlin Waldhör, BSc

Betreuer: Dipl.-Ing. Dr.techn. Oliver Hödl

Arbeitsgruppe: Cooperative Systems Research Group

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