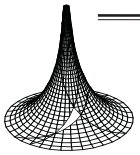

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Smartphones and QR-Codes in Education – A QR-Code Learning Path for Boolean Operations

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Abstract. During the last few years new technologies have become more and more an integrative part of everyday life. The increase of the possession rate of smartphones by young people is especially impressive. This fact asks us educators to think about a didactically and pedagogically well designed integration of smartphones into our lessons and to bring in ideas and concepts. This paper describes a specific learning path where learners can work step by step on the topic Boolean Operations with QR-Code scanners which have been installed on their smartphones. Student teachers for mathematics who completed the learning path took part in a survey where they were asked questions about their willingness to integrate smartphones into their lessons. The results of the survey are presented in the second part of the paper.

Key words and phrases: Smartphones, QR-Code, Boolean Operations, learning path.

ZDM Subject Classification: D30, D40, G10, G50, Q60, U70.

Smartphones in Education

Nowadays smartphones counted among the articles of daily use for young people. Numerous studies show the considerable increase of the possession of smartphones by young people during the last few years. In the year 2013 in Germany an average of 96% of girls and boys between the age of 12 and 19 had a mobile phone of their own and 72% a smartphone of their own (Feierabend et al., 2013). Up to April 2014 there was an increase of the possession of smartphones of up to 84% of the young people in Germany at the age of 12 to 13 years (Bitkom,

2015). Because of these numbers we can expect that in 2015 (nearly) every girl and boy will have a smartphone and is therefore equipped with a high performance computer. This fact is the reason why many educators are thinking of ways of how to integrate this new digital tool into their lessons and how smartphones can enrich teaching. Since about 2012 many materials which integrate smartphones in a great variety of subjects can be found in the internet (e.g. at `http://saferinternet.at`).

In this paper a deepening example will be presented for this purpose: A whole learning path with up to 13 stages for a special topic which can be reached via smartphone (where a QR-Code scanner is installed) will be introduced.

At the same time as educators had their first attempts for a well-balanced integration of smartphones in education many people in the school environment thought about the disadvantages and dangers of the use of smartphones in school. Meanwhile you can find a lot of brochures with a summary of many facts and hints and further material (e.g. videos) for teachers and parents in the internet (e.g. at `http://saferinternet.at`).

The potential of smartphones can mostly be exploited when users install and use additional software (apps) on their smartphones. In the year 2013 young peopleon average installed 19 apps on their smartphone - girls on average 15 and boys on average 24 (Feierabend et al., 2013). One type of apps are so called QR-Code scanners. These apps enable the users of smartphones with the help of the integrated digital camera to scan the little square codes which guide them forward to further texts or websites.

QR-Code

The term QR-Code stands for "Quick Response"-Code (fast answer). QR-Codes are two-dimensional square patterns, which consist of many small black and white fields. These small fields visualise the binary structure (0 and 1) and are arranged by exactly defined criteria. QR-Codes were invented by the Japanese company Denso Wave in the year 1994 (Denso Wave, n.d.) and after their rapid worldwide dissemination they were included in many standards such as AIM (Association for Automatic Identification and Mobility), ISO (International Organization for Standardization),and JIS (Japanese Industrial Standard) (Wikipedia, n.d.). In industry QR-Codes are mainly used for data gathering. In everyday life the codes are very popular because of their ability to provide internet addresses graphically. The codes are read via smartphone or tablet and

users are guided directly to the linked website and no longer have to typewrite sometimes very long and hardly readable internet addresses. This characteristic of the codes delivered the motivation to provide the stages of the learning path to the students via QR-Codes. All the codes of the learning path were generated and downloaded as images with the help of the website `http://goqr.me/de/`. This generator provides the possibility to translate texts and internet addresses into QR-Codes which can be downloaded in many different formats, colours, and error correction levels.

The Scientific Basis of the Learning Path

The scientific educational basis for the conception of the QR-Code learning path was provided by the Blended Learning Concept from Maresch (2013). The paradigmatic fundament of the concept is the constructivistic based approach Cognitive Apprenticeship with its seven central stages: Modelling, Coaching, Scaffolding, Fading, Articulation, Reflection, and Exploration (Collins et al., 1989).

The Blended Learning Concept contains four steps: Input, Guided Assignments, Applied Usage, and Presentation/Articulation/Discussion/Reflection (Maresch, 2013). The QR-Code learning path with its up to 13 stages was developed along these four levels. In addition to that many other recommendations for the concept (e.g. for well-balanced use of social forms and regarding to the cognitive load (Sweller, 1988)) have been taken in account.

Introductory Comments on the QR-Code Learning Path

With the help of the QR-Code learning path students between the age of 13 and 17 can work out the topic Boolean Operations in highly flexible and autonomous ways. Learners improve and consolidate their knowledge of the three different Boolean Operations union, intersection, and difference by operating with a big variety of different learning materials. Finally at the last stage of the learning path students provide their digital anonymous feedback (Hattie, 2013), which enables the teacher to adopt and improve the learning path continuously.

For handling with the QR-Code learning path the students must have a smartphone with an access to the internet. In addition to that a installed pdf-reader is required. The teacher can provide the learning materials of two stages (stage 4 and 5) as hardcopies. For the work with both these working sheets students need

Figure 1. Three results of Boolean Operations of a cylinder and a sphere

to have a pencil and some coloured pencils. For the four optional stages 7 to 10 the learners must use a didactical or professional 3D-geomerty software such as GAM (`http://www.gam3d.at`) or MicroStation (`http://www.bentley.com`).

Partner work is the recommend social form for the learning path. Here on the one hand students can discuss all the questions regarding the Boolean Operations with their partner and on the other hand students can help each other if they have technical problems (maybe by solving the technical problem or working together on one smartphone).

Students should need at least 30 minutes to work with all the stages of the minimal version of the learning path (9 stages) and 90 minutes when they are also working out the stages 7 to 10 (constructions with the 3D geometry software).

Figure 2. QR-Code with a direct link to the learning path

The whole QR-Code learning path can be retrieved at `http://www.geotic.at` in the rubric "Materialien" in three variants:

- Website where all the QR-Codes and all the explanations are listed in a table. In addition to that all the links to the learning materials are provided. So therefore the whole learning path can be reached without a smartphone and can be attended as a "classical" learning path on the computer.
- Printout of the minimal variant (9 stages) to be posted in the classroom and
- Printout of the whole learning path (13 stages) also to be posted in the classroom.

The QR-Code Learning Path

Stage 1: Theoretical introduction into Boolean Operations. An overview of the three different Boolean Operations union, intersection and difference is provided for students. In addition learners can find many 2D- and 3D-examples. (format: pdf) (`http://www.adobe.com`)

Stage 2: The second stage provides exactly the same information as stage 1, but as a ppt-file. So users can also see all the integrated animations. (format: ppt) (`http://www.microsoft.com`)

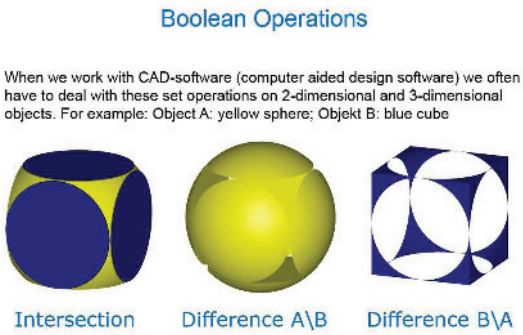

Figure 3. An example of stage 1 and 2

Stage 3: The 3D-objects of the stages 1 and 2 are provided as an interactive pdf. Students can move, rotate, and zoom all the objects and will get a more realistic 3D-impression of the objects. (format: pdf with integrated u3d)

Stage 4: Self-test of the topics of the stages 1 and 2. Here learners can answer all the questions on their own and after that can discuss their answers with their partner or ask the teacher for help and information. The test can be taken with apps which allow the editing of pdf-files but teachers also can provide the test as hardcopy for students to solve the questions with pencil and colour pencil. (format: pdf)

Stage 5: Four tasks which can be solved with freehand drawing. The exercise sheet shows a pyramid and a prism four times. The task is to find all the possible solutions of Boolean Operations with these two objects. Students should find all the visible edges. This stage could also be provided as hardcopies from the teacher. (format: pdf)

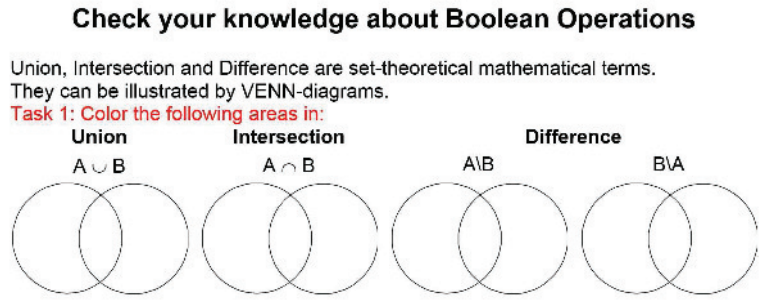

Figure 4. An example of stage 4

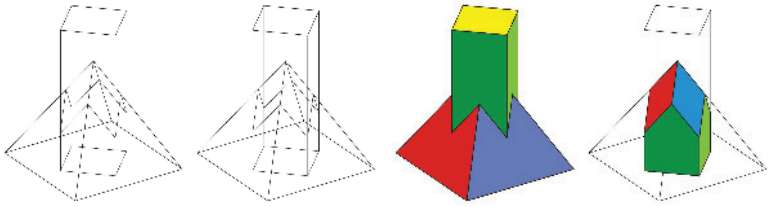

Figure 5. An example of stage 5 (left) and stage 6 (right)

Stage 6: This stage provides all the solutions to the exercises from stage 5. (format: pdf)

Stage 7 to 10: In the working sheets of stage 7 up to 10 you can find many dimensioned objects, which can be constructed with a didactical or professional 3D-geometry software. It has to be mentioned that at stages 7 to 10 you can see all the given objects on the smartphone and you can construct these objects on a computer. This means that there will be no switching between two windows on the computer (task and 3D-software) where students sometimes lose their orientation within the construction. (format of all four stages: pdf)

Stage 11: Interactive self-test which can be solved within a few moments. You just have to move some given objects to the matching quadrant. This exercise was generated at the platform `http://learningapps.org`. (format: html with an integrated learningapp)

Stage 12: At this stage learners pass a final self-test with 10 different questions regarding to Boolean Operations. After the click on an answer the program

automatically gives feedback if the answer is right or not and shows the correct answer. This stage was generated with the help of the tool eXe-Learning (`http://exelearning.org/`). (format: html)

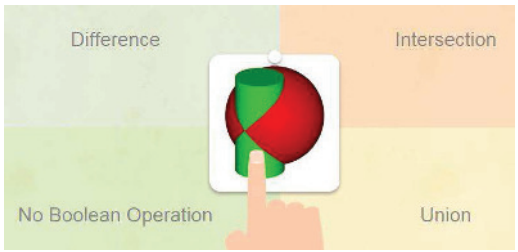

Figure 6. An example of stage 11

Stage 13: Here students deliver their digital and anonymous feedback regarding the QR-Code learning path while answering multiple choice questions. Teachers are invited to generate their own questions to give them the possibility of receiving individual feedback from their students. This stage was generated on the platform `https://surveymonkey.com/` where you can create your individual survey for free. (format: html)

A Survey on the topic "Smartphones and QR-Codes in Education"

Between November 2013 and January 2015 exactly 100 teacher students for mathematics at the University of Education Salzburg and the University of Salzburg took part at the survey. They were asked three questions regarding their opinion to the use of smartphones and QR-Codes in education. The questions were answered anonymously by students between the age of 19 and 24. All the questions were asked in German. So below you can find the original question (in brackets) and the English translation.
Question 1: Did you like working with the QR-Code learning path?
(*Frage 1:* Wie hat Ihnen das Arbeiten mit dem QR-Code-Lernpfad gefallen?)

very good (sehr gut)	good (gut)	moderate (mittel)	rather less (eher weniger)	not at all (gar nicht)
53	36	7	1	2

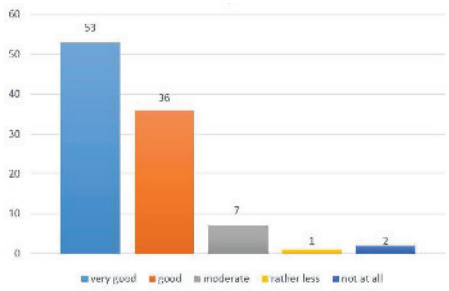

Figure 7. Results of question 1

89 (90%) of at least 99 students, who answered this question, liked working with the QR-Code learning path (very good or good). They expressed their positive impression of the QR-Code learning path.

Question 2: Can you imagine working with QR-Codes in your lessons?
(*Frage 2:* Können Sie sich vorstellen auch in Ihrem Unterricht hinkünftig mit QR-Codes zu arbeiten?)

yes, I definitely will work with QR-Codes (ja, ich werde damit ganz sicher arbeiten)	rather yes, not immediately, but soon (eher ja, noch nicht sofort, aber in absehbarer Zeit)	well, for sure not in the foreseeable future. Maybe later. (naja, sicher noch nicht in absehbarer Zeit. Eventuell später)	no, definitely not (nein, sicher nicht)
32	51	15	2

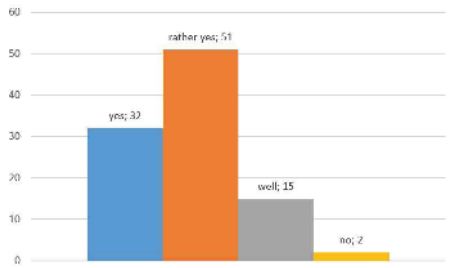

Figure 8. Results of question 2

As in question 1 students provide a predominant positive outlook regarding the use of QR-Codes in their lessons. 83 (83%) student teachers of 100 students,

who answered this question, answered with "yes" or "rather yes". In contrast to question 1 you will find most took the second option (rather yes). Just 2 (2%) of all students cannot imagine working with QR-Codes in their lessons and just 15 (15%) of the student teachers are sceptical and answered question 2 with "well, for sure not in the foreseeable future. Maybe later."

Question 3: Can you imagine integrating smartphones into your lessons?
(*Frage 3:* Können Sie sich vorstellen, die Verwendung von Smartphones in den Unterricht zu integrieren?)

yes, for sure (ja, ganz sicher)	rather yes (eher ja)	rather no (eher nein)	certainly not (sicher nicht)
49	38	11	2

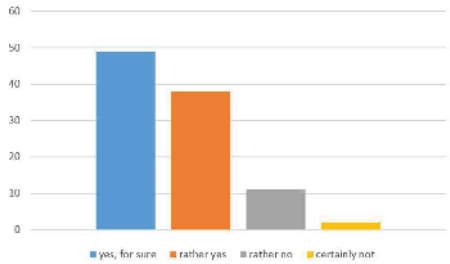

Figure 9. Results of question 3

The positive trend from questions 1 and 2 is continued in question 3 where students are asked if they can imagine working with smartphones in their lessons. 87 out of 100 students (87%) who answered this question can imagine integrating smartphones into education and vote with "yes, for sure" or "rather yes". 11% are sceptical ("rather no") and just 2% of the student teachers cannot image to using smartphones in their lessons.

Summary

Since the turn of the century we recognise a very big impact of new technologies in teaching geometry. On the one hand high performance computers and professional CAD-Software (Computer Aided Design Software) made it possible that nowadays nearly in every classroom new technologies arrived. On the

other hand an important reason why new technologies (computers, tablets, smartphones,...) are used in teaching geometry is that our curricula for geometry (in lower and upper secondary schools)requires the use of didactical and professional CAD-Software.

The results of the survey at the final stage of the QR-Code learning path show clearly the very optimistic view of student teachers of mathematics in regard to the integration of new technologies and especially of smartphones into their lessons. This supports the outlook that in future more and more new technology will be used in our classrooms.

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