Elementary optics lab with smartphones and instant messaging

Gerhard Rath
University of Graz

Abstract. Smartphones were integrated in an introductory optics course with elements of inquiry based learning. The aim was for the students to gain knowledge in basic optics, to exercise fundamental scientific methods, and to use the student’s mobile devices in meaningful ways. Beside the LED light, the camera and some apps, in particular WhatsApp was used as a tool for communication and exchange. A small evaluation on the usage of instant messaging for physics lessons brought good results and lead to some suggestions for the integration of WhatsApp into physics lessons.

1. Introduction

How can we integrate smartphones low-key and easy into physics lessons? This question follows the fact, that we teach students of the so called “Generation Z”, who grow up in a digital world, using mobiles and tablets in a natural way within their daily lives (Scholz 2014). On the one hand, the usage of smartphones in secondary schools is under debate. In some schools they are even totally forbidden. On the other hand, a lot of articles and publications, such as the iPhysicsLabs series in The Physics Teacher (e.g. Thoms et al. 2013), promote working with mobiles in physics teaching and learning, mostly within experiments.

Our approach aimed at using mobile devices in a similar way adolescents do in their everyday lives. It was not announced to the students as a unique or exceptional situation, but we integrated mobile phones as naturally and simple as possible. This particularly concerns the usage of WhatsApp as instant messaging service for communication and data exchange. There are only a few studies about the integration of this tool into teaching and learning activities (Bouhnik & Deaschen 2014, Cifuentes & Lents 2010, Rambe & Bere 2013). Therefore we concentrated our evaluation on this aspect. Within a diploma thesis about instant messaging services in physics teaching a group of 15 students was surveyed using questionnaires.

Regarding content the field of optics seemed proper for this approach. It was adapted after some published contributions to optics (Haagen-Schuetzenhoefer 2017, Colicchia & Wiesner 2015) and also followed the work of H. Muckenfuss. We only needed a small number of apps as the most work was done with the internal camera and the LED light of the mobiles. Most of the pictures in this article were taken by the students with their mobiles. The didactical path started with students’ conceptions on “How do we see?”. This was followed by investigations of the behavior of light, step by step going to the level of a geometrical model. At last, we came back to explanations of daily experience and technical applications using this model, mainly focusing on the field of image formation. Some aspects of the Nature of Science were consciously integrated, for instance reduction and abstraction.

All of that was embedded in real time communication. Using WhatsApp, pictures and screenshots were exchanged and discussed, including some observations at home. The lessons were held within an interdisciplinary subject called Science Lab, a combination of biology, chemistry and physics lab, and one semester of an interdisciplinary project. The physics part contained an introductory optics course in four groups, each of about 15 students, in 8th grade. The subject is mainly organized as lab work in
small groups with student’s experiments, using some elements of Inquiry Based Learning, mostly on guided levels (1-2 following Blanchard) (Blanchard et al. 2010).

2. Introductory optics

How do we see?
We started with a simple exercise: You see a sheet of paper lying in front of you. How does an image of the sheet come into your brain? The student’s drawings in Fig. 1 show a wide range of conceptions. In total, about half of them already used physical models, but some students were still thinking that rays were coming out of the eyes. After a discussion concerning optical illusions we came up with a simple, physical model of seeing.

Fig. 1. Drawings of students: How does an image of a sheet of paper come into your brain?

Fingers behind a glass of water
The first experiment discussed a rather daily observation. What do fingers behind a glass of water look like, seen inclined from above? Most of the student’s assumptions were wrong. It was very surprising for them that sometimes the fingers could not at all be seen through the glass of water. A lot of questions occurred as the situation is in fact very complex, when trying to explain it with our model. Here we used the smartphone camera for the first time (Fig. 2). The pictures could be exchanged quickly and provided suggestions for new observations. In addition, they showed that the phenomenon is not an optical illusion created by our brain, but must be a physical phenomenon, when a technical tool can fix it.

Fig. 2. Fingers behind a glass of water
From seeing to light
So we had to change the focus from our perception to the behavior of light passing through the glass. Using the phone’s light we got fascinating pictures (Fig. 3). Unfortunately the situation stayed complicated, as a lot of possible arrangements could be made. The results depended on many variables, such as the angle of incidence, the glass or the water level.

Fig. 3. The smartphones LED passes a glass of water

Forcing the light
In order to create measurable situations, which are needed for scientific evidence, we bundled the light into thinner rays (Fig. 4). The left picture realized this with the light of the phone combined with a lens and a slit. In the right picture we can see the next step of reduction: laser beams and geometrical objects of glass. This setup enabled the students to verify the basic laws of reflection and refraction, which made us reach an abstract level of geometrical and mathematical models.

Fig. 4. Left: A “beam” generated by the phones LED with lens and slit passes a glass of water. Middle: Laserbeam in water; Right: Laserbeam in semispheres of glass

Image formation
Staying on this abstract level, we investigated the image formation of lenses. Phone displays were used as light emitting objects, as the student’s picture shows (Fig. 5). The relation between size and distance of the object and the image as well as the lens equation could be estimated. On this level we also used the smartphone as a simulation tool to support the image construction, using the app “Ray optics”.

8 Ray Optics for Android: https://play.google.com/store/apps/details?id=com.shakti.rayoptics
Fig. 5. Image formation: A smartphone display (left) is used as light emitting object, the convex lens in the center generates a picture on the screen to the right.

**Water droplet lens**
A nice experiment for further inquiry followed: Place your phone on the table with the front camera on. Approach an object to determine how close you can put it to the camera while still getting a sharp image and what maximum size you can get (Fig. 6). As a next step, put a water droplet on the camera lens. What will happen? With that experiment we returned to the level of explaining the physical function of the human eye, or the camera as a technical application, using optical phenomena.

Fig. 6. Left: Approaching a pipette to the front camera. Right: With a droplet of water on the front lens we get an enlarged picture.

**Colors**
The phone’s display can create colors through a superposition of red, green and blue light. Surprisingly we can even measure colors, not in wavelengths, but in coordinates of color spaces (Bengtsson et al. 2014). The most suitable color space for that is the HSV space, with hue (H) as an angle from zero to 360 degree, representing the light spectrum. Measuring colors is a challenge and using the recommendable app “Color Grab”\(^9\) one can learn that colors not only depend on the object, but also on the surrounding light (Fig. 7).

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\(^9\) Color Grab for Android: https://play.google.com/store/apps/details?id=com.loomatix.colorgrab.
Fig. 7. Left: The app “RGB Color Mixer”\textsuperscript{10} generates yellow as a superposition of red and blue. Middle: Color of a piece of clothing (Color Grab) Right: Mixing light (red, green, blue) of lamps with estimation of the colors (Color Grab)

For all units WhatsApp was mainly used as a tool to send the pictures to the group instantly and to discuss them, in addition to ordinary lab minutes.

3. Evaluation of the use of WhatsApp
There had been no systematical evaluation about the effectiveness of the experiments. The outcome (pictures, discussions) showed a lot of successful activities, the feedback of the students was generally positive. Both had been communicated using WhatsApp, so we decided to perform a small evaluation concerning the usage of this tool in one of the classes (14 pupils). It was part of a study related to the impact of WhatsApp on doing homework, a diploma thesis at the University of Graz (Sorschag, 2016). The answers to the open question about the perception of WhatsApp were categorized. They showed acceptance for using WhatsApp for science classes (Fig. 8).

Fig. 8. Answers to the question “How did you perceive the communication with your teacher via WhatsApp?”

\textsuperscript{10} RGB Color Mixer for Android: https://play.google.com/store/apps/details?id=com.FlyingSolo.src
Fig. 9 shows a very high acceptance of the work with WhatsApp in the questioned group. Other groups had different results, but in the long run experience showed that the majority appreciates the extended communication. Nevertheless, there were always some students who did not like it or were not able to use WhatsApp at all.

![Fig. 9. Answers to the argument “I would like to use WhatsApp again in physics class”](image)

4. Conclusion
It showed that student’s smartphones can be a useful tool to support the teaching of elementary optics, when integrated in a natural way and mainly used in practical work. Further research could ask for the impact on the learning outcome or other possible consequences of the smartphone usage. Concerning WhatsApp we can point out some positive aspects:

- The real time communication can immensely support lab work.
- The students are absolutely familiar with this tool.
- We may open a new access point to physics, using this familiarity.
- WhatsApp is suitable for multimedia – pictures, text, videos and sound.
- It economically uses the volume of transferred data, which is important when sending pictures and videos.

On the other hand we could locate some problems:

- The usage causes a mixture between private life and work, mainly because you need to make your phone number more or less public in order to join groups.
- Skype and Facebook offer versions for the computer without the need of a mobile phone. WhatsApp has a PC version too, but this only works when connected to the phone.
- The linear chronology is sometimes impractical. Messages follow in real time and you do not have any structure or grouping.

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