Arousing Enthusiasm for STEM: Teaching 3D Printing Technology

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Abstract

3D Printing is about to revolve the way we think about, design and make products. While 3D Printing marks a hype even in private areas, it is fragmentarily taught in technical education.
3D Printing is at the same time an excellent tool to stimulate the enthusiasm of young people for STEM (Science, Technology, Engineering and Mathematics). Through an explorative and playful approach interests can be aroused and important competences are promoted.
Teaching 3D Printing technology needs to by carefully adjusted to different target groups. This involves elementary schools, to get the little ones playfully, secondary schools to develop specialist knowledge, and also teaching or research at universities as well as training on the job.
Our goal is to obtain a balance of theoretical knowledge and practical skills by an excursion supported hands-on training backed on theoretical lectures.
The methodology is somehow "up side down": To make parts or models, we start with barely no theoretical training. We visit the original to give the trainees an idea of what they will be doing. To reach this goal, once started, the trainees start asking for details by themselves (Intrinsically motivated). Following the questions, the necessary theory is taught step by step – so to say "on the fly".
The technology indeed makes it possible to link different technical disciplines but also to create transfer between completely different subjects, i.e.: humanities and engineering sciences. As an example, pupils learn to redesign an historic building and link the architecture to the different eras by color. Finally, they print the building true to scale and history.

1. Introduction/Motivation

The "GoetheLab for Additive Manufacturing", a research group of the University of Applied Sciences Aachen works in the field of Training on Additive Manufacturing (AM) and has developed, tested and evaluated a wide range of education formats for differentiated target groups. It ranges from student projects of different grades and formats, through teacher training courses, training weeks for the Chamber of Crafts, a summer school for students and academic staff/postdoctoral, to an online course of study and a training course for the "AM specialist" (University study course). And for sure elaborated Bachelor´s/Master´s lectures are in the portfolio. There are also different tested concepts for companies: day trainings, individual seminars or consulting on demand.

The overall result underlines the fact, that teaching new and emerging technologies is a multi-disciplinary and in terms of technical knowledge also a multi level task.
The task is not only to teach how to operate the printer but to teach the necessary computer aided design (CAD) capabilities. Because both, design and printing is necessary but time consuming, it is mandatory to keep the target group interested and motivated. For the long term success, it is inevitable to teach not just operating skills, but a deeper involvement in the topic by analysing and improving the results.

2. Teaching Approach/Sample Object

For the training, we developed an upside down approach, better known as the "v" procedure used for the development of integrated mechanical and electrical systems [1], in our case for both: The CAD, and 3D Printing part. We started with the most complex situation (which mostly is the original), then stripping it down to maximum simplicity and finally working it out to an optimum.
The target group was selected from young students. They all were very curious about 3D Printing but did not have no experience at all, neither in CAD Design nor in 3D Printing.

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As it is not just necessary but essential for (younger) trainees to have a fascinating example that origins in their daily experience, we first identified a suitable object. We found a fascinating building, the Aachen Cathedral which is an UNESCO World Heritage site, and which is seen by the members of the group every day on their way to school (Fig. 1).

Fig 1.: Aachen Cathedral, UNESCO World Heritage site

3. Teaching Concept

The task is to produce a model of the Aachen Cathedral. The data set of the model should first be created virtually and then be printed on a 3D printer. As learning outcome, the participants will be able to build skills in 3D CAD and competences in 3D Printing, parallel.

To involve not just the technical teaching staff, but to integrate other disciplines as well, thus rising the acceptance level among the entire teaching staff, the history teacher offered cooperation. He took over the analysis of the architectural heritage of the almost two thousand years old monument and the task to assign the elements to the history timeline (supported by the master builder of the Cathedral, Helmut MAINTZ).

Based on this knowledge and some preliminary visits to our 3D Printing Lab, we first went to the original church right around the corner and collected information about the building and its history. A closer view showed the details of architecture over the centuries (Fig. 2 - left).

Fig. 2: Aachen Cathedral (Source: Dan LEORDEAN)
left: in detail; right: model for visually handicapped

Additional to the original, we also investigated a very detailed model of the Cathedral situated in front of the church, which was made to support visually handicapped visitors (Fig. 2 - right). Although this model as well is somehow simplified, for us it defines the top level of the model making and therefore was chosen as the reference for our 3D printed reproduction.

After setting the top level, we structured the project bottom-up, working simultaneously on both main tasks: the CAD Design and the 3D Printing.

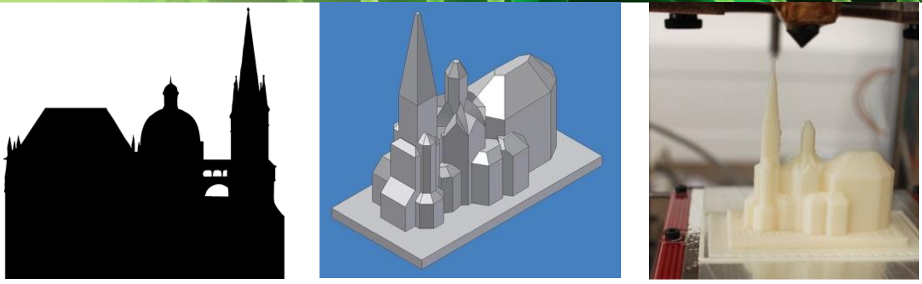

Fig. 3: From 2D drawing to a 3D print
left: 2D silhouette; middle: 3D CAD model; right: printed model (personal printer)

At the design side, we started from 2D sketches of the Cathedral (Fig. 3 - left). The first task that can be regarded as a basic law of model making is to understand, that the original is much too detailed for both, the 3D drawing and the Print. The success-factor is closely related to simplification. Based on a sequence of 2D silhouettes under different angles, a very simple 3D model was created. This served to explain the differences between a 2D and 3D Drawing (Fig. 3 – left/middle).

The participants have thus created their own 3D model in a relatively short time, they can virtually view, rotate or even scale their cathedral. By breaking down the complexity of the object, the motivation of the participants increases much and the next step can be started: The 3D Print of the model. After a basic introduction and some sample prints using prepared files, they were trained to export the data set to a plastic printer.

At this stage we had a first 3D CAD model (Fig. 3 - middle) and a first print (Fig. 3 - right), both not very detailed. But at least, what comes out is a component to touch: By holding the model of the cathedral in their hands, the necessary improvements became clear to the participants, automatically: A more detailed CAD model and an improved print.

Also the question after alternatively usable materials arouse and so we took the same data set and built it using acrylic resin and polymer printing, mild steel (Fig. 4 - left) and silver (Fig. 4 - right) using Selective Laser Melting (SLM) industry printers for metal.

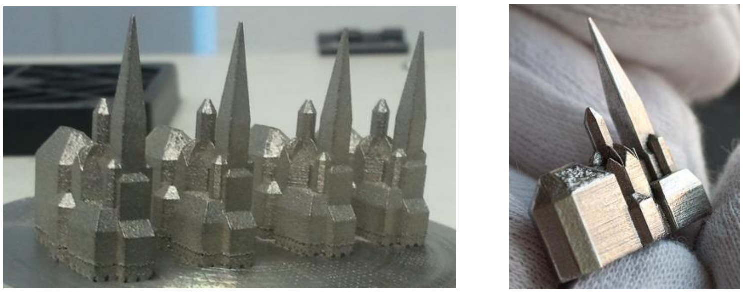

Fig. 4: Different materials
left: printed model, metal printer (mild steel); right: model after manual polishing (silver)

The lesson learned is that the same data set basically can be processed with different printers. This needs adjustment of the parameters, but it can also be improved manually e.g. by polishing. It has therefore been shown that the quality of the model can be strongly influenced by the use of different printers/processes. At the same time, the participants develop technical knowledge playfully: They can classify the different procedures, they understand the processes behind them and build up knowledge about different materials and their behaviour.

In terms of 3D CAD design, the model was stepwise refined. It was obtained by iteration between increasing knowledge concerning the historic building and the printer and printer processes. The entire procedure was motivated by the wish to make a very realistic model. As a consequence, the team wanted a much more detailed data model in order to improve the print.

Fig. 5: Examination of the results

So we went back to the top level of the model making, our reference for the 3D printed reproduction (Fig. 2 - right) and compared our model on site (Fig. 5). After an intensive judgement, the participants clearly realized on their own what they have to change in their 3D data set in order to design and print a more realistic model.

The improved data set (Fig. 6 – left) was taken to make another bigger and more detailed model of the cathedral (Fig. 6 - right). While designing the improved model of the cathedral, the idea aroused by to build it separately and doing so, to be able to make a much bigger model, thus exceeding the limits of the printer. The group was divided into teams, each team responsible for one part of the building. The different printed components are finally assembled with magnets to form the overall structure of the cathedral (Fig. 6 – right).

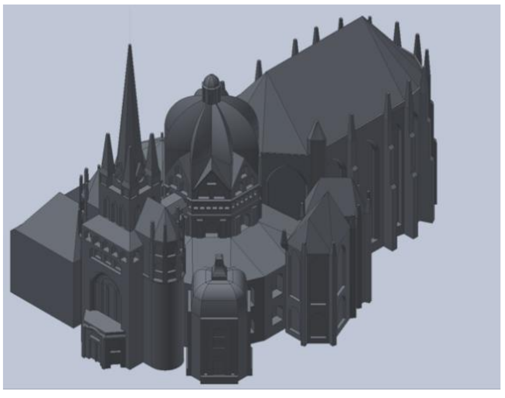

Fig 6.: Improved cathedral-model
left: detailed 3D CAD model; right: printed model in different colours

By using the upside down approach (“v” procedure), starting with the most complex situation (Fig. 2), stripping it down to maximum simplicity (Fig. 3) and working it out to an optimum (Fig. 6), we have not only been able to increase the motivation of the participants all along, but we can also motivate them in an instrumental way to incorporate new own ideas and incentives into the project.

History meets 3D Printing - extended
For centuries, the Aachen Cathedral building has been modified and expanded, look of the building has changed dramatically over time. This fact was used to develop an extended teaching module.
In history lessons the various epochs of the building were worked out and the participants were able to design the most important individual buildings in CAD and to produce the printed individual parts separately by 3D Printing. The parts can be added to each overall model and be used for the study of the historical sequence of the changes/extensions of the complex. In this case the different colours of the components represent the different historical building periods, dedicated to the historic era (Fig. 7).

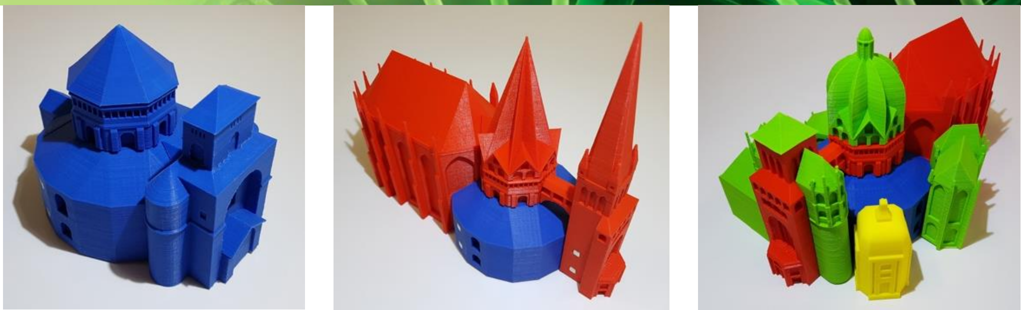

Fig. 7.: Architectural Elements dedicated to their origin
left: central/west construction: 803; blue;
middle: choir hall/porch: 1355 – 1414; red;
right: chapels: 1367 – 1487 – green; Hungarian chapel: 18th century; yellow

4. Conclusion

3D Printing can be taught very effectively if a brought theoretical approach is skipped and the trainees start into the real complex task right from the beginning. This leads to very fast results. As these results are quite rough, the trainees themselves want to improve it and consequently become the driving force.

It turned out that the combination of a direct hands-on course with a comprehensive, theoretical approach to 3D technology meets the demands to teach not just 3D Printing but a wide range of new technologies and is necessary to transfer the knowledge.

This concept can be regarded as an example of how to stimulate social competences by means of technical, interdisciplinary knowledge through the use of 3D printing: participants gain self-confidence by acting, they experience, give appreciation and learn from/with each other. Simultaneously the enthusiasm for STEM is awakened by an exploratory and playful approach to new technologies.

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References

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