The architectural gadget factory

Volker Koch¹, Matthias Leschok², Petra von Both³
¹,³Karlsruhe Institute of Technology²Matthias Leschok <leschok.matthias@gmail.com>
¹,³{volker.koch|petra.both}@kit.edu²leschok.matthias@gmail.com

The paper describes a course for architecture students in which by inventing things and products students enhance theirs skills in rapid prototyping, programming and manufacturing. A didactical background is specified in this context to prepare the students for a changing role in a broader professional environment. Different projects as outcomes of this course are described in detail.

Keywords: rapid prototyping, CAM, fab lab, DIY

INTRODUCTION
The project described is part of the architectural curriculum and integrated in the Virtual Engineering Laboratory (VEL) at our department. In the VEL we introduce on the one hand students to technologies, methods and applications of rapid prototyping (RP) processes, as it is common practice in many schools. Beyond this, we offer courses for graduate students where we extend the focus on tools and methods from other technical disciplines like electrical engineering, computer science and mechanical engineering. In this context we report on finished and ongoing projects in which architecture students have invented, planed and implemented different constructions, machines and setups in the broader sense of the popular open source fabrication laboratories (fab labs). The items the students have invented are in some cases close to architectural topics but can also fulfil requirements of everyday life or are built as a toy. We discuss the effects of this approach to the curriculum and identify positive impacts on creativity, construction capabilities, programming skills and interdisciplinary teamwork.

DIDACTICAL BACKGROUND
The course format, its extent and the equipment of the Virtual Engineering Laboratory offer extraordinary possibilities to train students’ skills in different ways. Since the students are free in choosing their topics, they are forced to position themselves in the fast changing and important environment of man-machine-interaction and technological developments. These processes strongly influence architecture and engineering in present and future. To handle their own tasks and to develop a product also helps to train organising a project in general, as they must collect all required sources, define a framework, set up a realistic timetable and resource management. Furthermore they have to find and involve external experts and work interdisciplinary to include knowledge and advices they are not able to acquire in the available time frame. The course format and the expected results encourage the students to work highly creative and unconventionally. The course profile and its spirit is therefore described as both playful and challenging by the students. In this sense it offers a stimulating environment,
where skills in programming, engineering and manufacturing can be trained together with project management capabilities and design tasks at the same time. Also students extend their chances to establish themselves in a broader professional environment outside of a classical architecture. These experiments are based on the shifts currently taking place within the architectural profession and their implications for the curriculum of architecture schools and faculties. As a critical appraisal of the professional circumstances of architects reveals, the process of change, besides being economically driven, is primarily traceable to structural factors that will permanently transform the relevant vocational framework. While the statistical evidence for these trends is unequivocal, the notion of crisis is avoided in evaluating the situation facing architectural practices. Rather, the focus is on taking the persistently adverse business climate as a starting point for a close analysis of the profession and its potential reorientation, followed by the development of various scenarios marking out a broader remit plus attendant educational concept. This involves a critical examination of the prevailing conception of the profession and the educational approach embodied by university courses, together with a delineation of the specific potential offered by architects. The Course definition moves away from the traditional understanding of architectural services and highlights the fundamental capacity of the profession for tackling complex problems, also outside the construction sector. The following hypotheses are put forward and examined:

• In future, over 50% of graduates in the field of architecture are destined to work outside the traditional professional environment.
• The complex nature of the construction process promotes the acquisition of soft skills amenable to application in fields outside the construction industry.
• The acquisition of soft skills is of greater importance in architectural training than the teaching of hard skills.
• The ability to handle knowledge and information efficiently constitutes the core competency required by architects. The versatile use of IT tools plays a pivotal role in the acquisition of this skill.
• Start-to-finish digital product data modelling, as a common communication platform between design team members, and the ubiquitous computer-assisted processing of information represent the technologies that will shape all future activities of architects.

ENVIRONMENT
Besides classic tools of a RP-laboratory as laser cutter, 3D-printer and 3D-scanner the VEL observes developments in the discount and mid-range price segment of the electro and toy industry. Due to the ongoing decline in prices of electronic equipment and a stunning improvement of performance at the same time, this market is full of affordable and also powerful sensors, controllers or other mechanical and electronic components. The most popular item in this context is the Microsoft / PrimeSense Kinect sensor which has become the fastest-selling consumer device ever since its introduction in late 2010. This development has caused a fast growing community of independent and creative hobbyists, who are able to realise objects and services of high quality and good effectivity with only a low budget. Very often these developers are organised in so called fab labs or hackerspaces to benefit from shared ownership of tools and from interdisciplinary discussions and support. This development is well described and predicted by Gershenfeld (2005) and Anderson (2012) and can be observe on platforms like instructables [1] or hackerspaces.org [2]. The described process is accompanied by a simultaneous observable simplification of man-machine-interaction and also in the use of software and software development kits (SDK). Especially easy to use SDKs and programming environments (i.e. Scratch, Processing) make it possible for non-specialized persons to construct, build and test prototypes and address therefore a broader range of possible users.
PROJECTS
In the past three years students in this course have produced about 30 machines, products, games or inventions in individual or group work. They have used objects, instruments and tools, which are normally not applied in design or planning processes, but seem to have potential to transport their principles into architectural frameworks.

These items have their origin in the games industry (e.g. MaKey-MaKey [3]), computer science (e.g. arduino [4]), electrical engineering (e.g. printed circuit board), medicine (e.g. brain computer interfaces), mechanical engineering, aircraft construction or other disciplines.

To realise connections between hardware components and user interactions the students have used easy accessible programming environments like Scratch [5], Processing [6] or built-in scripting languages. Typical results of finished projects are shortly described below.

See through sound
The students used the invention kit MaKey-MaKey [3] based on Arduino technology [4] in combination with tools and methods of printed circuit board (PCB) production for electrical engineering to produce haptic representations of paintings for blind people. By touching this object, the item communicates with the visually impaired person by sending acoustic information and impressions about the painting itself. The connection between the MaKey-MaKey board and the sound systems was realised by using the Scratch programming interface [5] (see Figure 1).

Music and architecture
The project combines a standard Midi Controller keyboard with an arbitrary 3D-geometry by connecting midi signals with specific geometrical parameters using the Processing environment [6]. By playing the keyboard the connected parameters of the objects (e.g. length, colour, position, etc.) change and lead to mutated spatial structures. The setup was then used to examine possible and meaningful relationships between musical and architectural elements (see Figure 2).

Drawing by brain
The emotive brain computer interface (BCI, [7]) has been used to operate basic drawing functions of Google Sketchup modeller by probands thoughts. The student started his work by connecting the BCI to Sketchup using the Ruby application programming interface. He then analysed which classes of thoughts are suitable to keep up a firm connection between the BCI and the modeller. He tried then to combine this mental man-machine interaction with mimetic elements and the built-in headtracker of the BCI (see Figure 3).
**Telepresence robotic system**

In this project students developed, constructed and evaluated a telepresence robot to grant disabled persons access to exhibitions in museums. They based their work on free available source code and affordable construction kits from the toy and game industry. After first tests with the prototype in the faculty building, they started to evaluate the concept with a more professional device in a local art museum. In this environment the proband’s feedback regarding the usability of the setup has been analysed and will be the background for future cooperation with museums in this context (see Figure 4).

**Integrating augmented reality elements into classical presentations**

The student explored possibilities to combine augmented reality (AR) technologies with classical paper presentation of architecture. She used the AR SketchUp plugin by InglobeTechnologies [8] and tried to figure out, if geometric parts of the shown floor plans, sections or elevation on paper can be used as effective patterns and therefore as markers to be tracked by the plugin during presentations. To be able to act flexible she used a wireless webcam. It could be shown that common presentation of design project can benefit from integrated AR elements to enhance quality of dialogues between experts and laypersons (see Figure 5).

**Living Rapid Prototyping**

This project is an interdisciplinary approach between rapid prototyping technologies and living materials in the field of biology. The thesis questions how the conjunction of digital and biological fabrication may look and to which opportunities this may lead for architecture in sense of biological and sustainable civil engineering. For all experiments the oyster mushroom (Pleurotus Ostreatus) was used in combination with wooden substrate offering shelter, nutrients and moisture. The focus lies on the mycelium roots and not on the fruiting bodies which normally refer to mushrooms. Test blocks made out of wooden substrate and mycelium were tested of their compressive strength. The results reveal that the compressive strength of mycelium blocks are comparable to the compressive strength of styrofoam and can be a sustainable substitute in some cases [9]. Despite the base material of mushroom substrate is made of wooden waste, it’s not flammable [10]. Even exposed to a gas torch a mycelium block only starts to glow but not to burn. This is caused by the fact that
Mycelium develops a dense polymer matrix while growing, and its cell walls are made of chitin, one of the most common biological building materials which isn’t flammable. To see if mycelium materials are usable on a larger scale, a chair was designed and 3D printed. Therefore, the enveloping surface of the chair was divided into segments. Afterwards, the different parts have been filled up with mushroom substrate and have been welded. After a few days, the mycelium starts to grow. Visible through the change of color, from brown (wood substrate) to white (mycelium). Waiting a few more days, fruiting bodies are starting to grow, searching for holes in the chair to break through and grow larger. From that point forward, the chair was dried to get its maximum load capacity. Only in a dried stadium, mycelium roots have load bearing capacity, which finally makes the chair usable. The results of all experiments done in this thesis led to a final future vision, which combines artificial and man-made structure with a natural cover. The symbiosis out of different knowledge sectors creates an optimised environment for humanity and nature. This vision shows that with a minimal effort of initial investment (man-made structure) in combination with a living organism like mushrooms, a very complex result could be achieved. The man-made structure shows a reduced and industrial character, meanwhile the organic growth with its different growing processes rises very complex geometries with varying shapes. The structure is made out of different layers, each serving a different function. There is a reduced structure for load transfer, a control unit for the distributions of nutrients or water and a layer of fabric enabling the mycelium to grow on it. After temporarily fixing the structure, the control unit starts to measure environmental conditions and adapt its behaviour to it constantly. It’s start pumping mycelium cells onto the fabric and enables specified growth on specified locations serving specified tasks. Is the building completely covered with...
mycelium the control unit stops feeding and starts the drying process [11], [12], [13], [14], [15] (see Figure 6).

CONCLUSION
As positive impacts on student work and skills development three effects could be pointed out as a first result: students have to observe technological developments and react on the appearance of new equipment, methods and principles. They have to be up to date about these developments and clear possible influences to architecture and design. Secondly the students get in contact with areas of expertise outside the architecture profession and can expand their possible fields of activities in the future. Alt last the project encourage students to train their creativity by inventing and create object more intensively than in classical architecture projects.

REFERENCES
Anderson, Ch 2012, Makers: The New Industrial Revolu-
tion, Random House Business, New York
Gershenfeld, N.A. 2005, Fab: the coming revolution on
your desktop - from personal computers to personal fabrication, Basic Books, New York
oom-insulation?variant=33632138433
05/green-styrofoam
_CytologieWS10_8.pdf