Flipped Classroom – a flexible way of teaching technology usage for diagnostics in the medical subdomain ENT

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ABSTRACT

A special problem area which ENT-Head/Neck (ENT: Ear-Nose-Throat) surgery specialists have to deal with is the air flow in the nasal cavities and paranasal sinuses. It is a burning problem to extend the morphological diagnostic by detailed functional analysis, i.e. the visualization of the nasal air stream and the physical analysis of its energetic. The simulation of the airflow via CFD (Computational Fluid Dynamics) is nowadays gaining importance for diagnostics, and the visualization and simulation of airflows from the nostrils to the nasal pharynx afford in first place a precise and high quality 3D reconstruction of the nasal cavities. But the successive validation and interpretation of CFD simulation results is a challenge for non CFD specialists. The introduction of these new technologies requires special education and training for students as well as for medical experts in order to learn how to use and handle different tools and methods when preparing a surgery. "Flipped classroom", a type of blended learning, is a preferred method for supporting knowledge transfer not only to students and employees but also among all kind of different members within organizations.

Keywords: ENT surgeries, 3D-modelling, CFD simulation, flipped classroom, collaborative learning, computer-aided training.

1. INTRODUCTION

University and workplace learning have changed tremendously with the introduction of online courses and networked information services. How we learn and how we obtain information is now strongly determined by digital technologies. New learning technologies as well as new theoretical approaches emphasize the benefits of active (online) learner's participation. They advocate collective content development and learning in networked communities that will help to filter out the important content for our needs from the mass of information provided globally. Open communication with team members or learning partners creates synergies and new insights into issues that create innovative solutions, creative alternatives, and new goals.

When learning environments are built often three phases are gone through [1]. As a first step, learning management systems provide materials and formal online training. In the second phase, multi-modal learning, mixed media learning, blended learning and informal learning become more important. Then the emphasis is on individual learning plans and competence development. Finally, in the third phase informal knowledge sharing and collaborative learning enabled by Web 2.0 is realized. Instead of the content, the learners move to the center and the choice of learning resources is closely related to the professional context.

An important additional function of virtual learning platforms is the simultaneous contribution to building a joint knowledge base. This means that the participatory contributions of learners and trainers can be clearly arranged and stored and kept ready for repeated training. This makes it possible to later build upon existing content, in order to expand the wealth of experience, the knowledge base. For this purpose, it is a good choice to pack the learning contents into small lessons (micro learning compositions) to take advantage of the rapid adaptability and structuring of the knowledge. Thus, the learner can consume the content fast and flexibly [2].

In case of training for highly qualified occupations it is important to develop the ability to solve problems by self-organization. The skill to recognize connections between subjects, ideas and concepts becomes a core competence [3]. Competence in this context is defined as the capability to combine learned knowledge with the right action and to master complex tasks and demands that cannot be met automatically

[4]. A good way to develop competence is via the assessment of observable behavior [5] and action. This corresponds with the fact that up to 80% of activity-based knowledge is acquired through informal learning, such as questioning, observing or trying out [6]. Collaborative learning environments support this form of competence building as the focus shifts from teacher to learner and knowledge is generated collectively through interaction [7] and the learning of teams [8]. Constructivist learning theory demands that a learning environment encourages the learners to interact and to contribute input themselves. This is especially successful when the flipped classroom method is used and the teacher adopts the role of a trainer or coach [9] as the self-organized interaction between the learners becomes the central source of knowledge transfer. Furthermore, the ability to discuss, present and evaluate the ideas of the team members is considered conducive to the critical thinking of the people involved and fosters the possibility of discovering new relevant content by chance. In a flipped classroom environment knowledge is assembled via social exchange, the guidance of a tutor and the delivery of self-created content.

Taking into account the above considerations in matters of communication means and media types a modern learning platform should enable the following interactive activities:

- Creation of structured micro learning units
- Integration of video sequences
- Integration of audio sequences
- Integration of external images and texts
- Integration of external learning units (podcasts, books, articles etc.)
- Collection and management of external resources
- Support for cooperation and communication
- Support for discussion and feedback
- Collaborative Problem Solving with Task Assignments

2. 3D MODELS AND CFD SIMULATIONS FOR ENT SPECIALISTS

Chronic rhinosinusitis (CRS) has a prevalence of about 10.9% in Europe and the US [10]. The usually creeping disease is associated with a considerable reduction in life and sleep quality and everyday performance. The first step for making the adequate diagnosis of CRS is the check-up done by the ENT-Head/Neck surgery specialist. In addition to the anamnesis, it is important to make a nose endoscopy and a spiral Computed Tomography (CT) of the paranasal sinuses, which should preferably be carried out in an inflammation-free interval. The extent of shading of the paranasal sinuses in the CT and the anatomical relationships determines the degree of CRS [11]. However, the 2-dimensional images of the conventional CT examination of the paranasal sinuses merely give an idea of the ventilation of the sinuses.

Nasal polyps can originate from parts of the nasal mucosa or paranasal sinuses and their development has been linked to chronic inflammation, allergy, autonomic nervous system dysfunction and genetic predisposition [12]. When conducting a functional endoscopic sinus surgery (FESS) an endoscope, a thin fibre-optic tube, is used to improve ventilation and drainage and to remove polyps. With the endoscope and specialized tools the surgeon removes unusual and obstructive tissue through the nostrils. This technique has now been used for several decades in treating sino-nasal conditions. The extent of surgery depends on the extent of the disease and the surgeon's individual practice. Advantages of FESS are that it is minimal invasive but nevertheless permits a good view of the surgical field, fewer complications occur and it allows for a precise clearance of the diseased area.

Current developments in the field of numerical flow mechanics and high-performance calculations will make patient-individually computer-assisted flow predictions possible that can help to detect and limit the anatomical location of a pathology and support FESS surgery preparation as well as rhinosinusitis therapy decisions. Unfortunately, due to their complexity and their costs, such methods have not yet been introduced into the day-to-day operations of hospitals. The European Union-funded project *Rhinodiagnost* (www.rhinodiagnost.eu) was started in September 2017 and will establish coordinated morphological and functional diagnostics services for ENT physicians that are organized in a rapid network [13]. New, additional decision aids, such as 3D models and flow simulations, will be offered to ENT physicians and radiologists. Renowned research centers like the Technical University of Aachen, the Supercomputing Center Juelich, and several privately owned companies in the information and medical-technical sector form the *Rhinodiagnost* project team. *Rhinodiagnost* aims to provide a network of easy accessible and low-cost service points for these diagnostic services and targets to introduce the new technologies as standard means for ENT diagnostics. The resultant information surplus will allow surgeons trained on the technologies to improve patient-individual operation planning and is supposed to considerably raise the success rate of operations and proper treatment therapies.

3. FLIPPED CLASSROOM METHODS FOR TRAINING ENT STUDENTS AND DOCTORS

ENT physicians have to be trained on new technologies provided by projects like *Rhinodiagnost*. Considering the advantages of the flipped classroom method the project looked for a tool that would not just offer a comprehensive learning management or content management system, but rather support the participatory design and documentation of subject areas. Another central requirement was that the system would allow the rapid integration of multimedia content. After evaluating various platforms, the open source platform *Mediathread* (http://mediathread.columbia.edu/) was selected.

Mediathread has been developed by the Columbia Center for New Media Teaching and Learning at Columbia University since 2010 and is used in a variety of courses, including at other American universities. *Mediathread* was developed using Django, an open source Web application framework written in Python. *Mediathread's* source code is published as open source code and is freely available to anyone on *Github*. Prerequisite for installation is an existing Python 2.7 Postgres or MySQL database management system.

The focus of *Mediathread* is on providing a platform for the preparation, management and analysis of online multimedia content and the tool works best with a small, focused scholarly community or seminar, supporting connections, open access, and networked learning. The system enables the linking and integration of content from various external media platforms such as *YouTube*, *Flickr*, the *Internet Archive*, *Vimeo*, *Wikimedia Commons*, *Pinterest* or *Kaltura*. Using *Mediathread* the content can be further edited, annotated, organized and embedded in texts. It is possible to link descriptions to external content and enrich them. Instructors and coaches can coordinate respective threads. The tool also supports the

creation of short assignments or questions that learners and team members need to work on and contribute online. Thus, step by step, a knowledge base is built cooperatively.
A standard *Mediathread* course is divided into lessons which cover the learning of a concept. Students learn remotely according and in response (elaboration of an essay/"composition") to assignments received from the instructor for each lesson. The instructor can keep track of the activities of students. Contributions are made in the system with the Composition Editor. These contributions can be instructions from the instructor, or even research by team members and contributions to posted questions. With the *Mediathread* bookmarklet the function of the web browser is extended and it is possible to transfer multimedia contents and metadata from external websites to the local *Mediathread* system with a mouse click. *Mediathread* does not load this data (videos, pictures, audios) into the system, but simply refers to the content and embeds it in the courses of the platform. Doing this a student can contribute information of his or her interest into a lesson. There, the content can be further distributed, annotated, tailored and referenced in the discussion and knowledge contributions. In addition, it is also possible for administrators or tutors to enable an upload function for existing local multimedia content.
The Discussion Board supports group discussions on specific topics. Like the Composition, this functionality also provides a WYSIWYG (What You See Is What You Get) editor.
Using the Assignment functionality the instructor can publish questions and tasks, which are then edited and discussed by the learners. The instructor can give feedback to the student's responses.
The courses (threads) can be used to create a specified vocabulary of the most important terms and these terms can then be linked to the content. This functionality renders it possible to search the course / thread using a structured term vocabulary. All activities filtered by whole class' or student's contributions allow measuring the input and level of participation of each participant in a course.
For the ENT case the tool *Mediathread* provides the possibility of elaborating "compositions" which can either explain a specific concept like: image processing, 3D modelling, CFD simulations, definition and processing of clinical pathways, etc. or present an "assignment" to a student, asking to elaborate on various topics. Through the continuous interaction of students and instructors the *Mediathread* platform is enhanced in an iterative process and supports competence development according to a knowledge maturity model [14].

4. MEDIATHREAD COURSES FOR ENT STUDENTS AND DOCTORS

Main activities for rhinosinusitis diagnostics ought to include the visualization of nasal cavities (using 3D modelling), the execution of CFD-simulation, and the interpretation of airflow simulation results. A 3D mesh generated from the CT DICOM-images allows the doctors and surgeons to view the diseased areas from all perspectives, even making it possible to inspect diseased areas haptically when printing them out on a 3D printer. Supplementary to advanced diagnostics, the mesh of the paranasal sinuses is an important aid for the planning and preparation of endoscopic surgery (FESS) and the 3D mesh can play an important role for surgical education and training as it can be used for learning and virtually training FESS.

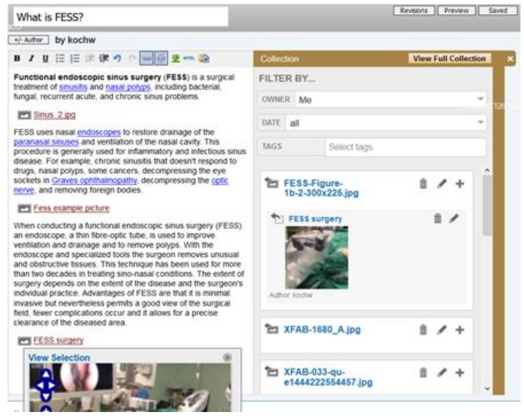

Figure 1 Preparation of a composition on FESS

Figure 1 shows the composition panel in *Mediathread*. Left the information texts are entered which are enriched with media items selected from the media "Collection" list on the right hand side.
Media that is used to enrich the written information may be annotated and selected in total or partially for the course. Figure 2 depicts the tools for making and describing selections of content and Figure 3 shows the starting section of the introduction into 3D meshing.

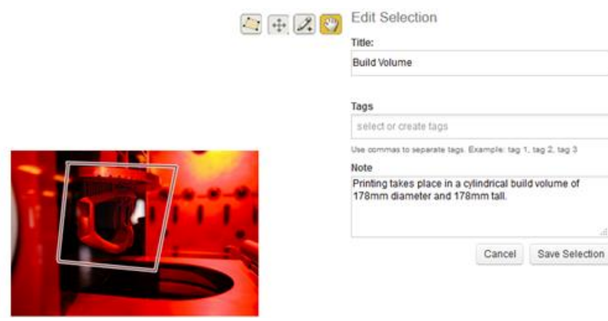

Figure 2 Selection from image parts

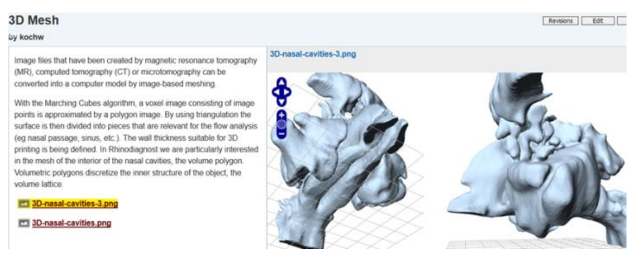

Figure 3 Composition on 3D meshing

After the mesh has been examined, a CFD (Computational Fluid Dynamics) simulation of the nose and the paranasal sinuses can be performed [15], [16]. With this method, the inner nose can be virtually traversed, and the slight flows in the area of the paranasal sinuses, especially the very narrow passages, can be visualized [17], [18]. The main advantage for the radiologist and the ENT-Head-neck surgeon is that additionally to the static CT-examination the CFD will show the dynamic function of the ventilation in the nasal cavity and the paranasal sinuses. This improves both: sensitivity and specificity in the assessment of a CRS. Figure 4 shows part of a composition describing the basic principles of CFD accompanied with a video showing a simulation of the nasal airflow.

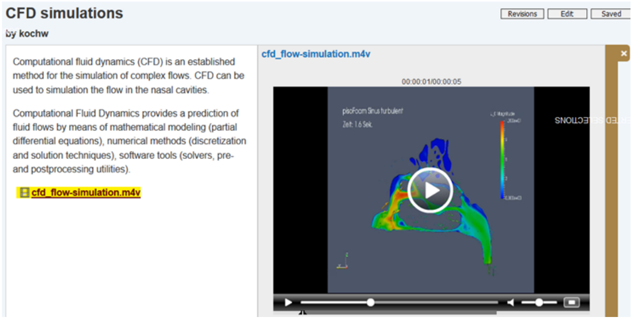

Figure 4 Basic introductions to CFD with a video example on the nasal airflow

In order to correctly use and interpret the results of the 3D meshes and the CFD simulation doctors and surgeons need to be trained on these new technologies. Surgeons shall be able to use both technologies to improve surgery planning and to simulate possible post-surgery scenarios. For that it is important to know what the CFD simulation predicates about the airflow for the patient, and how to use and interpret the 3D mesh generated out of the DICOM images. In addition to using CFD and 3D meshes for better diagnostics both technologies can be applied in training, for virtual surgery or for the production of 3D printed training models for surgeons-to-be. 3D printing provides additive information for specific surgeries and helps to provide better insights to certain pathological Regions of Interest (RoI). Figure 5 depicts parts of a composition on this topic.

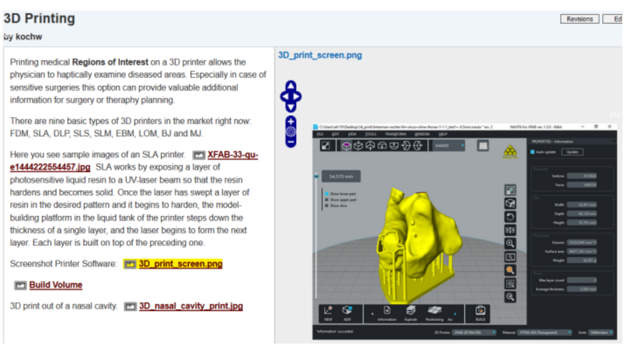

Figure 5 Introduction to 3D printing

With around 500.000 FESS-surgeries taking place every year in the US only, an amount of about 2.000 surgeries per working day or 300 per working hour is a reasonable figure [19], [20], [21]. Even when this workload is split among several service centers or well-trained and experienced surgeons, it is important to optimize the different activities in a surgery preparation workflow. The definition of clinical pathways reduces variations in practice and aligns decisions with evidence-based medicine, operational efficiency, and quality. It is highly recommended to use standards like the Business Process Modelling and Notation (BPMN), the Decision Management and Notation (DMN), or the Case Management Model and Notation (CMMN) when designing clinical pathways. The Object Management Group (http://www.omg.org/), being an international, open membership, not-for-profit technology standards consortium, has started in 2016 an initiative to standardize the description of clinical procedures, the "Health BPM Pilot". A "Field Guide to Shareable Clinical Pathways" was delivered in a draft version in October 2017. In order to be able to contribute and develop clinical procedures medical students need to know about standard notations and have to be able to read and comment on business process diagrams.

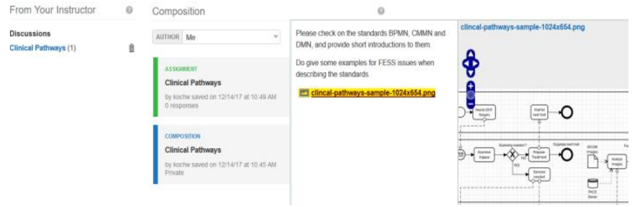

Figure 6 Assignment for elaboration on standard notations for business processes

Figure 6 depicts the starting chapter of introducing ENT specialists and students into the topic of clinical pathways and the use of international standards for business process, case, and decision management.

5. CONCLUSIONS

ENT students and doctors need to be trained to correctly assess the input provided by modern technical methods like CFD simulation and 3D visualization. Hence, the *Rhinodiagnost* project develops a flipped classroom course in collaboration with experts in the domains of ENT treatment and surgery, physics, mathematics and information management. Recognizing the benefits of collaborative learning via flipped classroom approaches a series of online courses is set up using the online tool *Mediathread*. The courses teach the students and doctors how to use CFD simulations, 3D meshing or 3D printing, and introduce into the topic of business process modelling for clinical pathways. They offer introductory online compositions, assignments for participants, media material and the possibility to interact with a tutor or coach. Trainees may actively shape and contribute online to the knowledge base of the online classes thus strengthening their ability of self-organization, networked collaboration and digital competence.

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