E = MC^2 + 1: A FULLY DIGITAL, COLLABORATIVE, HIGH-DEFINITION (HD) PRODUCTION FROM SCENE TO SCREEN

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This article presents a unique course for students, the course took place at the Tampere University of Technology (TUT) in the NAMU – New AMbient MUltimedia research group. The basic idea was to create a five-minute production involving all the new technology available to the modern film-maker. We want to prove that even a non-experienced team of film-makers are capable of creating a short HD film with (almost) commonly available equipment. A full high-definition (HD) digital workflow was undertaken – from scene to screen. In each production step, new technologies and approaches were tested to explore the world of digital film-making. In pre-production the movie-script was written collaboratively with Wiki tools. The participants' experience was evaluated, and the results are presented in this article. In production we focused on HD methods to create content and applied the Material eXchange Format (MXF) to handle metadata in production; the final movie was distributed via typical television channels, such as DVB-T, IP-TV, and DVB-H. The experimental results are presented in this article as well. In this article we present our experience in terms of technology, introduce a learning-by-doing concept during course development, and give a complete analysis of a full digital HD workflow.

Categories and Subject Descriptors: J.5 [**Computer Applications**]: Arts and Humanities; K.3.1 [**Computers in Education**]: Computer Uses in Education–*Collaborative learning*; *Computer-assisted instruction*

General Terms: Experimentation, Human Factors

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1. INTRODUCTION

Traditionally, media content creation was always reserved for professional studios, due to the necessity for the specialized and expensive equipment and the artistic skills for such an undertaking. Since the explosion of the digital world, media creation has become more

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and more accessible to the general public. The YouTube [http://www.youtube.com/] phenomenon is a very good example: people just grab a digital camcorder, setup a mini home studio and start publishing their material themselves. Still, nowadays very few people actually use the full potential of digital technology: first, there is a lack of understanding of the process of artistic creation; second, the technology is available to consumers, but understanding the techniques required to use its full potential is poor. Artists might argue that technology is only a tool to realize the artistic masterpiece. Nevertheless, to be able to tell a story with a fully digitally produced movie, the underlying technologies have to be well understood.

The obvious convergence between artistic movie creation, common IT technology, and the Internet makes the life of the modern film-maker even harder. Nevertheless, only by understanding the underlying techniques and methods of this technology enables the modern film-maker to make production cheaper, get greater audience exposure, and create a never-before seen story world for the consumer. Film-making is still about telling stories and immersing the consumer in a fictive world – only the underlying technology to create this fictive world has changed. The possibilities in the says that a single story can be told by utilizing digital film-making technology are becoming infinite. However, exploration by artists of this technology is still in its infancy, but is proceeding rapidly. This trend can be seen in the advances made by animated films during the recent decade. Nowadays many different digital media techniques, ranging from graphics art technology, 3D content production for TV and film, large-scale content management systems for new media, computer game development, network design techniques for high-demand media systems, systems for new media solutions, software design methods, media technology are available to tell a story in many new ways. And this exactly is the content of this article.

1.1 Context and Novelties of this Work

In this article, the course “Modern Techniques for Producing Media Content” is described from the students’ as well as the teacher’s point of view. The course was offer-

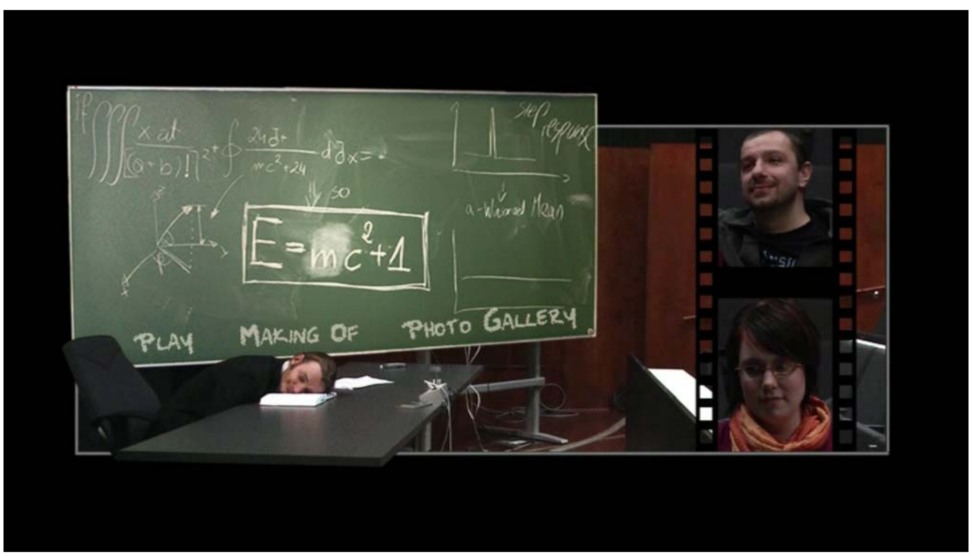


Fig. 1. DVD menu of E=MC2+1.

ed by NAMU (New AMbient MUltiemdia Lab. [www.cs.tut.fi/sgn/namu]) at the Tampere University of Technology (TUT). The goal of this course was to create a short high-definition (HD) movie by applying many new digital production paradigms. The course was intended for non-professional film-makers, that is, for people with no previous experience in film-making. The digital production process involved, besides many typical aspects in film production (namely, pre-production, production, post-production, distribution, and data management processes), many new methods in digital film production.

In this course, the following experiments and techniques were applied during production:

- implementation of a full digital workflow – from scene to screen;
- collaborative script-writing with Wiki tools;
- evaluation of user experience with collaborative script-writing;
- high-definition (HD) digital production workflow;
- introduction of learn-by-doing concept during course development;
- partial application of the Material eXchange Format (MXF) in production;
- analysis of improvements due to full digital workflow; and
- research of film-media technology.

1.2 The Movie E=MC2+1

Our short film shows a typical day in the life of some students: it is a humorous presentation, which shows students partying with their teacher the day before a lecture. Everyone is there – the nerd, the cool guy, and the Latin lover. And everything is there – fun, alcohol, jealousy, and love. But was it just a normal student party?

*Production Team***:** Director: Piotr Golebiowski, Assistant Director: Teemu Karjalainen, Actors: Simon Reyman, Volker Bruns, Satu Jumisko-Pyykko, Carol Rus, Piotr Golebiowski, Marjo Meija, Alberto de Martino, Antonietta Pepe, Dirk Matthes, Linda Franke, Judith Radau, among others, Cinematographer: Jarkko Kauranen, Camera Operator: Adrian Hornsby, Camera Assistant: Asta Kybartaite, Lights: Alberto de Martino, Makeup Artists: Satu Jumisko-Pyykko, Sound: Antoinetta Pepe, Boom: Fernando Ubis, Distribution: Mikko Oksanen, Stills: Carol Rus, Production Assistants: Juan Luis Garcia, Dirk Mathes, Executive Producer: Artur Lugmayr

2. RELATED WORK

Comprehensive work dealing with workflow management for fully digital productions is rather scarce. Nevertheless there are a few such that cover different parts of the entire workflow, such as asset management and metadata [Lugmayr et al. 2004; Mauthe and Thomas 2004]; the TV production side [Millerson 1999]; and the artistic side [Bordwell and Thompson 1997]. Practical studies of a file-based 4:4:4 HD production project in Finland was presented in Golebiowski [2006]; Golebiowski et al. [2007]; and Lugmayr [2006]. Other related work is cited in the course of this article.

3. CAPTURE IN HIGH-DEFINITION (HD)

Capture in movie making is currently shifting from its analogue form to a digital counterpart. In principle, we have to distinguish between video and film capture. Film capture is based on a chemical analogue process. Video is digital, and has been applied for television, but now increasingly is entering the world of film. While many still argue

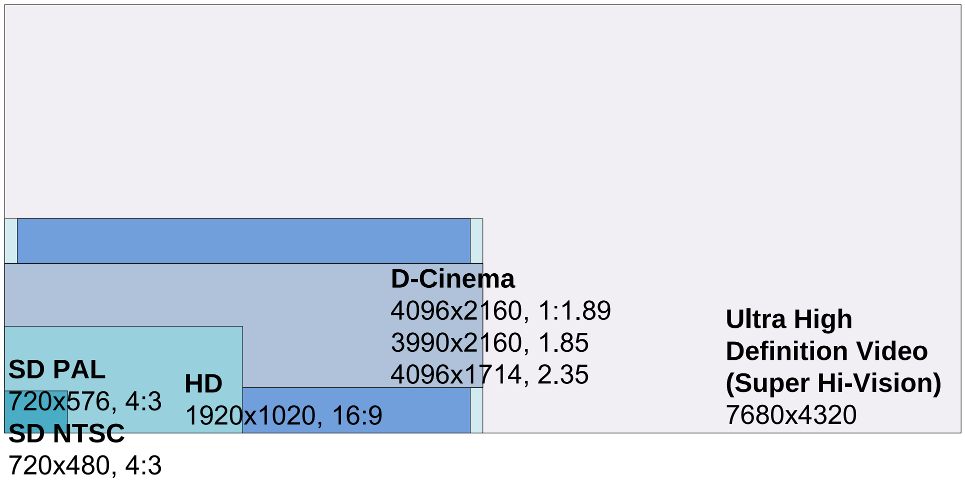


Fig.2.Various high-definition (HD) resolutions, ranging from television to digital cinema.

about quality issues, the full digitalization of the film medium is a matter of a few years. For a long time, video was rejected by film-makers as being non-artistic, low quality, and cheap; but nowadays video is one of the most important media for communication and entertainment, due to progress in digital electronics and computing

Video was initially recorded and stored in analogue form, due to progress in digital electronic and computing a brand new world has opened up for video, i.e., digital video. Since the late 1980's, video compression has became a very important research area and has led to many different applications in storage, transmission, and visualization of digital content (e.g., DVD's, IP-TV, digital television (DVB), video conferencing).

Nowadays there is much confusion about the key parameters in HD (see **Fig.2** for an overview of various HD resolutions). In the following, we present the relevant key parameters for a full production workflow:

- *HD resolution***.** We have to distinguish between different HD formats used in different stages of a production (see **Fig.2**). The consumer mostly comes in touch with the television formats, which come in a resolution of 1920x1080 or 1280x720. The first one has 2.25 times more pixels than the second, affecting encoding time, decoding speed, and storage space requirements. However, digital cinema (D-cinema) provides even higher resolutions, going up to 4096x2160 pixels.
- *Interlaced/progressive***.** The different video standards offer two different types of frames for capture: progressive or interlaced. Progressive standards capture the full range of pixels in one frame. Interlaced standards work as a common analogue to television sets, and only every second line is captured. Choosing between them impacts the required storage space, decoding/encoding times, and compression ratios. Progressive is better than interlaced in term of decoding time and compression ratio.
- *Frame-rate.* Relevant HD frame rates are 24, 25, 30, or 60 fps. Frame rates also have an important impact on performance. The higher the frame rate, the higher the required bandwidth and processing power.

- *Color information.* Color information can be in RGB or YUV (Y'CbCr) values. RGB is mostly used in the IT domain on PC screens or for storing visual content. However, during production the YUV model is frequently used. The Y'CbCr color space can take advantage of the fact that the human eye is more sensitive to brightness in green tones, less sensitive in red tones, and least sensitive in blue tones. Depending on whether the color is sampled at 8 bits, 10 bits, or even 12 bits per sample per component, bandwidth for each component can vary a lot. With HD formats, the values of Y, Cb, and Cr are displayed differently than with other standard definitions (SD). Indeed, HD formats use the 709 color format instead of the Consultative Committee for International Radio (CCIR) 601 color format.
- *Bit rate.* Video formats have either 8-bit per channel (256 steps from black to white), 10-bit per color channel (1024 steps), or even 12-bit per color channel (4096). This affects video quality during editing or post-production. The bit-rate is highly affected by the sampling rate of the video; 4:4:4 and 4:2:0 are the most commonly used in digital film-making. Typically, 4:4:4 is used inside a production environment, and means that the different color channels are sampled at the same rate; 4:2:0 is mostly used for play-out and sub-samples the different color channels at a lower rate, leading to smaller data rates.

4. COLLABORATIVE PREPRODUCTION BY APPLYING WIKI TOOLS

In this section, conservative or traditional script-writing is briefly discussed. This section presents the process of collaborative script writing. As summary, the results of a user evaluation of the anonymous online poll are presented as well

4.1 Conservative Script-Writing

In professional film production, the first and most obvious phase is pre-production. During this phase the scope and preparation of all essential elements of the film are taking place. This includes writing the screenplay, breaking down the script, creating production plans, defining schedules and film-budgets (see Millerson [1999]). However, more and more alternative production methods, emphasizing online collaboration, are integrated into this phase of production. In this section, we describe the experiences with collaborative script-writing with Wiki tools during the course. Wiki tools were applied to convey the general idea of collaborative script-writing to students.

Thomas Edison said “Genius is 1% inspiration and 99 % perspiration”. In other words, a genius is a talented person who has done all his or her homework. This applies well to script-writing. Script-writing is a complex task and requires much experience, passion, and creativity. Traditionally, one person creates a script based on a basic story idea. And to be successful, and eventually start making money, requires years of training and time to get a script right.

Table I. Overview of Various HD Formats and Typical Parameters

Resolution	frame-rate	Sampling rate	Data-rate (Mbps)	Storage (GB/hour)	Bit depth
1280x720	24p	4:2:0	332	146	10
	60p	4:2:0	818	364	10
1920x1080	24p	4:2:0	746	328	10
	60i	4:2:0	932	410	10

Every media demands certain rules that writers must comply with to get a message to an audience. For example, writing for electronic media enables the reader to go back and re-read a sentence that may not have been well understood. In a film production, however, the meaning is lost if it is not grasped immediately by the audience. In a cinema exhibition, there is no way to play it again: the viewer would be distracted by the ongoing content while trying to figure out what was meant. So writing for the ear is totally different from writing for the eye [CyberCollege 2007].

Despite what was previously stated, conservative script-writing can be a collaborative approach as well. Discussions, sparking ideas from others or giving the script for friends or colleges to read can often lead to new developments in the story. The Internet allows new models for script-writing by involving the community of the net. Still, to produce a really well-written script, Internet script-writers must also follow certain guidelines and to create an acceptable format (i.e., font-size, punctuation, style). One simple example is the use of three dots "…" to indicate a pause. There are several forums and web communities that discuss these style issues (see, e.g., Academy of Motion Picture Arts and Sciences [http://www.oscars.org/]). In general, there is no fixed standard or anything similar for the process of script-writing, since it is and always will be a creative process of either one or multiple persons.

The approach described in this article is to create a script by involving multiple students via the Internet – especially Wiki – technology and was a challenge for the duration of the course. In terms of management and team-building collaborative scriptwriting requires a well-organized framework in which contributing writers can easily introduce their ideas, refine them, and let their imagination flow.

4.2 Collaborative Scriptwriting with Wiki Tools

New technologies, such as wikis, blogs, and podcasting are challenging the traditional way of collaboration. Community-driven services are gaining influence on relations between producers and consumers. Indeed, with a system like Wiki, readers can instantly become writers and influence the story.

The idea of using a Wiki-based system for collaborative script-writing emerged during the course. After very long discussions we had lots of brilliant ideas, but could not merge them or settle on an agreement. We tried to come up with a system that could allow anybody in the course to write and defend their ideas at anytime of the day. But that the style of the collaborative script should still be the style of a professional movie script. We soon came up with the idea of using Wikis to be more flexible in writing the script. We surmised that Wiki tools would be more flexible than print versions or circulating digital documents, as the course participants could just read, think, and insert their thoughts, and make them available to everyone. Thus, people did not have to wait until the next face-to-face meeting to debate the ideas or circulate digital documents containing many un-viewable revisions. Still, the success of collaborative script-writing using a Wiki system relies on the participation of the users, their dedication to developing the script itself, and the sense of digital community.

In the course, both traditional and collaborative script-writing methods, as described in this section, were taught during a single teaching session. Afterwards, the students gathered in groups of two or three to brainstorm ideas and topics for the script in a limited amount of time. Next, the individual groups had to select one of their ideas and further elaborate on it. At the end of this phase, a member of each group gave a brief presentation of the idea in front of the class. At this point, the stories had clearly not yet been worked out very thoroughly, they consisted of a basic idea that the final script could

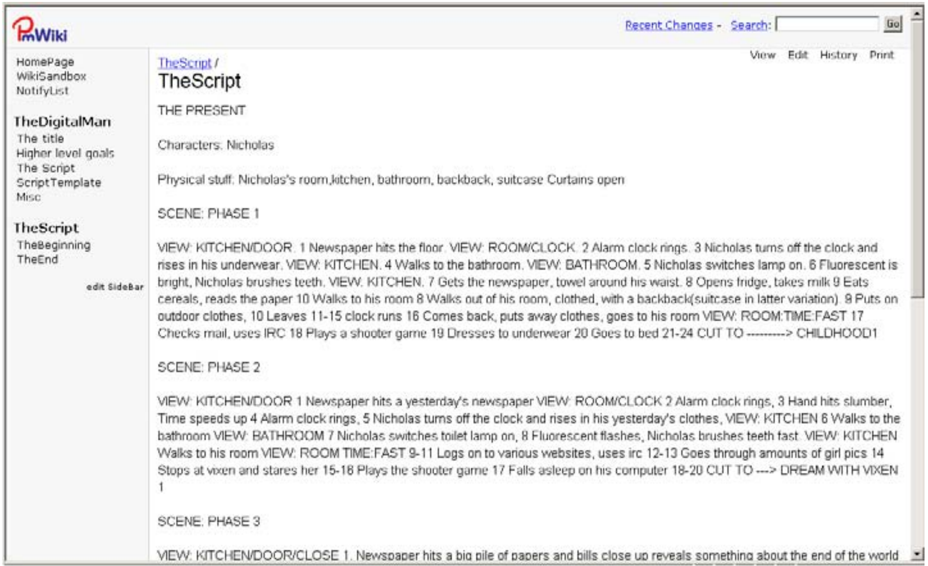


Fig. 3. Screenshot of the PmWiki system prepared for collaborative script-writing.

be based on, as well as a central message to get across to the audience. The presentations contained quick drafts of some key scenes as imagined by the group. After all groups had presented their ideas, the class voted anonymously for their favorite, which was to become the basis for the final script.

From this point on, the idea was to collaboratively refine the basic story by contributing ideas, scenes, dialogs, and other details via Wiki tools. The online Wiki-system PmWiki [PmWiki, http://www.pmwiki.org/] was selected and served as the central platform for collecting all contributions. The group whose script had been democratically selected as the winning story put their superficial version of the script onto the Wiki. Other sections of the Wiki system were used for collecting ideas, title suggestions, and character descriptions.

Originally, the script was divided into chapters, each presented by a separate thread in the Wiki, but the students mostly merged their input directly with the overall preliminary version. Even though the Wiki contained a change tracker and allowed the user to view the history of the thread, the script soon became messy. This was due to the fact, that students had different writing styles, formats, and a lack of moderation with Wiki tools, owing to the category of tools. At the end of the online collaboration, a single train of thought was no longer obvious; a coherent story-line was lost. It was necessary to refine and finalize the script in a face-to-face meeting among a small group of volunteers. This lead to a more compact script, based on the original idea. This version incorporated many of the students' contributions as well. Furthermore, the script was stripped down to the point where it was realizable in the available amount of time. In addition, a storyboard was drafted which illustrated the scenes as imagined by the small group of volunteer scriptwriters.

4.3 Experiences in Collaborative Script-Writing and Wiki

A poll among students that provided information about their experience in collaborative scriptwriting using Wiki tools was done retrospectively via a questionnaire. The goal was

Table II. Demographic Description of Students in this Course.

Demographic description	
Gender	80% Male, 20% Female
Age	M=24,5; SD= 3,5 years
Previous film-making experience	No 73%, Yes 27%
Nationalities:	Finnish, German, Polish, Spanish, Italian
Technical background:	100%

to evaluate comfortable and uncomfortable factors and major improvements in the scriptwriting process as a part of the course in order to improve it in the future. The questionnaire included both closed and open questions. Eight closed questions presented claims to be answered in a seven-point scale (strongly agree to strongly disagree); six open questions were also presented. Data collection was targeted for all the students who participated on the course. The questionnaire was posted via the online tool Webropol at the end of the course [http://www.wikipedia.org].

The answer rate was 80%. Most of the participants were male, novices in film-making, represented several nationalities, and had technical background (see Table **). Descriptive results including mean and standard deviations for each claim are shown in**

Table. Low mean values can be interpreted as strong agreement and high mean values as strong disagreement. The results of closed questions do not present strong arguments as to whether collaborative scriptwriting was a motivating part of the course, or whether it should it be part of a course in the future. However, people did feel that their ideas were taken into account during the process. The descriptions of using Wiki tools in scriptwriting agreed that the tool was not suitable for collaborative scriptwriting; it was found uncomfortable and unpleasant to use.

Analysis of open questions used a data-driven approach, called Grounded theory. It can be used when the research area is relatively unexplored and the research aims at understanding the meaning or nature of a person's experiences [Strauss and Corbin 1998].

The results from the experience in the collaborative scriptwriting process summarize its comfortable and uncomfortable factors. It should act as a guide in finding the biggest

Table III. Descriptive Results with Mean and Standard Derivations for Each Claim

Claim	**Mean**	**Standard Deviation**
Collaborative script-writing was a motivating part of the course	4.0	2.3
Script-writing should be included in the course in the future as well	3.9	2.3
I was motivated to contribute to script-writing, but I felt that my ideas were not taken into account	5.1	2.1
I felt that collaborative script-writing online with Wiki tools was successful	5.2	2.7
The Wiki system supported collaborative script-writing tasks	4.2	1.9
The Wiki system was easy to use	3.5	1.9
The Wiki system was not easy to learn to use	6.4	2.0

The Wiki system was pleasant to use	4.5	2.1

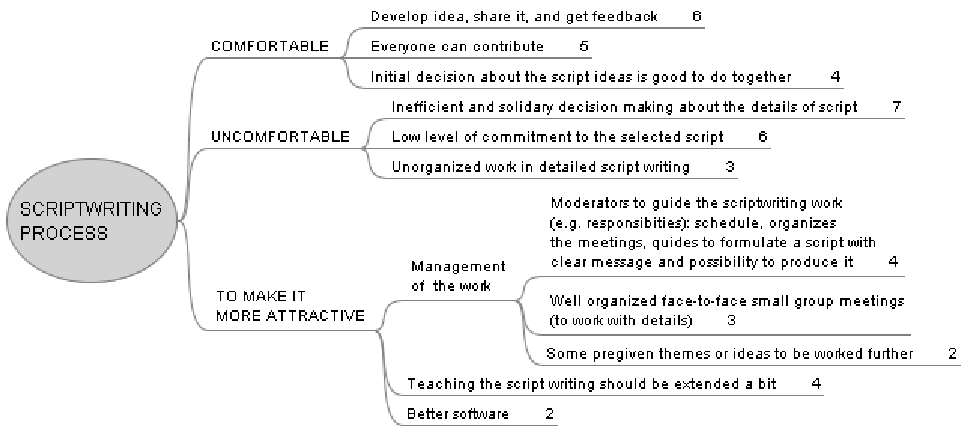


Fig. 4. Student experience in the collaborative script-writing process. The numbers in each branch show the number of cmentions in each category.

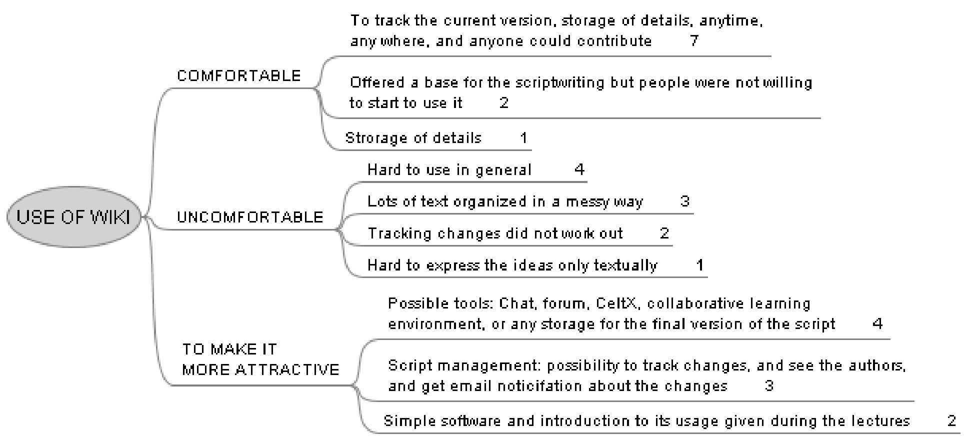


Fig. 5. Student experience using Wiki tools as part of collaborative script-writing process. The numbers in each branch show the number of mentions in each category.

challenges for similar teaching projects in the future (see Fig. 4). Brainstorming and the possibility for everyone to contribute at the every early and general stage of scriptwriting was described as pleasant part of the process. However, the detailed scriptwriting process

was found uncomfortable due to inefficient decision-making on details, a low level of commitment to the script, and a generally unorganized working style. To get beyond these negative factors, suggestions to future collaborative attempts were the following: organize a bit more teaching on the topic; start the process with a pre-defined theme or ideas; or work so that the process is partly guided by a moderator organizing good face-to-face meetings, especially during detailed scriptwriting; and finally use better software.

Use of the Wiki tool as a part of collaborative scriptwriting process was examined for comfortable and uncomfortable factors, which should suggest improvements for the future to make its use more attractive (see Fig. 5).

4.4 Applying Online Collaborative Tools to Film-Making

Using the Wiki tool was experienced as pleasant because it offered to store the script so it could be viewed anytime, anyplace, and by anyone. It was also seen as a good platform. However, people were reluctant to start using it: it had a huge amount of weakly organized text, expression was limited to text, and it lacked a feature to track changes, which all made the Wiki tool uncomfortable to use. Software should be simple, and a short introduction should be given at the beginning of the process to make people more willing to use it. If any software is to be used to support collaborative scriptwriting, it should have more features for script management, including online synchronous and asynchronous working possibilities and storage for the final version. There should also be a feature for tracking changes, see the changes others have made, and send email notification whenever changes are made.

Another option for applying collaborative script-writing technology is the well-known software tool, celtx [http://www.celtx.com/]. Celtx is increasingly evolving to a quasi-standard software in terms of screenwriting. Besides providing collaboration features and scheduling tasks among multiple authors, it offers the creation of storyboard sequences and the possibility of tagging certain elements in the pre-production phase. It runs on several operating systems and is free and open-source.

5. DIGITAL HD PRODUCTION WORFLOW BASED ON MXF METADATA

As stated in the previous section, collaborative cooperation with Wiki Tools is a useful, and nowadays widely appreciated, method for shared collaborative content pre-production. However, the more participants are involved in the co-preparation of the media material, the greater the number of contributions that have to be taken into consideration while deciding on the final version. This affects the production workflow as well. To allow for a full digital production workflow, new digital tools for enabling a (semi-) automated flow are necessary. The idea is to make all data associated with the essence (the actual material) available at each workflow step. This relates to information about the script, the script itself, why specific decisions have been made, camera settings, shooting quality, camera reports, and shot descriptions. This section describes the step that enables a digital workflow between pre-production, production, and post-production. Since comparing the different points of view of the movie-maker team and decisions during the production phase are pivotal aspects of collaborative cooperation, especially

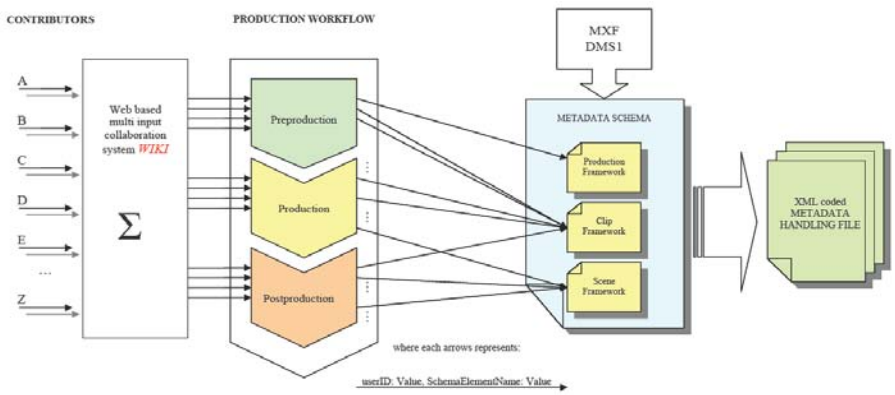


Fig.6. Applying the Material eXchange Format (MXF) as a digital workflow management tool within the scope of E=MC2+1.

while using new information exchange systems, all information, including single parameters, must be stored, correctly assigned to existing material, preserved, and what is more, uniquely identified.

The technology to cope with the digital production workflow in E=MC2+1 is the Material eXchange Format (MXF) [http://www.mxf.org/] in combination with a web-based information management system developed by the research group [Golebiowski 2006; 2007]. An overview of how MXF was applied for E=MC2+1 can be seen in

Fig.6. The MXF information management system had the following tasks:

- digital management of the movie-script;
- storage of captured data (e.g., camera parameter); and
- generation and annotation of shot descriptions, storyboard, special effect sheets, and camera reports.

5.1 Material eXchange Format (MXF) Basics

Metadata fully describes essence, and is a cornerstone in content preparation. Metadata itself must be logically arranged, extendible, and easily accessible. Besides numerous database solutions for metadata storage and supervision, the XML coded metadata schemas [Caplan 2003/2004] represent one of the most important possibilities for metadata administration. Correct and effortlessly available metadata schemas ensure preservation and powerful digital content management in preparing the workflow, as well as at the very end of the production chain (i.e., distribution and play-out). MXF provides a solution especially suited for the movie production side.

MXF is a wrapper format, which can encapsulate essence and all associated data with it. MXF is (mostly) standardized by SMPTE [http://www.smpte.org] and is used as professional production format for enabling a fully digital workflow. We applied the MXF information system, which was developed by the NAMU research group at the Tampere University of Technology. In principle, the MXF standard consists of two major elements (standards available from SMPTE):

- the wrapper element allows encapsulating any type of content into a package (e.g., audio-visual content); and

- the DMS1 specification allows tagging production information to essence (e.g., shot description).

The application of MXF DMS1 metadata, besides delivering the production information, storage medium, and a management system, also delivers the complete description of the material and essence-related matters. The MXF description may also serve as the source of information for public essence description in the form of a narrative summary, subject description, or genre for programs' web portals or TV guides.

MXF DMS1 elements consist of many different production-associated parameters and characteristics arranged into frameworks via metadata. Each framework encapsulates a set of logically interconnected elements essential during the production process. Thus, the production framework stores all administrative information such as staff data, contributors, and so on. The clip framework organizes the pre-production and capture process and collects related data related. Thus it organizes information in pre-production, covers the capture process, and is capable of assigning shot descriptions, shot animations, camera parameters, and set in/out points to essence. The scene framework of MXF wraps scene-elated information, such as placing actors in a timeline.

Moreover, the MXF elements identification method ensures the unique identification of single essence elements. Due to the possibility of storing different versions of the same material, it is not sufficient to use scene, shot, and sub-shot numbers. MXF provides unique identification of essence elements via UUIDs, which are a unique generated hexadecimal value. However, every database entry must be localizable via a unique identifier according the MXF DMS1 specification. To comply with real movie production, the identification of each shot is also identified with a triple scene number/shot number/sub-shot number.

5.2 Applying MXF to the E=MC2+1 Production Case

In E=MC2+1, the collaborative script-writing was done with the help of Wiki tools. The final script was inserted in our MXF-based information management system for further processing. During the production process, we experimented with modern digital production technology to emphasize collaborative processes as well. We stored the movie script in the MXF information system. After the storyboard, including its graphics, had been generated, this was stored in the same system as well (see **Fig. 7**).

During production, collaborative access to the data was possible, but a decision on production-related issues was left to professionals rather than to a democratic decision to maintain the highest quality. In practice, decisions on camera settings, action flow, shot quality classification, and additional information on the participants' individual preferences were stored in the MXF information system. In the case of E=MC2+1, the MXF information system was not used as a collaborative tool, but as a tool for professionals to manage relevant data during capture. A collaborative approach in using these tools would have been counter-productive at this step.

CAMERA ANGLES - STORYBOARD - FOR: E=MC2

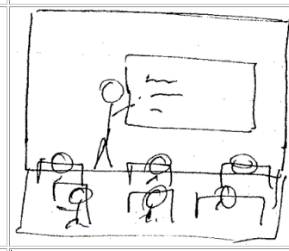
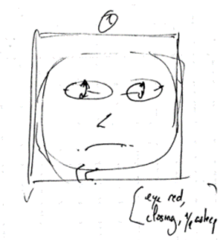
SCENE NO	SHOT NO	SHOT TYPE	DESCRIPTION	SHOT DESIGN
1	1	Wide	General view of the classroom -> from the back. Teacher starts the lecture. Some equations and figures already on the blackboard.	
1	2	CU	View: classroom/person 1 - close. Person 1 sweats and holds his head with both hands. Painful expression on his face, 8kHz wave is heard on top of everything.	

Fig. 7. Storyboard generated on the basis of MXF metadata.

E=MC2 version 1

SHOT ID	1/3/1	***TAPE NO***	1
TIMECODE	***START:***	01.20.35.22	
	STOP:	01.21.35.22	
PLACE	The location of an action. Nijinsky's room.	***TIME***	Night
ACTORS	All crew. Student 2, Student 3(GIRL), Student 6.		
ACTION DESCRIPTION	Student 2 is making moveon Girl (Student 3), but is too wasted. He gets nauseated and needs go to the bathroom. Some less drunk guy (Student 6) comes in and start to chat with the girl.		
REQUISITS	Glasses full of beer and drinks, Normal disco equipment. huge speakers next to the dance floor.		
CAMERA MOVEMENT	Translation to higher elevations (Y) in meters : -0.18		
OBJECTIVE	10	***FOCAL INFO***	6
CAMERA HEIGHT	0.85		
DISTANCE TO OBJECT	1.76		
LIGHT	Disco red - yellow lights.		
BLUE SCREEN	No effects		
3D	No effects.		
COMMENTS	Girl chatting with girlfriend, sitting by the table in the left corner of the room. Other students in the background.		

Fig. 8. Shot report for one shot based on MXF metadata.

While the MXF information system was used to manage data coming from pre-production phases before capture, during production it had two tasks. The first was to manage production metadata coming from the camera; the second was to generate reports after shooting. These reports included the camera report (see **Fig. 9**) as well as the special effect sheets (see **Fig. 8**). The camera report shows essential information related to time-codes and brief shot descriptions. The special effect sheets represent all information related to special effects and their setup.

namu	CAMREA REPORT	Production Setting Date:	21.02.2007	Page:	1/3
Production / CO. :	E=MC2+1/2007	Main Title:	E=MC2+1		
Director:	Mr Piotr Golebiowski	Cameraman:	Mr Adrian Hornsby	Recordist:	Mr Jarkko Kauranen
Camera:	Sony HD	Film:		Storage Medium No.:	1

Scene No.	Picture No.	Take No.	Start Time	Stop Time	Essential Info.	Lens Info.	Camera Height
1	1	1	01.00.40.01	01.01.41.13	Shadow of the camera. Camera on teh opposite side of the classroom.	10	1.23
		2	01.01.41.13	01.02.27.01	Lights ok. Slight movement in the entrence door direction necessary.		
		3	01.02.27.01	01.03.23.16	OK		
4	13	1	01.03.23.16	01.04.20.23	Students leave class room too fast.	10	1.23
		2	01.04.20.23	01.05.28.02	Teacher - wrong hand on the desk.		
		3	01.05.28.02	01.06.05.10	OK		
		4	01.06.05.10	01.06.44.10	Too slow action.		

Fig. 9. Web-based daily camera report based on MXF metadata.

5.3 MXF for Screenplay, Storyboard, Special Effect Sheets, and Camera Reports

The MXF DMS1 standards contain a wide variety of film and broadcast industry parameters. These parameters can be used to generate other production-related documentation in the form of special effect sheets, shot lists, and camera reports during production.

The specific parameters required to fill these reports are defined by the SMPTE RP210.6 Dictionary, which defines the structure of data during capture, as for example objective information, focal information, camera height, or camera object distance required for capture. The production framework defines the structure of production-global valid data and was mostly used for generating the camera reports. This data included production dates, director, cameraman, title sets, timeline information, and was the basis for generating camera reports.

Taking the E=MC2+1 collaborative script-writing as an example, all script versions are stored in the centralized Wiki repository and can be accessed by any registered collaborator. Using the MXF information system, automatic script generation is possible by a simple single click. Each Wiki entry of the movie-script needs to be added to the MXF-based information system. For example, shot comments (*ShotComment*) originating from Wiki are added to the author of the comment (*ShotCommentKind*). Thus, at this stage, the MXF-based information system contains more possible versions for the movie-script.

However, the decision on the final script version must be taken beforehand, since the actual script must consist of a unique sequence of single scenes, including several shots. In other words, if several different versions of single shots are stored in the repository, many different versions of shots will lead to many different versions of the total script. Should the final script contain numerous entries with the same shot identification, errors are reported by the system, as the final version entries have to be uniquely identified. Optional sequences can be annotated via a Boolean flag (*IsOptional*) to indicate the script optional or required elements. XSLT transformations in combination with XQueries are used to generate a human-readable form of the final movie script. The final version only includes the non-optional elements of the database entries.

The storyboard is edited on the basis of the movie script, and is manually annotated. Additional storyboard images can be uploaded to the MXF information system. The storyboard contains sufficient information to initialize the capture of the movie.

However, the real essence of collaboration in movie-making – despite the high importance of extra information – is the movie as such. So the “real” essence is captured in the next step of production. All information required for camera reports and special effect sheets has been collected and added to the MXF information system. The generation of reports is based on XQueries and XSLT style-sheets as well, to make them readable to humans. This follows the two-way input approach of metadata and essence as discussed in Cox et al. [2006]. More practical examples of MXF files can be found in Appendix A, in **Fig. 12**, and in **Table** .

6. DIGITAL HD POST-PRODUCTION

After the capture process, the next step is post-production. In post-production the final movie is created by arranging suitable parts of the footage in a correct and timely order. From the director’s artistic viewpoint, the original material is simply a huge number of different shots. During the post-production process, especially during editing, special effects and sound are added, and faults in the material corrected.

Traditionally, editing required the physical cutting of the original material, and afterwards gluing it together. Nowadays the process is called non-linear editing. Traditional editing was tricky, as the original material was processed, but it let the editor or director of the movie have more of a relationship to his material. With the emergence of videotape-based editing, a new linear editing method was becoming available. The desired parts of a movie were copied from the original tape to a master-tape. The copying process led to quality degradation, and analogue devices were mostly used in the process. Special effects could also only be added with difficulty, as they had to be created in real-time while the material was being copied. Due to the tape-like workflow, this method was called linear editing.

However, modern editing systems are usually fully digital. The original analogue film is digitized and processed by a computer system. In principle, this is a step backward to the non-linear editing method. Computer-based editing has the advantage that a film can be edited virtually rather than on the actual material. A virtual timeline in the computer system acts as container for the actual material. This can also be described as file-based editing, as the original material is pulled from digital tapes and converted to clips stored on a hard disk. It is obvious that the storage space becomes a major issue and high computational power is required to realize the image and sound processing tasks. E=MC2+1 was edited using this method.

For E=MC2+1, the material was captured on digital tape and afterwards copied to the computer’s hard disk. Where the essence was available on hard disk, the MXF information system was used to manage all the essence-associated data. As our editing station did not support MXF as a wrapper standard, this seemed to be the most efficient way of working with the material. For editing, Adobe Premiere was facilitated. Unfortunately, various scenes could not be detected during the capture of the HD material from tape, as Adobe Premiere did not support this functionality. This made it difficult to edit the high-resolution material, which led to huge files on the hard disk that were cut manually using editing software.

Another problem was that the audio sync was frequently lost in the middle of the clips, and this could only be corrected manually. Despite this, the basic editing was quite smooth, and no more problems appeared. But we were faced with new challenges when we added color-correction filters and other effects, and the computer system had to deal with a rather demanding and difficult task. Despite an InterCore 2 Dual processor and 3 GB of memory, the process still seemed very slow, and we ran out of memory many times. We could not track back if this problem was due to too little computational power or to the editing software.

The Adobe After Effects software was used to create the special effects. However, for E=MC2+1, we wanted only a few simple effects, as the student team did not have the professional experience required for more complex special effects. The effects we were aiming at were

- green-screen compositing with chroma keying;
- slow motion effects; and
- color correction.

As in previous versions of Adobe products, After Effects and Premiere integrated well. After adding the special effects, we obtained a final master of the movie, which was a huge uncompressed HD file. The final master was used to encode different versions for distribution to IP-TV, DVD, or mobile-TV.

6.1 Green-Screen Compositing with Chroma Keying

Fig. 10. E=MC2+1 chroma keying shot of actors and beach background.

Chroma-keying allows us to segment objects from the background and to combine them with another background. In practice, a color transparency is created and replaced by another image. This technique is currently extensively used for weather forecasts, elections, and some children's TV shows. The foreground object (e.g., the presenter of today's weather) is in front of a solid colored background. The solid colored background is replaced by another background – n the case of today's weather, with the weather map. Typically, this is a non-human-flesh color such as blue, but a green background can also be used for this purpose.

Traditionally, analogue video mixers in combination with a blue background were used, since blue is one of the three main colors that is not or very rarely part of the color of human flesh. Green backgrounds have become popular, as they give better results when working with compressed digital video formats. It is also a much brighter color than blue, as its luminance value is higher. A green background makes for better results and needs less light in lightening a scene. It provides another advantage, as today's single-chip cameras perform better with a green background due to the structure of the chip.

In E=MC2+1, one compositing shot was created by using the chroma key effect. Compositing is the process of adding up the various layers of image material. In the scene in which a student in a classroom is dreaming about a holiday with his girlfriend, the dream image was taken against a green background. The final effect was then created in Adobe After Effects, which had the tools required for keying; specifically, the keylight effect. (We had to fine-tune the settings to make decent results with not-so-perfect video material.) As the course was intended for non-film-makers, it was obvious that the original material would not be perfect. To obtain good results, required a greater amount of work in post-production. The major problem was lightening the background, which was not properly arranged for during shooting, so that some areas at the bottom of the image were darker than others. Another problem was the lady's sun-glasses: it was rather difficult to make the sunglasses look good and make all the green areas transparent at the same time. The problem was solved by using various keying settings for different parts of the image.

6.2 Slow Motion Effect

E=mc2+1 has several scenes with alternations in speed. One scene is completely implemented at a high speed: a scene in which a nerd goes to ask for a cigarette from the "cool student" in a bar. The original action material in the scene had only two image sizes. One was very large, so it was not usable most of the time. The action in the shot took quite a long time, so showing it in real time would have broken the rhythm of the movie. Hence the solution was to speed up the action and show only the important parts. The other parts were cut when there was no possibility of changing the image size. The result was still nice, because the audio consisted of music only (as in music videos).

Slow motion was used in some other scenes. The green screen scene, where one student is dreaming of a holiday with his girlfriend, included playback at half speed to give a more "dreamy" feeling to the scene. The effect was made by actually doubling the number of frames. Every other frame was created using information from the next and previous frame. Motion vectors were used for creating the new frames. So it was an implementation of morphing. The result was quite natural, as though it had been filmed at a double frame rate and then played back at a normal frame rate (although the disadvantage is that this method needs quite heavy calculation: together with the green screen effect, After Effects took almost three hours to render this seven-second effect). Also, it often fails with complicated backgrounds or items like rotating objects that change shapes fast. This effect was also used in a scene where a girl student turns her head towards another student who flirts with her, although her boyfriend is sitting with her. The slow turn of the head made the scene more dramatic.

Another type of slow motion was used in the last of the party scenes in which the teacher falls down at the party and the image cuts to the classroom where he falls asleep. The slow effect is basically slow motion, but frame blending gives more motion blur to the image and makes the movement smoother.

6.3 Color Correction

Color correction is a process that includes selecting correct lighting and camera settings when shooting the scene. As this is frequently faulty, tuning the colors in post-production is required. The scene can often be made more interesting by adding light sources with different colored lights. The final goal is not always to create a realistic image as possible, but to create images that best serve their purposes. Two examples are the creation of a beautiful visual and the evocation of a mood. Typically this means modifications to all aspects of the image, not just setting the color temperatures. The contrast can be altered in many ways, leading to rather complex processes.

For E=mc2+1, the editing application (Adobe Premiere) was also used for color correction. In practice, the corrections were done by using a combination of various effects settings. The basic tools were contrast curves designed for each scene, for luminance, and red, green, and blue channels.

Another issue was that our movie took place at two completely different locations: the lecture and the party.

The lecture scenes were supposed to happen in the morning, when students are tired due to partying the night before. So the lecture scenes were set to look colder compared to the party images. This represented the mood of the students visually in a better way. During capture, the original material was recorded using the basic camera settings, however the settings were set to film-like gamma to create a movie look. To create a darker mood for the students, some compression was done to the black tones in the image. Brighter tones were not altered. In wider images, the effect was applied in a milder way. A colder color was achieved by changing tones, especially in the mid-range, a little bit towards blue and by reducing saturation while keeping the whites white.

The party scene presented a completely different kind of situation for color correction. The color here should be different from the other scenes, which were shot with different camera settings as well. So another type of cinematic gamma was used, and the blacks were compressed somewhat. The lighting in the scene included a purple fluorescent light, a greenish fluorescent light, and some indirect light from regular 3200K halogens. In the dancing scenes, the purple light was dominant. The purple tones were changed towards red in the color correction, and the effect of the greenish light was emphasized. As result, the colors in the dancing scenes were dominated by a combination of red and green. In the other parts of the room the purple light was not dominant, so different color correction settings had to be applied. The room was actually quite dark for movie production purposes, and so grain was used in the camera, which is not usually a good thing in feature film production, but in this case it was considered a practical solution. The dim lighting with different colors served our purpose better than a bright studio-like environment. At the beginning there was 6db more grain in the image than in classroom scenes. Still, the visible film-like grain seen in the image in the party scenes is mostly generated in post-production. The contrast in the scene was enhanced by lifting some areas in tonal range while suppressing black more. In a couple of clips a smoke effect machine was tested at the location, but it only caused the blacks to rise towards grey. This was corrected in post-production.

6.4 Audio Editing

Audio is an important part of a movie, and may also need a lot of work in many editing projects. In the case of E=MC2+1, audio was recorded on location using a hard disk recorder. The audio clips were synchronized to the video later using the editing software.

The music for the movie, a song called “Quantization Matrix” was written and composed by a student in the course; the clips were also added during the editing process.

The voice tracks were compressed to make the speech clearer. EQ was used to make the speech sound correct, and to fit the music and speech to the scenes. The audio levels were corrected, and the music was mixed a (a bit) lower than speech.

7. HD DISTRIBUTION OF THE MOVIE

Since the goal of the course was to look at the complete production chain, from scene to screen, we tested the following distribution methods for HD content:

- IP-TV
- DVB-T
- DVB-H
- DVD

7.1 Distribution for Television

The laboratories at the Tampere University of Technology (TUT) were utilized for distribution (system architecture in **Fig. 11**). The laboratories provide the technical facilities and environments for both the full-chain DVB test-bed [European Telecommunications Standards Institute (ETSI) 2004] and the IP multicast network. Hence the selected platforms were based on DVB and IP-TV. Today these technologies represent the most common distribution media. In addition, TUT provides a mobile streaming test-bed. To test this distribution channel, the material was transcoded for DVB and resolution and bitrates downscaled for mobile broadcasts. Several digital television distribution channels (DVB-T, IP-TV, and DVB-H) were utilized to find ideal requirements for HD content.

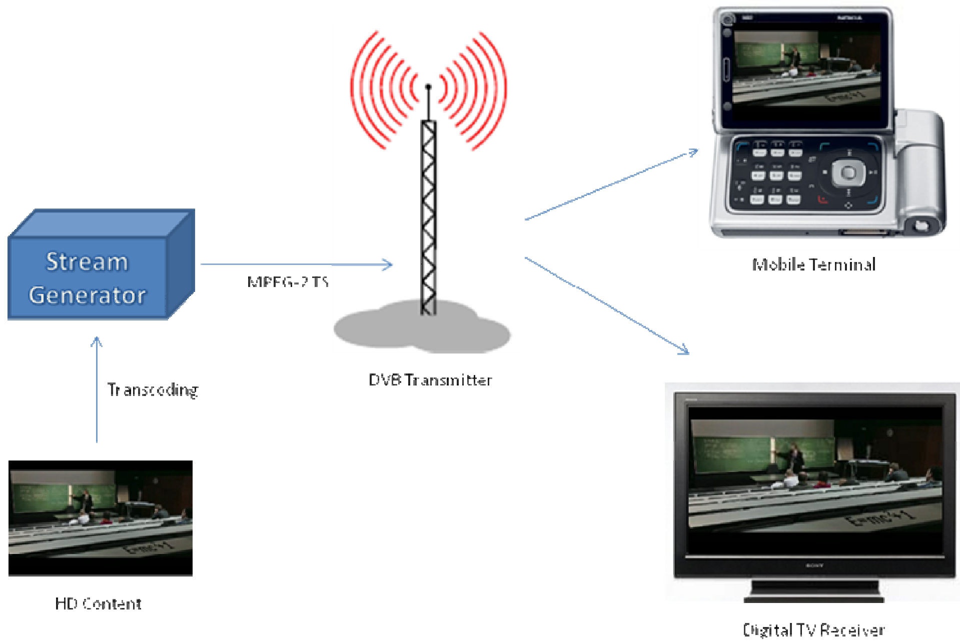


Fig. 11. DVB distribution architecture.

The main components of the DVB test-bed are the stream generator and the transmitter. In addition, content servers and content description tools are used when needed. Eventually this could facilitate the creation of an Electronic Service Guide (ESG) [European Telecommunications Standards Institute (ETSI) 2006] for mobile broadcast. We used a wide range of available set-top-boxes, PC cards, mobile phones, and USB sticks as reception devices for DVB applications for terrestrial and mobile reception. For DVB-H [European Telecommunications Standards Institute (ETSI) 2004], we tested our system with the Nokia N92 acting as a mobile television receiver.

The heart of the system is the stream generator, which is a server for creating an MPEG-2 Transport Stream and feeding it to the transmitter through an ASI interface. The TS can also be created separately and saved on the server for the transmission. In addition to generating the MPEG-2 TS, the server provides all the necessary properties to manage DVB-T/H broadcasting. It creates the PSI/SI tables [European Telecommunications Standards Institute (ETSI) 2005] and executes IP encapsulation for the DVB-H network and other mobile broadcast-related properties like Multi-Protocol Encapsulation (MPE), time-slicing, and MPE-FEC (Forward Error Correction).

The transmitter system is professional equipment for DVB provided by Rohde and Schwarz. It contains an exciter unit, two 50W amplifiers, a separate unit for controlling the amplifiers, two vertically polarized omni-directional antennas, and two bi-directional antennas. The dual-amplifier multi-antenna system is built for testing diverse transmissions. The exciter unit includes encoder, pre-corrector, modulator, and synthesizer for signal generation. It is equipped with operating and monitoring software installed on a PC which is connected to the exciter through a serial interface. The software provides full control of the exciter properties and transmission parameter modifications. The amplifier control unit is manufactured separately to flawlessly adjust output power. The antennas are installed on the roof at 25 meters above ground level. The other antenna combination is located on a moving platform to adjust the distance between antennas.

7.1.1 *Transcoding the Material.* The content had to be transcoded into a compliant format in order to be distributed through a DVB network. For DVB-H distribution, the material was encoded into MPEG-4 format, optionally using H.264 coding. All mobile terminals equipped with a mobile television (DVB-H) receiver support these formats. The bit-rate of the encoded streams was reduced to 500 kbps and the resolution was down-scaled to 320x180. The bit-rate of 3000 kbps and the resolution of 720x576 were also used experimentally.

For DVB-T distribution, the material was directly transcoded into MPEG-2 TS format. Some professional TS editing was also needed to add the network information required by DVB-T receivers. The parameters of the transcoded streams are described in **Error! Reference source not found.**. All these streams were also used in IP-TV experiments.

Table IV. Transcoded Streams

Version	File Format	Codec	Bitrate / kbps	Resolution	Target platform
1	mp4	MPEG-4	500	320x180	DVB-H
2	mp4	H.264	500	320x180	DVB-H
3	mp4	MPEG-4	3000	720x576	DVB-H
4	mp4	H.264	3000	720x576	DVB-H
5	trp	MPEG-2 TS	6000	720x576	DVB-T

7.1.2 *Results of the Experiments.* To test the mobile television-viewing experience, a Nokia N92 multimedia phone was used. At the moment it is one of the few phones equipped with a mobile TV (DVB-H) receiver. To test the reception quality, the transcoded streams were transmitted using the DVB system and received with the phone. The viewer experience and reception quality were good with 500 kbps streams, but 3000 kbps streams were already too heavy for the receiver, causing a deterioration in video quality. These results suggest that even lower bitrates (200 to 300 kbps) could be used in the mobile television environment and still achieve good quality.

The digital television was tested with a digital DVB-T receiver (STB) and a plasma screen. The reception and video quality were excellent, as the bit-rate (6000 kbps) was higher than usual (2000 to 4000 kbps) in a digital television environment. IPTV experiments were performed with all the streams using the VLC application to feed them to a multicast network. The results were good in every case, but it was noticeable that in an IPTV environment, network load and network performance capabilities played a big role in reception quality. In conclusion, all the experiments were done using down-scaled resolution, even when DVB-T and IPTV allowed full HD resolution. This will be the goal in future testing.

7.2 DVD Production

To prevent any copyright problems with commercial entities, a condition for the DVD menu was to draw on self-produced materials only. This restriction not only offered a financial advantage but it also furthered an original design of the menu. The main purpose of the menu design was to give a foretaste of the movie with interesting pictures to tease the audience. The final implementation consisted of two parts: the background picture with a second layer that overlapped the proper image borders and a collage of the actors in the form of an animated movie strip that makes the menu more active. All these images were extracted from the movie which has a widescreen HD resolution.

As the images were calculated with squared pixels, the exported pictures had to be horizontally resized for a correct resolution. A further objective was to emphasize the funny character of the movie. This comic style was realized via two rapidly sliding menu objects and by an open source font type to create chalk-like menu text in front of the blackboard. In addition, music was composed to support both the activity and the humor of the menu. This music was based on the piano harmonies of the song in the movie, called "Quantization Matrix". The software we used was the Adobe Production Suite. The menu was designed in Photoshop, image extraction was done with Premiere Pro 2.0, the animated menu was created with After Effects 7.0, and the final DVD was built by Encore DVD 2.0. As of today, not every DVD player supports HD movies, so this DVD contains a standard version. Additionally it holds an HD version for the computer in a separate folder, and the still images shown in the DVD gallery are stored as JPEG in a DVD folder as well.

8. DISCUSSION

Tampere University of Technology (TUT) in general and the NAMU (New AMbient MUltimedia Research) group in particular offer courses based on the latest available technologies. Students not only have the opportunity to learn, but to also experience contact with cutting-edge technology.

The NAMU group offers courses in which students have the opportunity to experiment with the latest developments in technology to realize their own ideas. The concept of learn-by-doing is implemented in the content production course mentioned in this article. Although the implementation of more experimental tasks requires additional work from the faculty, as the teaching effort increases with the practical exercises, the advantages to the students makes it worth the additional effort.

The experience of learning-by-doing improved innovation and collaboration among the participants of the course. The students were eager to obtain solutions the moment their tasks were complete. The open environment allowed the students to use their imaginations, and provide solutions that overcame their difficulties.

The implementation of a Wiki environment came after some of the course participants had difficulty in arranging meetings for editing the script. Open-source software solutions such as Wiki software encouraged the team to install new software quickly.

The students' involvement in course activity demonstrated their interest in collaboration and learning. The fact of collaboration is remarkable, far from the typical course where the main objective is passing the exam.

The video production process was an educational one, where knowledge related to media technologies was created and developed. Its main outcome was a short movie, the result of inputs from all class-team members. In general, teamwork is superior to an individual working alone. The greater human resources sharpen ideas through discussion and argument, and support for a tentative idea motivates a common successful outcome. But teamwork might end up with disappointing results due simply to a lack of communication or contradictory opinions. During our course, the process was controlled by avoiding unnecessary team meetings; although generalized comments were emailed to all the members, providing observations and information with suggestions on how to continue.

We also recognized that special tasks could be done more effectively by individuals rather than teamwork. The video production process involved many stages, so that tasks and areas of responsibility were shared by class participants. The responsibilities varied: there was a director and assistant director; cinematographer; camera, sound, and light crew; music, sound, and graphics designers; a production designer and a stylist; SFX supervisor; production manager; editor; workflow manager; and a group of student actors. As the tasks were shared, knowledge became diffused through the group; no one person had a monopoly of knowledge. This approach was different from that in a traditional class and required students to become self-regulated and collaborative learners.

Collaboration is a process defined by the interaction of knowledge and mutual learning among two or more people working together towards a common goal, typically creative in nature [Wikipedia. http://www.wikipedia.org]. Collaborative learning requires participation in a learning community, but it limits individual flexibility [http://home.nettskolen.com/~morten/], hence its success may depend on a mutual understanding that all participants have an obligation or commitment to it. Collaboration was successful in this course, but typical group dynamics, especially during script-writing, were visible. Many different opinions, personal viewpoints, and approaches led to strong and heavy discussions. As pure technology-oriented courses tend to present theorems, a more creative course tends to involve human emotions.

Nowadays, as media technologies are evolving, collaboration in knowledge creation can be easily realized. There are various learning environments, management systems, shared boards, forums, chats, and so on, where students can express their ideas, learn from each other, find answers to their problems disregarding time and place constrains. Special opportunities can be created by free and open source software (F/OSS). One of the significant features of F/ OSS is that they can be accessed, formatted, enhanced, and applied by any internet user; the Wiki open-source tool was used in this course.

This course was different from a traditional one: the overall goal and problems were set by the course instructor, but the students could set their own learning objectives. The areas of their responsibility were divided according to their preferences (e.g., interest in the camera). Formal instruction was avoided, but still (or perhaps due to this factor) students were motivated to participate in this course.

ACKNOWLEDGMENTS

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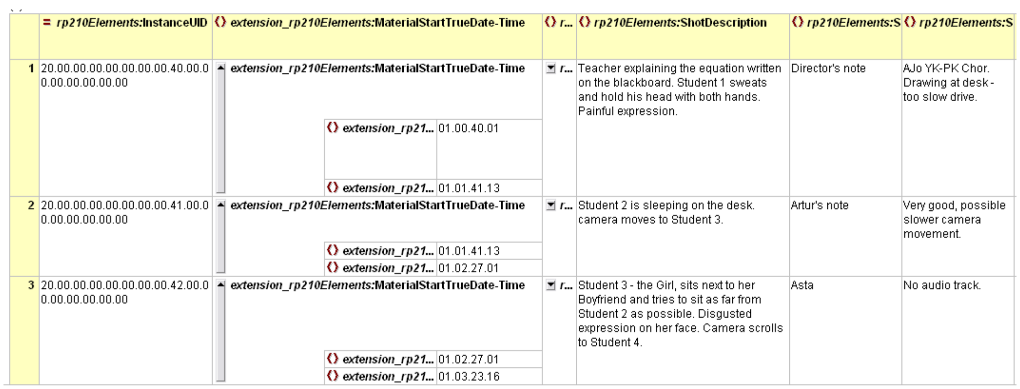
Section 6, by Jarkko Kaurnen; Section 7, by Mikko Oksanen and Dirk Matthes; and Section 8, by Asta Kybartaite and Fernando Ubis.

APPENDIX A: DETAILED MXF EXAMPLES

Table V. Example MXF File that Describes One Shot (take)

```
…
<rp210Elements:TakeNumber>10</rp210Elements:TakeNumber>
<extension_rp210Elements:IsOptional>false</extension_rp210Elements:IsOptional>
<rp210Elements:ScriptingSets>
   <DMS1:Scriptingrp210Elements:InstanceUID="23.00.00.00.00.00.00.00.30.00.00.
                                             00.00.00.00.00">
      <rp210Elements:ScriptingKind>Script</rp210Elements:ScriptingKind>
      <rp210Elements:ScriptingText>Student 1 sits with head down.
         </rp210Elements:ScriptingText>
   </DMS1:Scripting>
</rp210Elements:ScriptingSets>
<rp210Elements:TakeNumber>10</rp210Elements:TakeNumber>
<extension_rp210Elements:IsOptional>true</extension_rp210Elements:IsOptional>

<rp210Elements:ScriptingSets>
      <DMS1:Scriptingrp210Elements:InstanceUID="24.00.00.00.00.00.00.00.
                                               00.30.00.00.00.00.00.00.00">
      <rp210Elements:ScriptingKind>Script</rp210Elements:ScriptingKind>
      <rp210Elements:ScriptingText>Student 1 sleeps on the desk.
         </rp210Elements:ScriptingText>
   </DMS1:Scripting>
</rp210Elements:ScriptingSets>
…
```



	rp210Elements:InstanceUID	extension_rp210Elements:MaterialStartTrueDate-Time			r...	rp210Elements:ShotDescription	rp210Elements:S	rp210Elements:S
1	20.00.00.00.00.00.00.00.40.00.0 0.00.00.00.00.00	extension_rp210Elements:MaterialStartTrueDate-Time	extension_rp21...	01.00.40.01	r...	Teacher explaining the equation written on the blackboard. Student 1 sweats and hold his head with both hands. Painful expression.	Director's note	AJo YK-PK Chor. Drawing at desk - too slow drive.
			extension_rp21...	01.01.41.13				
2	20.00.00.00.00.00.00.00.41.00.0 0.00.00.00.00.00	extension_rp210Elements:MaterialStartTrueDate-Time	extension_rp21...	01.01.41.13	r...	Student 2 is sleeping on the desk. camera moves to Student 3.	Artur's note	Very good, possible slower camera movement.
			extension_rp21...	01.02.27.01				
3	20.00.00.00.00.00.00.00.42.00.0 0.00.00.00.00.00	extension_rp210Elements:MaterialStartTrueDate-Time	extension_rp21...	01.02.27.01	r...	Student 3 - the Girl, sits next to her Boyfriend and tries to sit as far from Student 2 as possible. Disgusted expression on her face. Camera scrolls to Student 4.	Asta	No audio track.
			extension_rp21...	01.03.23.16				

Fig. 12. MXF example file for movie-script entries.

APPENDIX B: SHOTS FROM THE MOVIE

Fig.13. The drunken student approaches ladies at a bar.

Fig. 14. Sleepy teacher the day after the party, while a nerd removes a mistake in the famous E=MC2 formula.

Fig. 15. Teacher partying with students.

Fig. 16. Teacher explains the famous E=MC2, that is, ahem, the E=MC2+1 forumula.

Fig. 17. The cool student flirts with female students.

Fig. 18. Female student tries to hit the cool student.

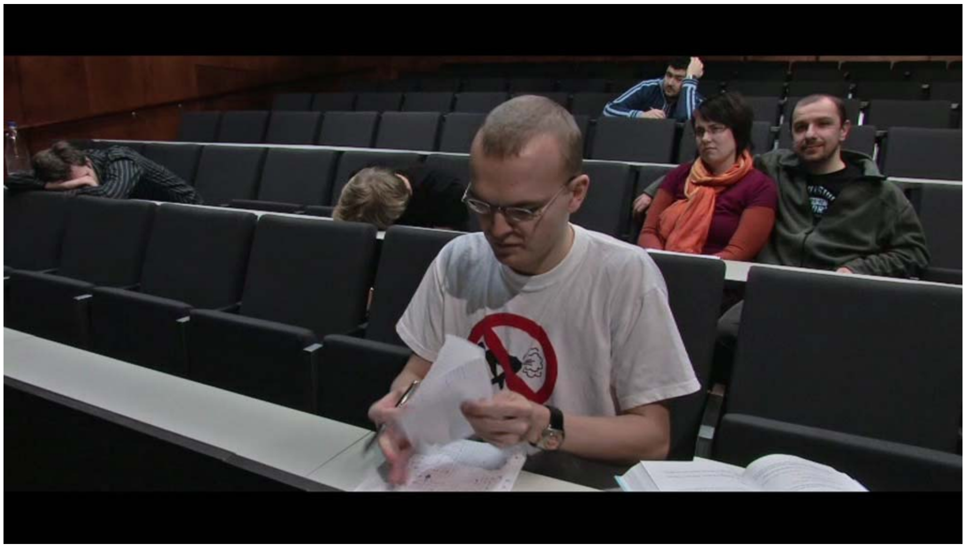


Fig. 19. Nerd studies his papers.

Fig. 20. Nerd s tries to smoke his first cigarette.

Fig. 21. Drunken student still has a headache during the lecture.

Fig. 22. Drunken student at the loudspeaker.

Fig. 23. Another student sleeps during the lecture.

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