How-To: Instructional Video

Recommendations for the Design of Software Video Trainings for Production Workers

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Abstract— **This paper gives an overview of design aspects of software instructional videos resulting from a literature review. The goal is to identify design dimensions and recommendations for instructional videos for software training and to make the results usable for the production of Computer-Aided-Design/-Manufacturing (CAD/CAM) instructional videos as part of a training concept within a Research and Development (R&D) project. The qualitative analysis provides four key design dimensions: (1) didactic design, (2) influence of the object, (3) material-technical implementation and (4) linguistic-visual design of the instruction. Recommendations were examined for similarities and differences and, if necessary, supplemented with findings from studies on particular aspects. The guidelines' recommendations are mainly influenced by contextual factors. Fewer design solutions are discussed at a linguistic or visual level. The results provide valuable input for the design of instructional videos as learning materials for CAD/CAM software training in professional contexts.**

Keywords-instructional videos; software video training; digital education; CAx systems; digitalization in industry sectors.

I. INTRODUCTION

Instructional videos present a solution process for specific tasks, enable users to act independently [1] and support Demonstration-Based Training (DBT) [2]. Multimedia products are increasingly discussed as a suitable means of knowledge transfer in a rapidly changing technical world. They can be produced quickly due to technical developments [3] and they use a familiar form of knowledge transfer (instruction) with new means. They are among the most used tools in the 21st century for the efficient, independent solution of activity-related tasks [4]. In addition to private use, there is a growing interest in the use of instructional videos in professional fields. Instructional videos have a high potential for companies (e.g., software training). As a blended learning format, they facilitate to make training and education of employees more efficient; employees are given the opportunity to acquire knowledge in a self-regulated way [5].

Within the R&D project "WerkerLab - A modular training concept for Small and Middle-sized Enterprises (SMEs) in the production technology environment" a training concept that prepares workers in SMEs for the use of CAD/CAM systems and for requirements of Industry 4.0. is developed. A major part of the modular training concept is the use of instructional videos. Therefore, a literature-based orientation framework for the production of CAD/CAM training videos is developed. This framework will then be enriched by the perspectives of workers and trainers from industrial project partners. Based on this framework videos will be produced and evaluated. The goal was to identify requirements for the design of instructional videos in this field of application. The results are presented in a systematic manner with reference to four design dimensions: didactic design, influence of the object, material-technical implementation and linguistic-visual design of the instruction. The latter part focuses on the central aspect of instruction and its implementation. From the perspective of communicative usability [6], questions of linguistic and visual design are considered in particular. The paper addresses three research questions:

- RQ1: Which design dimensions of instructional videos are considered in the research literature?
- RQ2: Which design aspects are discussed? Which recommendations are given?
- RQ3: How are aspects of communicative usability taken into account?

In the following, the theoretical framework that guides the literature evaluation is established (Section 2), followed by the description of the methodological procedure (Section 3). The evaluation is based on the four design dimensions mentioned above (Section 4). After a discussion in Section 5, the article closes with a conclusion and outlook for further research (Section 6).

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II. THEORETICAL FRAMEWORK

This paper addresses instructional videos from a linguistic point of view and refers to it as a communication pattern (A). Their main purpose is to instruct. Instructing is understood as a linguistic design task that takes didactic principles into account (B) and must meet the requirements of communicative usability (C).

A. Instructional videos as a communicative format

This paper treats instructional video as a communicative tool (or genre) for solving recurring problems (in this case lack of knowledge to operate CAD/CAM software). The design of the tool is oriented towards an overall goal (mediation or acquiring knowledge about software operation) and its pattern is conventionally agreed upon [7][8]. The design is limited by external parameters: the object (here production software), contextual factors (e.g., the domain or industry in which the software is used, with its values and conventions, and the cultural-economic context), as well as situational factors (conditions for video use, e.g., embedding in didactic measures). Other restrictions concern the material-technical implementation as well as the users. The design pattern encompasses different levels [7][8]: the topic hierarchy (main topic, secondary topics), structuring and sequencing of content and design solutions, the types of actions (instructing, naming target states) with typical linguistic and visual means as well as a typical average length.

B. Instructing

According to action theory, instructing is a directive writing or speaking act [9: 255]. They are intended to enable people to acquire (long-term) procedural (how-to) knowledge in order to independently carry out action steps and achieve a desired target state. Ballstaedt [9] defines action as the intentional change of a state by an agent.

From the perspective of learning psychology (and theories of comprehensibility that are based on it), actions (and their mediation) are framed by goals, conditions, consequences and potential disturbances [10]. The learning process is more efficient if the learner knows about the purpose of the action and the context. Every action has initial conditions that must be described [9]. Initial state S1 requires action A (rule: name conditions, then describe action). Every action has its consequences, it changes the initial state S1 and transfers it into a state S2. State S2 gives feedback whether action A was successful or not. S2 must therefore be described, even if it is not directly observable. Instructions always contain series of the sequence S1, A and S2 [9]. They need to be described in the order in which they are to be executed. Actions can be hindered by disturbances. Instructions must describe what the target state looks like when an action step has been carried out successfully and name potential disturbances and offer problem-solving options for them. This can also be done by means of supplementary measures (further sources of information) [11].

Instructions must describe goals, conditions and consequences in the correct order to avoid mistakes, which can sometimes be costly or even dangerous. They must be segmented in the right granularity and sequenced in a logical manner [11]. The content structure of an instruction is hierarchical, consisting of a main action with several subactions [9]. The hierarchically highest action represents the superordinate activity, which is implemented via actions and operations [9: 256]. The level of detail depends on the target group and its requirements. Experts understand process descriptions without a detailed level of instruction (high-level instructions); intermediate experts or laypersons require instructions in small steps (low-level instructions).

The quality of the target naming and the description of initial and target states are relevant for success. Beginning and end of the instruction are functionally assigned. A task-oriented heading at the beginning, e.g., helps the recipient to mentally establish a meaningful context. Based on the representation of sub-goals (action-target state scheme) the user can verify whether he has executed an action step correctly.

A special component of instructions are warnings. Their intention is to induce the user to "refrain from certain actions or to carry them out imperatively in order to avoid unwanted consequences" [9: 259]. Since product liability exists in Europe and America, warnings in technical documentation are legally relevant and writing acts are mostly standardized. Established components are information on the severity of the hazard, the type and source of the hazard, the consequences of the hazard and measures to counteract it.

C. Communicative Usability

The concept of communicative usability complements other forms of usability (e.g., cognitive or ergonomic) [6]. It focuses on the use of communicative modes in digital communication and interaction contexts and sees language as the most important modality of interaction between humans and machines [6][12]. The quality of design is measured by the extent to which linguistic-visual means support the user in fulfilling higher-level (pragmatic, hedonistic or affective) interests of action and the resulting hierarchies of goals and tasks. The reception of instructional videos as part of professional training is motivated pragmatically - the acquisition of skills is part of the professional activity.

Communicative usability considers communicative artifacts in their embedding in superordinate contexts of action, which are influenced by domain-specific, socio-cultural as well as temporal-spatial aspects [6].

Based on the theoretical framework, four perspectives are used to analyze the literature: Aspects of the didactic design (purpose: transfer procedural knowledge), impact of the object (CAD/CAM software, use in SMEs producing tangible goods) and its contextual embedding, the material-technical implementation as well as the linguistic-visual implementation of the instruction. The starting point is the assumption that the first three factors mentioned above significantly expand or limit the scope of design for the instruction itself.

III. METHODOLOGICAL APPROACH

The literature search and selection (corpus building) was done in four steps. Step 1: The search included the following terms: instructional video, video tutorial, video instructions, how-to video, recorded demonstration. The search was carried out in the databases Scopus, Web of Knowledge and

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Google Scholar. For reasons of manageability it was limited to German and English articles published between 2004 and 2019. In a second step, the results - 13317 findings - were limited to publications that discuss video tutorials as learning material and software use. The resulting corpus comprises 67 publications. In step three, the corpus was limited to contributions to video tutorials for software in the production area or as part of training courses that give design recommendations for their production. The adjusted corpus contains 13 publications. In step four, two subcorpora from this cleaned-up corpus were formed. Subcorpus 1 comprises contributions that formulate design recommendations in the form of guidelines (n=4). Subcorpus 2 includes individual studies on the topic (n=9).

The two subcorpora were evaluated qualitatively [13] - firstly the guidelines, then case studies. The evaluation was based on the dimensions of didactic design, influence of the object, material-technical implementation and linguistic-visual design of the instruction. The determined categories within the main categories (dimensions) were transferred into a category system. Five subcategories were determined for the dimension didactic design, three subcategories were determined for the dimension influence of the object, seven subcategories were determined for the dimension material-technical implementation. The dimension linguistic-visual design of the instruction was initially divided into two categories - user guidance and instruction. Three subcategories were determined for the category user guidance. The category instruction comprises four subcategories. The design recommendations were compared in terms of similarities and differences.

IV. DESIGN RECOMMENDATIONS FOR INSTRUCTIONAL VIDEOS

A. Didactic design

All evaluated guidelines discussed didactic requirements for instructional videos [1][2][4][14]. Taken the fact that instructional videos convey knowledge about action processes, they have didactic elements per se. In the literature mainly five design aspects of didactic design are discussed: (1) relevance of types of knowledge, (2) the user's prior knowledge, (3) knowledge application, (4) self-efficacy, (5) autonomy of the learning material.

Relevance of the types of knowledge: All guidelines address the types – conceptual knowledge and procedural knowledge [1][2][4][5][14]. They emphasize their dependence on the learning content [1]: it makes a difference whether basic mathematical knowledge should be taught or whether the user should learn how to set up a tool in the tool database. In the first case, the focus is on teaching conceptual knowledge. In the second case, the learning material mainly provides procedural knowledge [1]. Software training is designed to teach the user the sequence of necessary steps (procedural knowledge). Swarts [4] emphasizes that processes are simultaneously demonstrated (procedural knowledge) and explained (conceptual knowledge). Plaisant and Shneiderman [14] call this hybrid of both types of knowledge "instructional information".

User's prior knowledge: During the learning process, new information is incorporated into existing knowledge [2]. The evaluated guidelines emphasize that learning success depends on how the user's prior knowledge is activated [1][2] and on how much prior knowledge the addressee has [2]. Van der Meij [15] recommends the use of Advanced Organizers for the activation of prior knowledge. They should show "initial and final states" [15: 1370] of the action in order to clarify the learning goals and purpose of the video. This preview of the task supports orientation and the development of a bigger picture (Guideline preview the task [1]). Users with little prior knowledge benefit from added instructional support, i.e., design solutions that additionally support the learning process such as markers. Users with a lot of prior knowledge need less instructional support, it rather hampers their learning process.

Knowledge application: Instructional videos provide knowledge for the autonomous solution of action-related tasks. The literature emphasizes the value of using practical exercises [1][2][15][16]. Practical exercises support retention (i.e., they help to anchor knowledge in long-term memory) and give the user the opportunity to check whether he can solve the problems on his own ([1] Guideline 8; hereafter referred to as "G.1-8"). The video should explain the problem and the way to solve it, which should be the starting point for practical exercises. During the application the learner should be able to consult the video again and solve the task without having to resort to other teaching materials/staff.

Self-efficacy: Two guidelines address affective aspects of learning [2][4]. An affective design "helps users engage with and feel comfortable about a message". [4: 196]. During the instruction the user should develop the feeling of being able to solve the task successfully (perceived self-efficacy) [2][4][15][16]. The user should have the feeling to be able to reach the target state by following the instructions. The instructor has to be convincing (confidence and expertise) [4] and not deviate from the previously determined solution. Important information should be repeated, the speaker should explain confidently (script, practice before recording) and confidently execute actions in in the interface.

B. Influence of the object

The evaluated literature focuses on instructions for acquiring operating knowledge for software. The target group receives the videos in order to gain knowledge for a specific "task domain" [2], e.g., to achieve better performance in university studies or in everyday working life. The object (software, operating tasks) is part of the task domain. Considered are aspects of (1) content selection, (2) content segmentation and (3) content sequencing.

Content selection: The selection of content should take the application context (task domain) into account as well as characteristics of the target group [14] in order to serve the interests of the user best. To anchor the learning content in the (professional) domain of the user has a motivating effect [2][16]. Also, content (problem, solutions, target states) should be oriented to the users' core tasks [2]. Content in instructional videos should be representations of sequences

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of actions. Only essential information relevant to the learning objective should be given [1][4]. Relevant content is always up to date. Brenner & Walter [17] emphasize the updating of content as an essential and continuous task of producers.

Content segmentation: Instructional videos should not exceed a certain duration (see 4.C.). If the content to be conveyed cannot be presented in a given time, it must be divided into segments [1][2]. Segmentation means the division of the superordinate content into smaller but self-contained tasks.

Content sequencing: The learning content in the video must be sequenced. The sequencing of the actions demonstrated should be based on the correct order in which the user has to solve the problem [1]. The object (e.g., software) usually determines which content must be learned first and what must be learned later. If a video is divided into several segments, and the sequence of those is not determined by the object, the presentation sequence should follow the simple-to-complex principle (problems that are easier to solve are presented first and more complex problems later) [2].

C. Material-technical implementation

Instructional videos are complex multimedia products that are produced with technical aids. In the literature the technical implementation is dealt with extensively. The following design aspects are addressed: (1) duration of the video, (2) coordination of image and sound, (3) user control, (4) quality of the visual recording, (5) screencapture, (6) quality of the auditory recording and (7) voice-over.

Duration of the video: The most discussed technical design aspect in the literature is the duration of the video [1][2][14][16][18][19]. Guidelines and individual studies agree that videos should be kept as short as possible (G. 7). Differences can be seen in the exact determination of length. Plaisant and Shneiderman [14] do not address the length of an entire video, but rather the length of individual segments that ideally last 15-30 seconds but should not exceed 60 seconds. The exact number of such segments needed to form an instructional video is not given. In contrast, guideline [1] specifies a maximum length of 3 minutes. Guo, Kim, and Rubin [18] find that shorter videos have a more engaging effect and suggests keeping videos shorter than 6 minutes. If a topic cannot be dealt with in a given length, it should be divided into shorter videos to not overwhelm the user with too much information.

Coordination of image and sound: Information in videos are multi-coded (visual, verbal, auditory) and must be orchestrated. The majority of the guidelines [1][4][14] consider this and recommend that the actions performed on the visual level should be presented simultaneously with the content-related information on the auditory level. The user is cognitively relieved as he/she does not have to keep out-of-date information active on one coding level while waiting for the presentation of information on another coding level [1]. Swarts [4] goes into more detail and recommends that sound should slightly precede image.

User control: User control allows the user to independently navigate through the video and to determine their learning pace individually. This should be realized by allowing the recipient to use the following functions via the video player software: starting, pausing, stopping, repeating, fast-forwarding/rewinding and (chapter) skipping [1][2][4][14][20]. Recommended interface elements are buttons and an interactive timeline. To enable the user to move through the content in a self-determined way, segmented content (sections) should be labelled and be directly selectable. Individual segments can be marked by short breaks, the insertion of black screens or title slides [1][2][4][14].

Quality of visual recordings: The quality of the visual recording is taken into account by most guidelines [1][4][14]. The visibility of the actions and objects that are manipulated is a prerequisite for users to be able to follow the processes. The literature recommends the image in the video to be as stable as possible. The resolution of the video should be at least Near HD (vertical resolution = 720P). The visibility of objects and the readability of texts must be guaranteed by using a zoom effect [1][14]. However, the zoom area should not overlay important elements [1][14].

Screencapture: Usually, video recordings are edited. Among other things, the producers decide whether or not to adapt the screen recordings. Two guidelines [1][14] take this into account. They recommend to always show the entire interface in the video without cropping the edges (G. 2). In practice, the user is guided by what he has seen in the video. Hence, it is important that the video shows what the user will see later in practice. If it differs, the user will have problems orientating.

Quality of auditory recordings: In contrast to the visual quality, the auditory quality is hardly discussed. Only [4] states that information presented in video must be of sufficiently high quality to ensure that the user can understand everything. Swarts [4: 202] speaks of "high resolution audio".

Voice-over: If there is a voice-over narration in the video, it can be performed either by a computer or a human. The explanations should be spoken by a human voice [1][4]. The learning process would be facilitated by a human voice (G. 2), as users perceive it as more natural and appealing.

D. Linguistic and verbal realization of the instruction

With regard to implementation, in the following, a distinction is made between the framing of the instruction (user guidance) and the instruction itself.

1) User guidance

The majority of the recommendations in the guidelines relate to user guidance, i.e., how the instruction is framed communicatively or how the beginning and end of the video are designed. The framing pursues different goals: (1) accessibility of the information, (2) directing attention and (3) narration.

Accessibility of information: Instructional videos must ensure the accessibility of information; relevant information must be easy to find. A distinction can be made between external (finding the video itself) and internal (in the video) accessibility. If a learner is looking for a video, he/she must be able to judge whether the video is suitable for his/her purposes based on the title (G. 1). Therefore, the title should be well chosen. With the help of a table of contents, an index or

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by using keywords the learner can assess in detail the relevance of the topics covered within a video.

At the beginning of the video, in the title sequence, the learning objective should be formulated and afterwards a short overview of the content should be given [1][4]. It is important to cover all announced contents [4]. A preview can be used as a tour through the components of the main screen [14]. However, detail should not be described in advance.

User attention: The user's attention can be directed visually and/or audibly. Especially visual signals and markers are recommended in all guidelines. Elements in the interface can be highlighted by the cursor or in editing process by e.g., circles or arrows [1][2][4][14]. Auditory signals and markers can be edited in the form of a voice-over and can indicate content or details [1][2][4][14].

Narration: Narration is the reproduction of an event in oral or written form. Instructional videos for software can be understood as screen capture with narration [1]. It is important that all communicative modes (video, audio and text) are well coordinated [1, 4]. The spoken narration should be a human voice (G. 2). The language should be personal [1][2][18] and functional (G. 4). The ideal speaking rate is a bit lower and should be supported by natural pauses in speech. The speaking rate should follow the shown action sequences [1][2][18].

2) Instruction

The presentation of the instruction itself requires design decisions on different levels: sequencing, wording, visual, auditory.

Sequencing the instruction content: The sequencing of the instruction and sub-actions follows the sequence of actions that must be performed to get from the (superior) initial state to the (superior) target state [1]. The process from the superordinate beginning to the superordinate goal should be divided into manageable, meaningful sequences. Those sequences should also have a clear beginning, a clear middle section, a clear end and should comprise three to five subactions. This is described as a three-part division [1]: (1) the starting state or the problem to be solved, (2) the solution path, and (3) the target state (see similarly [9][11]).

Wording: The Guidelines recommend few aspects concerning the wording in instructions. The vocabulary should be adapted to the user group [1]. Technical terms and foreign words should be defined and explained; abbreviations should be avoided [14]. They should be explained in a tour through the user interface. Technical vocabulary should be explained during the demonstration and in context, according to the just-in-time principle (G. 4) [1]. The narrator should address the learner directly and use the personal pronoun *you* to emphasize that the objectives of the video are relevant to the learner [1]. Plaisant and Shneiderman [14] apply the criteria of simplicity, directness and precision to language. Active language should be used and sentences kept short and simple. The imperative is best suited to describe the visual demonstration [1].

Visual parts: The visualization of the instruction should represent the entire interface that the user sees in front of him when he performs the task himself (G. 2). High resolution and stable images should ensure that all relevant information is clearly visible at all times [1][4]. If good visibility or legibility cannot be guaranteed a zoom effect can be used. Otherwise the complete interface should always be visible. The pace of the demonstration has to follow the pace of action in the real performance but also has to consider the pace of the learner [1][2][4]. Actions in the video must be executed fluidly and correctly [4]. Consequences of user actions has to be made clear [1][4][14]. The cursor should be highlighted with an animated circle that changes color depending on the performed action (right or left click) [14].

Auditory parts: All guidelines mention the high relevance of auditory parts for the reception of the instruction [1][2][4][14]. The spoken description should begin shortly before the visual demonstration, so that users can make a mental model of the actions to come [4]. During the visual demonstration, the spoken explanation should firstly describe what is being shown. On the other hand, it should give reasons for what is shown, explain why something is done [1][4][14]. It should contextualize the actions, place them in a higher level of action. The speaker should use the interface at the same time to ensure synchronicity of the auditory and visual parts [14]. In addition to the spoken instruction, other auditory components such as sound effects play a subordinate role. Sound effects should be used e.g., to highlight mouse clicks or scrolling audibly [14].

V. DISCUSSION

Communicative usability and the guidelines see the embedding in and dependence of the communicative instructional video on superordinate contexts of action that are shaped by the domain. The embedding in professional contexts and the pragmatic motivation of the guidelines are particularly evident in the focus on learning purpose-related knowledge about action sequences and the recommendation to apply this knowledge in practice. The recommendations show that the scope for designing instructional videos is primarily influenced by external parameters.

In contrast to the communicative usability approach [6], the guidelines, do not measure quality by how linguistic-visual means support the user in fulfilling higher-level interests of action, but rather by how the didactic design and the material-technical implementation relieve the user cognitively and make the learning process effective [1].

The focus in the recommendations is primarily on "technical guidelines" [14], which are intended to provide users with easy technical access to the learning content. In this respect, there is a consensus on the technical and media requirements that instructional videos must meet in order to effectively support the learning process. Details regarding the exact duration of a video differ.

Regarding the linguistic-visual implementation of the instruction, recommendations for user guidance include considerably more aspects than recommendations for instructing as a linguistic action. Although there is an awareness that the beginning and closing of the video is crucial for learning success, linguistic-visual aspects are only addressed superficially. The guidelines mainly discuss material-technical conditions as factors influencing the design of the instruction.

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In contrast to individual studies, the guidelines have a greater claim to general validity; they address software training in general - not for specific products. The applicability of the guidelines should always be checked in the context of the interface to be presented and the target group [14].

The guidelines focus on conveying best practice recommendations. In industry, however, a failure-oriented approach is also used to convey how action should not be taken. This is, e.g., also part of warning. This approach is not found in the literature and there is no research that contrasts both approaches. Warnings play a subordinate role in the guidelines, although it is legally relevant [9]. Only [4] mentions that warnings should be issued at the beginning.

VI. CONCLUSION

Research on the production of instructional videos for professional purposes and design solutions includes best practice as well as research-based approaches. There are already "key notions of accepted thinking" [1] that provide guidance for the production and evaluation of well-designed, efficient software instructional videos.

Design requirements for instructional videos for software training are characterized by three main factors: Didactic purposes, influence of the object and technical-material conditions. The literature primarily addresses questions of didactic design and/or technical-material implementation. The communicative usability of instructional videos, i.e., the extent to which the linguistic-visual design supports the learner in the appropriation of content has rarely been addressed.

This article provides an overview of design dimensions as well as aspects and corresponding recommendations discussed in the literature. It aims to sensitize producers of instructional videos for CAD/CAM software training for established design requirements. In the research project WerkerLab, the results of this contribution will be presented to practitioners (workers and trainers) in order to evaluate the relevance of the identified recommendations from a practical point of view and, if necessary, to add new aspects. Preliminary results of interviews with practitioners already suggest that context factors such as video production costs are more relevant for practitioners than described in the literature.

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