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Technologies for improving laboratory learning in healthcare professions: the case of instructional video

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Abstract

Audiovisual cognitive artifacts in all their forms are increasingly used in flipped, blended, MOOCs and conventional teaching and learning processes. During the health emergency due to the SARS-CoV2 pandemic, they were in many cases, in schools and universities, the only response to the need to follow up on training processes, which were compulsorily remote, becoming the educational media *par excellence*. This work concerns the use of educational technologies, specifically two audiovisual didactic texts, carried out in compliance with international multimedia design standards, to support conventional face-to-face didactic activities, in the field of professional health training (Laboratory for the simulation of radio-pharmacy activities, at the University of Ferrara, Italy). It is functional research to verify, on the one hand, the reinforcement of declarative knowledge (through a questionnaire administered in person immediately after the videos had been viewed) and, on the other hand, the perception of the effectiveness of the educational resources used (through a questionnaire administered online one week after the video had been viewed) for the reinforcement of procedural knowledge. All the instruments were administered to the entire group of students attending the degree course for medical radiographers (21 subjects), divided into two groups: the first group consisting of 11 subjects who still had to carry out the practical internship period; the second group consisting of 10 subjects who had already completed the internship. The final objective is twofold: (1) to contribute to the research area of video-based learning aimed at experimentally verifying the design principles underlying multimedia learning; (2) to verify the application of this methodology within laboratory teaching of medical degree courses and the health professions in order to meet educational needs in terms of improving the learning processes of complex manual procedures.

KEYWORDS: Instructional Video, Video and Medicine, Subjective Shot, Multimedia Learning.

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1. Introduction

The work is part of the strand of international research according to which the use of educational videos that comply with instructional design standards can contribute to learning. There is much evidence today that shows how these texts can have a significant impact on learning, provided that they are carried out in accordance with precise theoretical paradigms (Sweller et al., 1998; 2019; Clark & Lyons, 2010; Mayer, 2009) and accompanied by the overall planning of the training intervention (Laurillard, 2012; Rivoltella, 2021). In particular, the audiovisual text defined as an "educational video" seems to be useful for experiential, laboratory teaching aimed at learning procedural knowledge. In practice, the outcome of the viewing can have a significant impact on the student's ability to solve problems or to carry out an orderly set of operations - professional skills and abilities - to be performed to achieve a particular purpose.

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The scope of the application is that of the health professions. Laboratory activities, especially in professional health-care courses, aim to provide practical skills. In our specific case, the *medical radiology health technician* must be able to carry out interventions that require the use of sources of ionizing radiation, both artificial and natural, of thermal, ultrasonic and magnetic resonance energies as well as interventions for physical or dosimetric protectionism. In this sense, the main objective of the teaching module called "Laboratory for the simulation of radio-pharmacy activities", in which the survey was carried out, is to integrate theoretical knowledge and practical knowledge, thus promoting the development of skills and abilities in students.

In view of the above, a training activity based on the use of the educational video was developed, designed and produced according to recommendations of multimedia design referring to a series of now classic studies on cognitive theories of multimedia and integrated learning from the latest scientific evidence in the area of video-based learning. The first ones argue and show how multimedia learning depends on optimizing the information presented in relation to the functioning mechanisms of students' mental and cognitive processes (Sweller, 1998; Sweller et al., 1998; 2019; Clark & Lyons, 2010; Mayer, 2009, 2014; Clark & Mayer, 2016). This means that mental effort must be pushed toward an active reasoning process based on the operations of selecting relevant incoming information, organizing it in coherent mental representations, and then integrating it with the mental representations already possessed. In relation to this field of research there are various international studies (Ibrahim et al., 2012; Brame, 2016; Clark & Mayer, 2016) according to which the enhancement of the educational content through video or multimedia presentations improves learning processes, as long as they are made with the intention of reducing the extraneous cognitive load, increasing the relevant one, and managing the intrinsic one.

In addition to this, a new research area appears particularly promising in the field of the design of the didactic video relating to the complementary use of the double point of view of the camera, objective or third person, subjective or first person. Such use would lead to an increase in the activation of the neural system (Mirror neuron theory) and positive effects on the learning processes: greater involvement and improvement of the processes of storing and subsequently retrieving information (Garland & Sanchez, 2013; Jannin et al., 2017); greater effectiveness in remembering and putting into practice processes observed in subjective terms thanks to psychological self-reference factors (Bugaiska et al., 2015) and incarnation/personification (embodiment theory) according to which one learns with the body as well as with the mind (Robbins & Aydele, 2009). The subjective point of view creates a state of self-reference (the student refers what he/she sees to him/herself) and of identification in what is being observed and therefore a higher propensity to deep learning. This plausible simulation of the media learning experience makes it easier to implement the observed procedure (transfer).

The scientific objective of our work is to highlight how visual artifacts, when resulting from the conjugation between didactic theories and design theories, can increase the effectiveness of teaching actions, facilitate the acquisition of practical-experiential knowledge and make students more aware of their learning processes.

2. Materials and methods

2.1 Research settings

The research is the result of a multidisciplinary collaboration. In fact, the work group consists of teachers from different areas – pedagogists with experience in technologies and disciplinary experts of the degree course considered – united by the awareness that in formal teaching-learning contexts it is necessary to find meaningful educational solutions, that is, such as to contemplate the dimensions of effectiveness, of project research and of critical reflection on what is being done during and at the end of the course. Thus, a training unit was designed focusing on the educational video as a tool. In fact, many studies indicate that audiovisual texts can improve learning when they reproduce the task to be carried out and especially when the task requires the acquisition of motor procedures (Arguel & Jamet, 2009). In our case it was a question of showing the activity that is carried out in the radio-pharmacy of a nuclear medicine, that is, the preparation of radio-pharmaceuticals of *Technetium-99m* (obtained by means of kits available in freeze-dried formulations) and the relative quality control.

The training unit was then the subject of a qualitative-hermeneutical survey aimed at detecting the point of view of students regarding the effectiveness and usefulness of the "educational video" tool.

2.2 Research steps

The research was divided into a series of steps. First of all, the creation of two videos on technical issues related to the production of Technetium radio-pharmaceuticals, which represent the most widely used radio-pharmaceuticals for single-photon nuclear medical diagnostics. Specifically, the first, *Elution of the* $^{99}Mo/^{99m}$ *Tc generator* (duration: 6'52"), with the aim of illustrating the process which starts from the acceptance of a portable Tc-99m generator to its elution, the second, ^{99m}*Tc-HDP: Production and control of radio-pharmaceutical quality* (duration: 11'20"), with the aim of illustrating the steps necessary for the production and

quality control of Technetium radio-pharmaceuticals obtained "by a kit".

The videos were produced by the multimedia laboratory of the University of Ferrara, as mentioned, in compliance with the international recommendation on the principles underlying multimedia learning, now recognized as valid by the scientific community in terms of structure (modular and indication of precise objectives for a single step), duration (short), presence/absence of the teacher (in relation to cognitive load), complementary use of visual and sound messages, attention towards the technical aspects to guarantee good audio and video quality (Brame, 2016; Clark & Mayer, 2016; Mayer, 2014). In addition to the use of these principles, the design of the two artifacts provided for an important use in quantitative terms of a mode of communication that is proving its effectiveness in learning procedural knowledge typical of the health education considered: use of perspective in subjective or first person, according to the mirror neuron theory, and considering the psychological factors of self-reference (Bugaiska et al., 2015) and of incarnation (Embodiment Theory) according to which learning takes place through the body as well as the mind (Robbins & Aydele, 2009).

Questionnaires

Two questionnaires were then prepared, the first (questionnaire A), composed of 16 multiple-response items, to check that the contents of the videos were understood and stored (declarative knowledge), the second (questionnaire B), composed of Likert scale, Yes/No, multiple-choice and open-ended questions, to record the perception of students in relation to the effectiveness and usefulness of the two educational videos. Questionnaire B, in particular, was structured in 4 sections related to the following dimensions:

1. the impact that the two videos had in terms of clarity of the message, duration, degree of involvement, perceived difficulties due to the speed of presentation of the educational message, the structure of the video;
2. the usefulness of the pre-internship video to systematize/reinforce the theoretical knowledge acquired during the teaching part, to better deal with the practical work in the hot lab, to identify the fundamental steps on which to focus in the laboratory activity;
3. usefulness of the post-internship video to systematize/reinforce the theoretical knowledge acquired during the teaching part, to mentally retrace the steps and procedures of the activity of radio-pharmaceutical training and to consolidate what was learned during the training;
4. personal views on the role of the video in terms of remembering/memorizing the illustrated steps/procedures, communicative and didactic aspects (duration, how to access the resource, preferences on the presence/absence of the teacher in the video, presence of a soundtrack).

Once the two questionnaires had been drawn up, they were subjected to screening (pre-test) by experts on the subject and to a group of subjects with characteristics similar to those of our survey. This made it possible to refine and reformulate some of the questions, in fact improving them.

It was then administered to the whole group of students (21 subjects) split into two groups:

1. the first group (group 1), composed of 11 subjects who still had to carry out the period of practical professional training, at the Radio-pharmacy facility of the Nuclear Medicine Service of the Ferrara University Hospital Trust;
2. the second group (group 2) composed of ten subjects who had already performed the internship.

This choice was dictated by reasons related to the pandemic. For safety reasons, the internship was to be carried out during specific weeks established by the University and this resulted in a substantial misalignment in terms of "time" between the participants, who could not all be present at the same time in the classroom at the time of projecting the video. It should be noted that in preparing "Questionnaire B", the research group took this data into account by providing different sections for the two groups.

Data collection

The data collection included the administration of the two videos on 30 March 2021 to group 1, which had already completed the period of practical professional training and on 6 April to group 2, which had not yet completed the period of practical professional training. However, one of the subjects in group 2 did not attend due to being in isolation.

The projection took place, for both groups, inside a classroom; the viewing was preceded by a brief introduction, by the teacher whose laboratory was being used, in order to specify in detail the educational objective of the two audiovisual texts. At the same time the subjects were informed that after the viewing a test would be administered on the contents conveyed by the videos themselves. The single video was viewed twice in a row, with a short pause between each time. The break was used for the teacher to answer the questions asked by the group.

After the second viewing, questionnaire A was administered on the educational content, while questionnaire B was administered online one week after the video had been viewed (group 1 from 7 to 22 April; group 2 from 13 to 28 April).

3. Results

3.1 Questionnaire A on declarative knowledge

Group 1 and 2

The knowledge acquired in relation to the predefined training objective was evaluated through questionnaire A. The evaluation criteria are as follows: correct answer: 2 points; wrong answer: 0 points; no answer: 0 points.

The performance of all the students (21 subjects) was more than satisfactory. However, it should be noted that there was no significant difference between the two groups. The critical analysis of the results referring to questionnaire A, which does not show any great differences between the two groups, and the comparison with the students in the classroom immediately after completion, highlighted the limit of the verification tool used due to the teacher's lack of familiarity with this new type of training tool delivered.

3.2 Questionnaire B on the usefulness of the video artifact

Below are the results of the questionnaire divided into groups: pre- and post-internship.

Group 1 pre-internship

The results of the first part of the questionnaire are very encouraging and, although referring for a small group, confirm the quality of the educational choice made. In question No. 1, which asked students to evaluate the clarity of the two messages conveyed by the videos for learning purposes, 7 subjects indicated the maximum value of the scale (5 gradient scale), 3 the value of 4, only one subject indicated the neutral value of 3.

For all subjects the length of the films (question 2) was appropriate and none of them had any difficulty in following them (as mentioned, the duration of the two instruments was respectively 6'52" and 11'20").

High results also emerged with respect to the degree of involvement: Two subjects felt “very involved” in the films, eight “involved”, while only one subject declared indifference/neutrality to this emotional-cognitive aspect.

Ten members of the group were then able to identify with the figure of the operator, one instead only at times; likewise, ten imagined themselves carrying out the actions described and narrated by the videos, while one did not.

The results of the second part of the questionnaire are also encouraging: the usefulness of the videos, both for tackling the internship and to support the preparation for the laboratory activities, was acknowledged by the majority of the group. Specifically, in order to systematize the knowledge, five subjects considered the educational video tool to be “very useful”, five “useful” and one subject “fairly useful”.

An identical configuration of responses was obtained regarding the perception of the effectiveness of the video in offering the possibility to discriminate between the fundamental steps of the activities represented, thus allowing a greater focus to be made on them at the time of the internship.

The data in part three of the questionnaire appear to be entirely consistent with the above. The whole group considered the video to be effective before the internship and also during it.

As far as the request for suggestions is concerned, in general, the subjects did not express themselves much, however, the few data obtained are interesting: two subjects proposed liberalizing access, on a dedicated channel or institutional platform, to the two artifacts, so that they can be seen, according to requirements, during the course of the internship; one subject, in expressing his appreciation for the educational initiative, suggested considering future video productions contemplating greater intervention (talking head) of the teachers of the course in addition to an “engaging narrative voice”.

Group 2 post-internship

From a preliminary analysis, the results of the subjects who viewed the videos after carrying out the internship seem to be in line with those of their colleagues in group 1 (pre-internship).

In question 1, on the evaluation of the clarity of the two messages conveyed by the video texts, the results were very high: Three subjects indicated the maximum value on the scale, five the value of 4, and one the value of 3.

All the subjects considered the duration of the two videos appropriate in relation to their understanding of the content transmitted by them (question 2).

The degree of involvement by the group of post-internship students also highlighted very high results: Two subjects reported the maximum value and six reported the value of 4, only one student assigned a low average score of 2.

Eight students were able to identify themselves in the figure of the operator and 1 “at times”; eight members of the group imagined themselves performing the actions described by the two video texts, only 1 did not feel this sensation. In particular, five recognized themselves in the production of radio-pharmaceuticals by a kit, three in the quality control of radio-pharmaceuticals by a kit, one did not respond.

Only one out of nine subjects had some difficulty in following the procedural information transmitted through the two videos.

The results of the second part of the questionnaire appear to be the same as in Group 1: the usefulness of the videos, in order to deal with the internship activity, and to support preparation for the laboratory activities,

was recognized by the majority of the group. Regarding the usefulness of the video to systematize and strengthen the theoretical knowledge acquired during the teaching part, three subjects considered the educational videos "very useful" (5 on the Likert scale), four subjects considered them "useful" (4 on the Likert scale), two expressed an average judgement (3 points on the Likert scale).

The educational video tool also appeared to be useful for mentally revising the steps and procedures of the practical training in a hot lab: on the Likert scale at 5 levels (not at all 1, very 5) three students responded "very", four gave a score of 4, therefore very high, two gave an average score of 3.

The two videos were also very useful for consolidating the actions and the specific procedures seen during the internship: on the 5-level Likert scale (not at all 1, very 5), five subjects responded "very", 2 gave a score of 4, and two subjects an average score, equal to 3.

For group 2, the data in part 3 of the questionnaire also appear to be entirely consistent with the above. Almost all subjects believe that it is more effective for learning to view the films before the internship (seven students), only two during the internship, and none after.

The most remembered video passages appear to be the Tc-99m elution process by three subjects, and the quality control by another three subjects. The comment of one of the three subjects with reference to the Tc-99m elution process is particularly interesting: "The video allows you to see an otherwise invisible step when attending the laboratory in a hot lab".

As regards the request for suggestions, the main indication points towards the use of the two free mode educational video resources, to promote customization and self-learning.

4. Discussion

The results in terms of reinforcing declarative knowledge and usefulness with respect to procedural knowledge, by our sample, confirms that compliance with the standards identified by international research in terms of the design of educational audiovisual texts results in positive outcomes on learning.

While working with a small group of students (21), the results reinforce our idea of an "educational video," reinforcing the choices made in terms of the strategy used to promote skills and abilities. They provide a clear indication of the need to transform/revitalize the teaching paradigm, based on verbal and written language, into a learning paradigm, integrated by the use of new digital languages and focusing on the student, in line with indications from international research.

As we have seen, the involvement generated by the two video artifacts was high, and this, in addition to being consistent with the affirmation of numerous researchers who indicate the audiovisual resource as the preferred resource by university students (Carmichael et al., 2018; Ramlogan et al., 2014; Mitra et al., 2010), indicates how useful it is for learning to have tools that can keep attention active, while avoiding the perception of excessive cognitive cost. The degree of involvement, which appeared to be "very high" for more than 80% of the subjects involved, also shows how the video texts used to support experiential, laboratory type didactics, particularly for the learning of procedural knowledge, determine greater participation in problem-based learning processes (Rasi & Poikela, 2016) thanks to the possibilities to learn by seeing experts work in the field as well as by following the procedures and operations in detail (Ramlogan et al., 2014; Cooper & Higgins, 2015). According to one approach, supported by audiovisual communication, it can reduce the cognitive load necessary in the attempt to mentally recall real situations or to perform a "mental animation"process in order to give concrete meaning to the processes, especially in STEM subjects (Castro-Alonso et al., 2018).

100% of our subjects considered the video duration appropriate to the content transmitted, confirming what is already recognized by international research, that is, the greater functionality of short videos compared to longer ones (Carmichael et al., 2018; Pi & Hong, 2016). A "short" length – in the order of 10-15 minutes – is in fact more engaging (Doolittle et al., 2015; Guo et al., 2014), results in lower rates of abandonment of online courses, for example, (Vitiello et al., 2018, in Wang et al., 2020), and encourages the desire to use video educational resources for future learning (Giannakos et al., 2016). Data on the analysis of millions of video sessions within MOOCs on mathematics and other scientific subjects showed a maximum average involvement time of 6 minutes, regardless of the length of the video (Guo et al., 2014). Other research shows that very long videos result in mental wandering effects (low concentration) linked to difficulties in retaining the information received (Risko et al., 2012). In the enjoyment of the videos administered to our two groups we found no difference in perception, in terms of differentiated involvement according to the different duration of the artifacts, 6' and 52" the first, 11' and 20" the second. This leads us to two considerations. *(1)* The student's attention is not an easily standardized parameter but may depend on different factors, internal to the video (design factors) and external (overall design of the training intervention or the teaching unit). In our case the use of the resource in the classroom, in the presence of the teacher, may have had a beneficial effect despite the longer duration of the second video. *(2)* A duration exceeding the identified attention threshold can be better managed through the application of the principles of segmentation (Mayer, 2009) and modularity; in fact, this prevents overloading the working memory and has a beneficial effect on the

involvement, attention and motivation of the students (Ljubojevic et al. 2014, in Altinpulluck et al., 2020).

A cognitive process without sustained attention that facilitates the selection of incoming perceptive information and limits the amount of external stimuli, makes it more difficult to achieve effective learning.

The video is an effective resource in terms of learning manual procedures by virtue of the use of the multiple point of view of the functional camera to "see better", the phenomena of magnification or underlining, and the simplification and organization of the observed events. Many complex procedures do not take place from a single point of view, but require changes in space and changes in focus on the areas where manual intervention takes place. We like to recall that the ability to learn procedural movements from observation is due to the effectiveness of our mirror neuron system and a relative neurophysiological circuit that is activated when someone is performing an action, but also observing another person performing the same action as the other (Pelligrino et al., 1992; Rizzolatti & Craighero, 2004; Rizzolatti & Sinigaglia, 2008). This learning mechanism, which is functional not only to imitation but also to memory and understanding, points towards the use of video in high-risk vocational training, such as that in the medical field (Boucheix et al., 2018).

Alongside the mirror neuron theory, the studies on viewing manual procedures according to a dynamic and subjective perspective should be mentioned (Jannin et al., 2017; Garland & Sanchez, 2013; De Koning & Tabbers, 2011). In these cases psychological factors, called self-reference factors, can play an important role in promoting the memory of the observed processes (Bugaiska et al., 2015). Not only that, according to the theory of incarnation-personification (embodiment theory), it is believed that people can learn with their body as well as with their mind (Robbins & Aydele, 2009): the first-person perspective creates a state of self-reference (what observers see refers to themselves) that establishes a stronger link between those who observe and what they observe, thereby increasing the propensity towards deep learning.

In our case, this phenomenon was experienced by 82% of the subjects, 14 % sometimes felt this sensation, less than 5% did not experience any sense of identification.

It can therefore be inferred that the learning of manual procedures is essentially based on alternation between "watching the instructor" and "putting what has been observed into practice." The alternation of the two points of view, objective and subjective, and the simplification-organization of the observed events determine a plausible simulation of the media learning experience which more easily determines the learning (in terms of transfer) of complex manual procedures.

The responses of the subjects in reporting the ability to imagine themselves performing the operations described in the video, confirm, on the one hand, the effectiveness of the mechanism described above and, on the other, the success of the design choices we made during the design of the instruments: more than 90% experienced the feeling of imagination compared to the personal performance of the actions/procedures described in the videos.

The video passages most remembered by the students were the Tc-99m elution process and quality control. It is also interesting to note the comment made by a subject in reference to the Tc-99m elution process: "the video shows a step that would otherwise be impossible to see even by being present during the process in a hot lab". These words emphasize how video images can be fundamental for knowledge of what is really difficult to see in physical reality.

5. Conclusions

In conclusion, the survey revealed how audiovisual texts can have a significant impact on learning provided they are carried out in accordance with precise communicative-educational paradigms.

The data obtained, although referring to a small group, confirm that the use of the first-person perspective in educational videos that are functional to learning skills and procedural knowledge is of extreme interest in the health professions (Thomson et al., 2017; Fukuta & Morgan, 2018). Moreover, the results indicate possible routes to be followed to bring educational innovation into teaching interventions that have their own figure in the laboratory activity.

For this reason, we believe that the improvement and application of this communicative-educational methodology within laboratory teaching in the medical and health field can respond to qualitative needs (improving the learning processes of complex manual procedures) and logistical needs (the number of students in the medical/health area has risen considerably in many Italian universities, making it difficult for them to attend practical and laboratory activities). We also believe that all university education can benefit from the contribution of digital educational resources to address the challenges of the post-pandemic era.

Note

The entire research project was shared by the authors. However, it is specified that: Licia Uccelli is the author of the Abstract and of paragraph 2.1; Lara Salani of paragraph 3.1; Giovanni Ganino of paragraphs 1 and 5; Loredana La Vecchia of paragraphs 2.2, 3.2, 4.

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