



**HAL**  
open science

## Videos for embryology teaching, power and weakness of an innovative tool

I. Koscinski, K. El Alaoui-Lasmali, P. Di Patrizio, C. Kohler

### ► To cite this version:

I. Koscinski, K. El Alaoui-Lasmali, P. Di Patrizio, C. Kohler. Videos for embryology teaching, power and weakness of an innovative tool. *Morphologie*, 2019, 103, 10.1016/j.morpho.2019.04.001 . hal-02139996

**HAL Id: hal-02139996**

**<https://hal.univ-lorraine.fr/hal-02139996>**

Submitted on 25 Oct 2021

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial 4.0 International License

**Videos for embryology teaching, power and weakness of an innovative tool**  
**La vidéo dans l'enseignement de l'embryologie, forces et faiblesses d'un outil innovant**

*Authors:*

I. Koscinski<sup>1</sup>, K. El Alaoui-Lasmali<sup>2</sup>, P. Di Patrizio<sup>3</sup>, C. Kohler<sup>1</sup>

Isabelle Koscinski and Karima El Alaoui-Lasmali contributed equally to this work and should be considered as co-authors.

*Affiliations:*

<sup>1</sup>Université de Lorraine, Département d'histologie-embryologie, Faculté de Médecine. 9 avenue de la forêt de Haye, F-54505 Vandœuvre-lès-Nancy, France.

<sup>2</sup>Université de Lorraine, Faculté de Pharmacie, Campus Brabois-Santé, 9 avenue de la forêt de Haye, F-54505 Vandœuvre-lès-Nancy, France

<sup>3</sup>Université de Lorraine, Département de Pédagogie Médicale. Faculté de Médecine. 9 avenue de la forêt de Haye, F-54505 Vandœuvre-lès-Nancy, France

*Corresponding author:*

Isabelle Koscinski<sup>1</sup>

<sup>1</sup>Université de Lorraine, Département d'histologie-embryologie, Faculté de Médecine. 9 avenue de la forêt de Haye, F-54505 Vandœuvre-lès-Nancy, France

Phone number: +33(0)3 72 74 61 35

isabelle.koscinski@univ-lorraine.fr

## **Abstract**

**Background and aim:** Difficulties are encountered in embryology learning such as imagining embryo modifications in three-dimensions and time. We provided an experimentation to evaluate if short videos during magisterial lecture could increase the quality and the efficiency of embryology teaching.

**Methods:** The study was conducted amongst students in first year of medical studies in France. It is an intense and highly competitive year at the end of which students can engage in medical or paramedical specialties depending on their rank. In a first step, pre-implantation embryo development and microscopic videos of *In Vitro* Fertilization were presented during a course of medical ethics. Three months later, students gave their opinion on this presentation in a satisfaction survey using a Likert scale. In a second step (the two following years), similar videos were integrated in the regular embryology lectures and the results of the subsequent embryology test were analyzed.

**Results:** In the first step, students declared that movies could increase their interest in Embryology and significantly help to the comprehension and memorization of embryologic processes. In the second step, we found that students answered better to the video-related questions of the test even if globally in the first year, results were weaker compared to previous years.

**Discussion:** The effects of movies in pedagogy are discussed, especially the accelerated rhythm imposed by this medium. Adverse consequences could be balanced by traditional drawing.

**Conclusions:** The association of complementary pedagogic methods like movies and drawing could allow an optimization of embryo teaching.

**Keywords:** *Embryology, Pedagogy, Video, Basic Science Education*

## **Résumé**

**Objectif :** La rapidité des modifications structurales embryonnaires dans les trois dimensions et dans le temps rend difficile l'apprentissage de l'embryologie. Nous avons évalué si de courtes vidéos permettaient d'améliorer la qualité et l'efficacité d'enseignement en embryologie.

**Méthodes :** L'étude a été menée parmi les étudiants de première année d'études médicales en France. A la fin de cette année intense et très compétitive, les étudiants peuvent s'engager dans un cursus médical ou paramédical en fonction de leur classement au concours. Dans un premier temps, des vidéos de fécondation *in vitro* ainsi que du développement embryonnaire préimplantatoire ont été présentées durant un cours magistral d'éthique médicale. Trois mois plus tard, l'avis des étudiants a été recueilli via un questionnaire de satisfaction dont le degré était évalué sur une échelle de Likert. Dans une seconde étape (les deux années suivantes), des vidéos similaires ont été intégrées dans le cours magistral d'embryologie et les résultats à l'examen subséquent ont été analysés.

**Résultats :** D'après l'enquête de satisfaction, les vidéos augmentent l'intérêt des étudiants pour l'embryologie et pourraient constituer une aide significative à la compréhension et à la mémorisation. Dans la deuxième étape, le taux de réponses justes aux questions basées sur des vidéos a été plus élevé que pour les autres questions, même si lors de la première année, le

taux global de réponses justes était inférieur aux années antérieures, résultat pouvant être lié au changement d'enseignant ayant rédigé les questions.

**Discussion :** Les avantages et inconvénients de vidéo en pédagogie sont discutés. Le rythme accéléré des informations délivrées pourrait être contrebalancé par le recours au dessin traditionnel.

**Conclusions :** L'association de méthodes pédagogiques complémentaires telles que la vidéo et le dessin pourrait améliorer l'enseignement de l'embryologie.

**Mots-clés :** *Embryologie, Pédagogie, Vidéos, Études Biologiques et Médicales*

## Introduction

In the embryology domain, the end of the nineteenth century and the beginning of the twentieth century has been the greatest period of embryology collections with the establishment of the Department of Embryology in Baltimore by the Carnegie Institution of Washington in 1913. This collection is certainly one of the largest gatherings of early human developmental material ever leading to the establishment of Carnegie stages of human embryo development. This chronological representation of a human embryo illustrates with a discontinuous manner the modifications of a human embryo, as it can be observed with a microscope. The difficulty to represent in three dimensions the growing human embryo naturally led to the big project of the Embryology Department of the Carnegie institution with image capture and archiving, image digitization and finally embryo reconstruction [1]. The online website called “The Multi-Dimensional Human Embryo” [2] offers a very good illustration of the possible reconstructions optimizing human embryology teaching [3].

It can help a lot of students since for most of them imagining modifications of a complex object evolving in time and in three dimensions is not easy. One of the difficulties is the integration of the microscopic scale of the described structures as well as the size difference of two microscopic structures developing at the same time [4]. Finally, the relative speed of development of different parts of the embryo is probably the most important difficulty to understand in embryo- and organogenesis. In addition, nowadays students devote less and less time to learning embryology since they concentrate on molecular biology [5,6] and humanistic disciplines, with the result that young senior practitioners present serious shortcomings in embryology knowledge.

Microscopy and picture recording progresses allowed the production of the first microscopic film of *in vitro* cell culture. At the same time, the development of cell culture systems allowed the real-time observation of the process of development of the embryo almost continuously at pre-implantation stage. Such time lapse systems are now regularly used to answer to clinical embryologic questions (for example, see supplementary videos of Liu *et al.*, 2014 [7]).

To optimize embryology teaching, we wanted to see if students engaged in health studies presented with short videos of an embryology process would be more motivated and if it would help them understand and learn embryology more easily and more efficiently. We evaluated this throughout the years of 2017 and 2018 in two steps. In the first step, a video about embryo development was presented during an ethical course in February 2017 and students were asked to answer a survey with a Likert scale. In the second step, the embryology development was taught within a discipline comprising cellular biology and histology in November 2017 and the next year in November 2018. We evaluated how well the students answered the questions of the test that concerned topics illustrated or not with videos.

## Methods

In France, students who want to engage in health studies (including medical, pharmaceutical, dental and paramedical studies) spend a year of intense preparation before taking a competitive exam that is decisive for their acceptance in any of the health faculties proposed. In this University in the north of France, more than 2000 students start the year but only 1500 remain and continue in the second semester and only approximately 1000 of them go through the second year.

*First step:* In February 2017, during a magisterial course focused on medical ethics, three short videos of less than 2 minutes were presented, illustrating pre-implantation embryo development (time-lapse recording) as well as classical and assisted by ICSI *in vitro* fertilization performing (supplementary data movie 1 and movie 2). Three months later, students were asked to answer to a short satisfaction survey (document 1 of supplementary data) using a Likert scale (ranging from 1 (strongly disagree) to 4 (strongly agree)). The survey explored how the use of videos had an impact on the interest, comprehension and memorization as well as on their interest for the discipline. The analysis of the results took into account if the students were repeating the year or not.

*Second step:* in November 2017 and November 2018, videos were integrated into embryology lectures. The questions of the subsequent embryology exam were not restricted to the content of the videos but were relative to the whole course of embryology. The objective was to test if students' motivation to learn embryology had been really increased by the use of videos presented during regular embryology magisterial lectures. The results of the test were compared to those obtained in the last five years for embryology (questions in supplementary data).

*Statistical analysis:* Results have been analyzed according with the status of the students: repeater or not. For comparison between both groups (repeaters or not), Chi-square and student's tests have been used. A difference was estimated as significant if the p value was less than 0.05.

## **Results**

In this curriculum, because of the high number of the students, all the magisterial courses are recorded, and the students are either assigned to the main amphitheater with the teacher or assigned to another amphitheater where the course is retransmitted live (Example in Supplementary data, movie 3). They also have unlimited access to the video of the course.

The results of the first step of the study are presented in Figure 1. 190 out of 1500 students answered the survey, including 59 students who repeated the year and mostly followed the course from home (A significantly greater proportion of repeaters assisted to the course from home ( $p=0.03$ )). Most of students (90.6%) think that the use of videos could at least certainly help to the comprehension of embryology with repeaters. Being the more optimistic, 72.9% of them answering that it would enormously help them (Figure 1, A).

Regarding the memorization of embryo development, 78.4% of all students considered that the video offers a certain or enormous help, with no significant difference between repeaters and other students (Figure 1, B). Similar response rates were found when students were asked how much the videos would increase their interest in embryology (Figure 1, C).

The question about the time devoted to the study of embryology lead to a gaussian-like response with the majority of students answering in the middle of the scale (2-perhaps and 3-certainly) (Figure 1, D). When asked if showing short videos of embryology processes could increase the interest of the students to spend more time for learning embryology, 82.7% of the students are very optimistic with 37.4% and 45.3% answering it would certainly and enormously influence them, respectively (Figure 1, E).

A question only asked to the repeaters showed that 76% of them agreed that this year's course was more comprehensible compared to that of the year before, based on the video content. Finally, for the future, students were in favor of video presentation during both magisterial (93%) and practical courses (85%).

Regarding the second step of the study, Figure 2 shows that when the teacher is new, the rate of success to the embryology questions is low the first year and then augments.

Considering only the embryology questions, the questions relative to a video-content presented during the magisterial courses (Q-Video) obtained the best scores with a mean rate of success of 30% (Figure 3). The questions not related to a video content have a rate of success of approximatively 9%. The number of questions in the two groups being disproportionate, we did not provide a statistical analysis.

## **Discussion**

In the twenty-first century, the importance of embryology knowledge has increased for many reasons, including the development of prenatal sonography and the necessity to treat congenital malformations for which the Developmental Origins of Health And Disease (DOHaD) concept is capital in mastering normal human development prior to understanding malformations and their clinical or surgical treatment. This probably contributes to a new interest for embryology teaching, that, considering the decrease of time devoted to embryology in medical studies for the past 50 years, has led to the proposition of a Core Syllabus for the Teaching of Embryology and Teratology to Medical Students [8].

Embryology is taught at the beginning of medical studies and, for the students, appears to be far from the concrete reality. A link between this fundamental discipline and concrete medical cases could increase the interest of students for the discipline, the same way that the inclusion of clinical cases in anatomy teaching increases the interest of students for the discipline [9,10]. As an illustration of this, the one question that was based on a clinical case presented in a new video (observation of the closing neural tube on video of a fetus sonography followed by a video of *in utero* surgery of spina bifida operta) had the higher rate of good responses (53%).

More than in most other morphological medical disciplines, embryology presents difficulties to be assimilated because of the rapid three-dimensional changes that occur simultaneously on a macro- and microscopic scale [3,4,11]. That is the reason why we provided this experimentation in two steps, the first one being the evaluation of the interest of the students when videos are introduced in magisterial course. For that matter, students were globally satisfied by having a video content that awakes their interest and helps them understand and memorize better the embryology processes (Figure 1 A, B, C). This can explain why in the survey, the item about the investment in embryology was not high. We think that by helping the comprehension through the use of our pedagogic method leads to a lesser investment. Students will not be needing to invest as much to understand the embryologic processes. (Figure 1, D). There was not a clear difference between repeaters and freshmen in the answers.

In the second step of the study, the rate of success to embryology questions regarding video content or not was analyzed. Higher successful rates of response were found for the questions regarding a video content for both years analyzed. When comparing with previous years, the results show that the rate of success depended of the teacher and thus of the questions of the exam. Obviously, this can be mentioned as a bias of the study, teachers were different, and questions were more precise in 2017/2018 which removed the advantage repeaters could have had. This can be seen as an adaptation to the teacher's methods and questions that is confirmed by the greater success of response in the following years for Teacher A and Teacher C. Moreover, private additional courses which are followed by a great majority of students to ameliorate their preparation to the exam were less adapted to these new questions than to questions given by previous teacher for several years.

Those results are in favor of continuing to use a video support in embryology teaching. When compared to the observation of static pictures, the video offers a time-saving approach because students can spend less time to build the association of all the successive pictures representing the embryo development and help in the memorization. Such real movies appear attractive for students, because on the one hand, it saves time and accelerates the learning and, probably in some cases, avoids a false representation. However, it can also set the students in a passive state, reducing the appropriation of the information and never lead to a transition of this information into long term memory [12]. Finally, students have the illusion that they have learned and memorized the whole content of the lecture, but in fact their knowledge is not sufficiently precise. This is illustrated by the poor results of tests consecutives of the lectures, even if the video content stimulated the motivation to learn, it was not enough for the memorization of extra-precise ideas that were asked on the test. Though we found that the use of the video has the potential to motivate for learning, this does not guarantee an efficient learning nor a long-term memorization.

In favor of this theory, we can cite the Diagrammatic representation of the classic Atkinson & Shiffrin model [12] which assumes that passage of knowledge from short term to long term memory is a linear process where knowledge enters into long term memory only by the way of elaborative rehearsal (i.e. the more we think about something, the stronger we will memorize its representation) [13]. This theory suggests a limitation of the quantity of

information students are able to memorize efficiently. When going above this limit, errors appear quite systematically due to a weak level of encoding [14]. In this context, video is probably not sufficient to lead to storage in long term memory because of the rapid rhythm of information and the eventual illusion that the notions are easy and that effort to rehearsal is superfluous while it is just essential.

In contrast, a physical action like drawing slows down the representation of the information, since it imposes the rhythm of the action. In a recent study authors tended to modernize the method using tablets instead of the blackboard [15] and showed that the time spent to draw is useful to receive, understand, confront the new information with previous knowledge's and finally memorize it. The movies in embryology are often viewed with an accelerated rhythm that may mask a complex element or introduce an inaccurate point. Thus, real microscopic movies should be reserved to call attention and wake up interest, reminding that events are real. Finally, the take home message should be as direct as possible and a static picture built step by step is perhaps a more appropriated method.

The magnitude of attention given by the students to the lecture is linked to their ability to memorize more or less easily the content of the lecture. Based on the cognitive load theory of Sweller, both visual and auditory information are involved in the creation of long-term memory [16] which is a point in favor of the use of videos in teaching. However, care should be taken in the type of video chosen as working memory can only accommodate a limited amount of information at a time. With the video, there is a risk to overpass this limit, impairing cognitive overload results [17]. Furthermore, the more distraction the video contains, the more the cognitive load will increase leading to a reduced attention and hence a less effective learning. So, animations are not always superior than static pictures and in some cases may impede learning by increase of extraneous cognitive load or decrease of germane cognitive load [17]. Explanation exposed by Ruiz concerning animations are of great interest because they could probably be applied to movies: explanations invoke extraneous cognitive load since learners may be unable to adequately process all the information contained in an animated sequence or in a video, especially when the content is new, complex and the learners are novice with a high intrinsic cognitive load. A supplementary difficulty occurs when attention has to be focused in different regions of the visual field simultaneously or when secondary elements attract the attention. Thus, learners could perceive the information but might not be able to integrate it. In contrast, static pictures offer time to review information as long as they need [17].

Beside the density of dispensed information, the difficulty is also a crucial element. For example, with a type of 2D figures, the more difficult a diagram is, the more mental resources the students have to use. If a diagram is too difficult to comprehend and requires too much cognitive effort, students are more likely to be less persuaded and the message would not be completely transmitted to the students [18]. An alternative can be to cut the long and complex videos into little chunks to reduce the cognitive load. So students would be more attentive to the important visual information [19].

Not only the type of material is important in learning but also the teacher-student interaction. Recent data show that the connection between the teacher and the students creates a working environment where students are influenced by the teacher and follow their enthusiasm. Hence, the students are more attentive and more involved in the learning process and not just passively attending the course [20]. Beale *et al.* confirm the advantages of face to face lectures even if online videos associated to face to face have led to similar learning outcomes as only face to face lectures [21]. Nevertheless, in our study, the positive reaction to the presentation of video was found in the same proportion whether the students assisted physically or not to the lecture.

To keep up the attention, live drawing could be used to slow down the rhythm of the lecture. Even if it has yet to be recognized as a form of teaching [22], it could be a good teaching tool to help the student be more captivated by the course and more motivated to learn because by being included in the teaching experience. Drawing can be seen as an external representation that uses cognitive processes responsible for task performance. It involves constructive learning processes that engage non-verbal representational modalities and require integration [23]. Not only students benefit from watching the drawing being made [20], the learner-generated drawing helps them construct their own representation [23]. Moreover, studies of Sweller *et al.* exploring the mirror neuron system suggest that the human spontaneously imitates observed actions and promote example-based learning [17,24].

For the future, we would propose to draw complex figures step by step, thereby maintaining the students' attention throughout the process while explaining the figure. We propose that during a lecture, different teaching materials should be used depending on the type of knowledge that students are required to acquire. For instance, for ophthalmic surgery, Prinz *et al.* showed that the addition of 3D animations to surgical videos helped the students to have a better topographical representation of the organ [25]. Likewise, in a human anatomy class, students presented with 3D videos had a better knowledge of the anatomy than those presented with 2D drawings [26]. In histology, Brisbourne *et al.* proposed the use of computer assisted animations to help students in forming mental models in histology accordingly with mental models of Lowe theory [27] that are supposed to facilitate the memorization [28].

## **Conclusion**

As proposed by Moraes & Peirera [4], the diversity of methods employed allows to avoid boredom and maintains attention at a high level. Almost 10 years ago, Marsh *et al.* [29] demonstrated the benefit of varied pedagogic multimedia tutorials in addition to traditional lecture of embryology for the long term memorization.

The optimization of embryology teaching at the twenty first century consists probably in choosing the best method for the appropriate step of learning (Figure 4): 1- presentation of a movie presenting the real event, 2- explanation of the mechanisms as comments of real-time drawing with 3- computer assisted animations (if pointing an element is relevant). 4- A

clinical application to come back to the concrete reality and 5- a take home message as a static summarizing board.

#### Practice Points

- The presentation of videos in embryology courses increases the students' motivation to learn
- The video contributes to a better comprehension
- Alone, it will not optimize the memorization of embryology because of it presents a very high concentration of information in a short time
- For an optimal teaching, it should be associated to an explanatory pedagogical tool

#### *Declaration of interest:*

The authors declare no conflict of interest

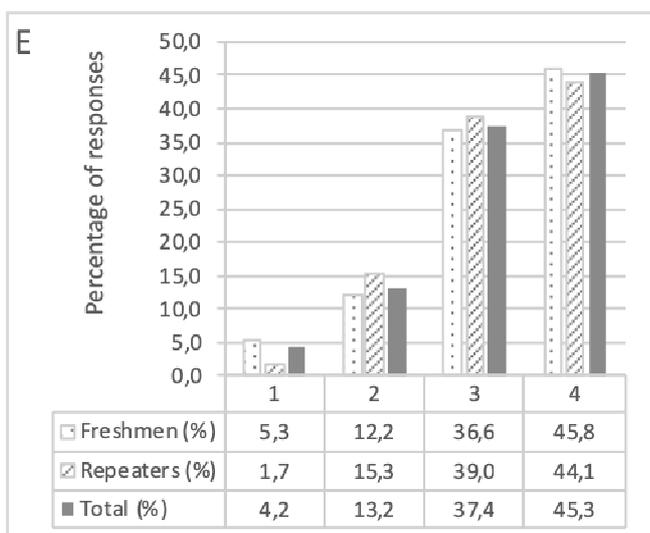
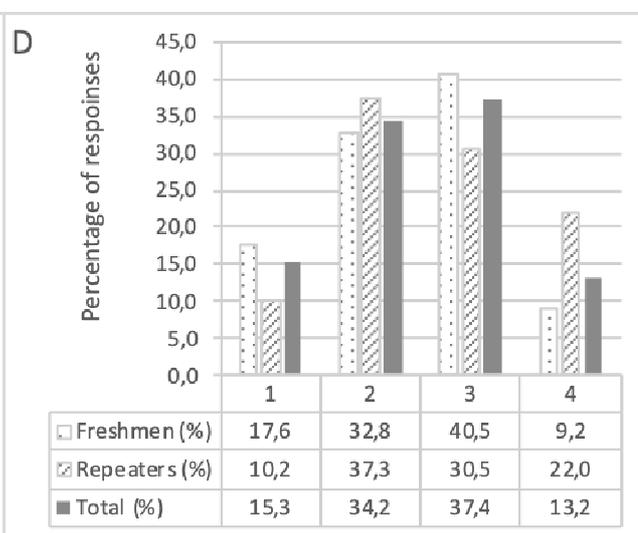
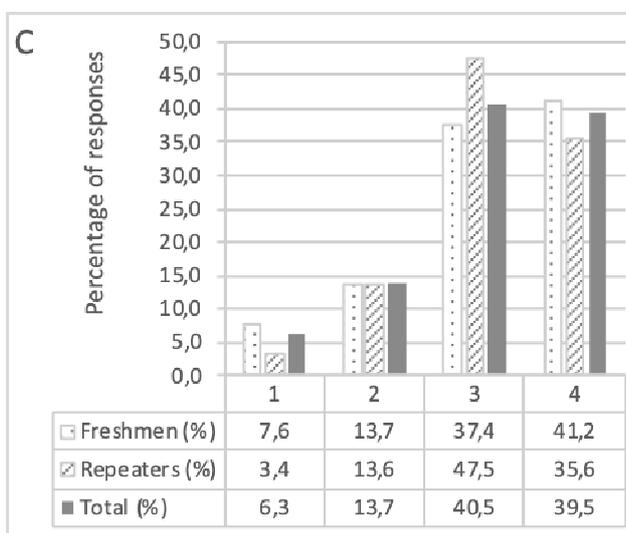
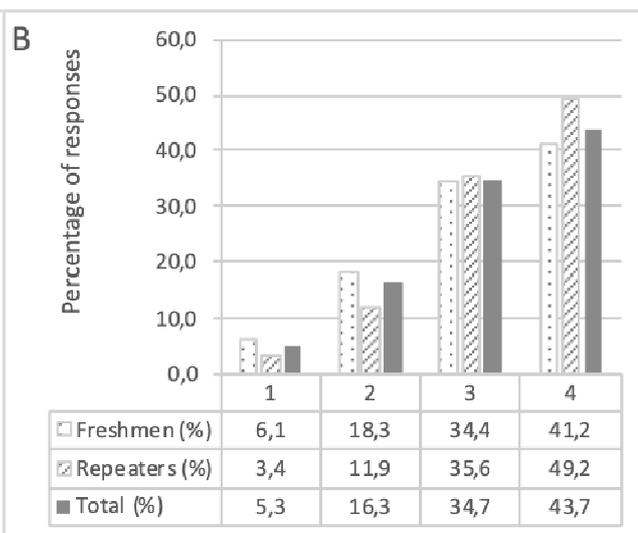
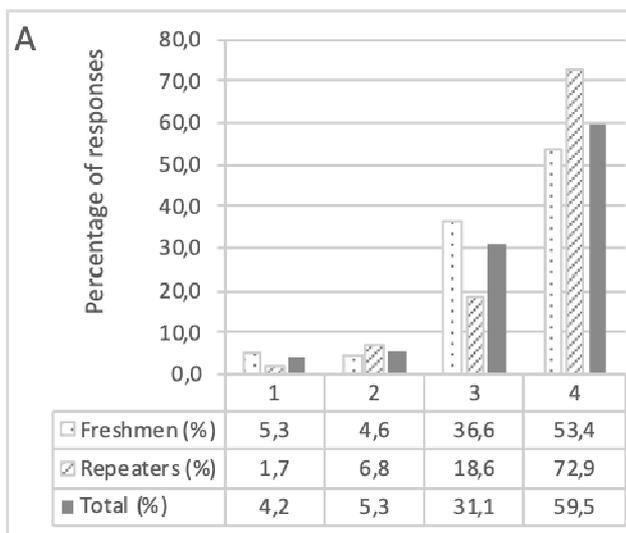
#### *Acknowledgement:*

The authors would like to thank Eric Dupal for his technical help in the realization of the videos.

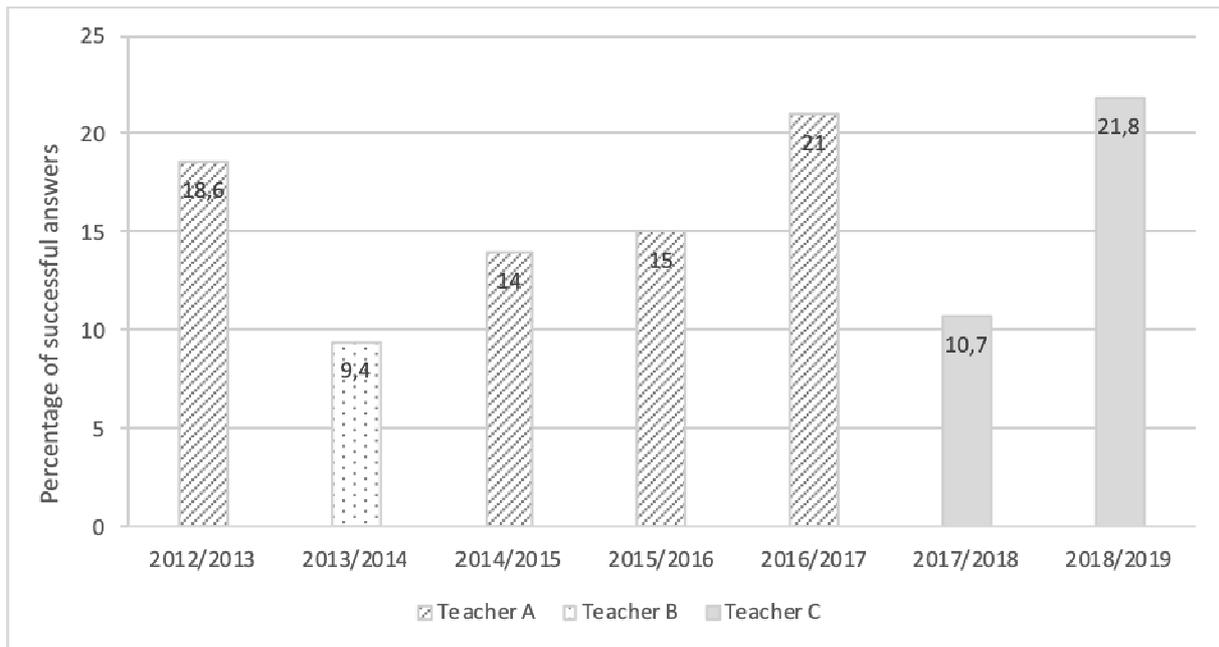
## References

- [1] Noe A. Serial sections and human embryology: a new research initiative. *Comput Med Imaging Graph Off J Comput Med Imaging Soc* 1996;20:415–22.
- [2] Carnegie Stages - Embryology n.d. [https://embryology.med.unsw.edu.au/embryology/index.php/Carnegie\\_Stages](https://embryology.med.unsw.edu.au/embryology/index.php/Carnegie_Stages) (accessed July 13, 2018).
- [3] Yamada S, Uwabe C, Nakatsu-Komatsu T, Minekura Y, Iwakura M, Motoki T, et al. Graphic and movie illustrations of human prenatal development and their application to embryological education based on the human embryo specimens in the Kyoto collection. *Dev Dyn* 2006;235:468–77. doi:10.1002/dvdy.20647.
- [4] Moraes SG, Pereira LAV. A multimedia approach for teaching human embryology: Development and evaluation of a methodology. *Ann Anat Anat Anz Off Organ Anat Ges* 2010;192:388–95. doi:10.1016/j.aanat.2010.05.005.
- [5] Hamilton J, Carachi R. Clinical embryology: is there still a place in medical schools today? *Scott Med J* 2014;59:188–92. doi:10.1177/0036933014550953.
- [6] Moxham BJ, Emmanouil-Nikoloussi E, Standley H, Brenner E, Plaisant O, Brichova H, et al. The attitudes of medical students in Europe toward the clinical importance of embryology. *Clin Anat N Y N* 2016;29:144–50. doi:10.1002/ca.22667.
- [7] Liu Y, Chapple V, Roberts P, Matson P. Prevalence, consequence, and significance of reverse cleavage by human embryos viewed with the use of the Embryoscope time-lapse video system. *Fertil Steril* 2014;102:1295-1300.e2. doi:10.1016/j.fertnstert.2014.07.1235.
- [8] Fakoya FA, Emmanouil-Nikoloussi E, Sharma D, Moxham BJ. A core syllabus for the teaching of embryology and teratology to medical students. *Clin Anat N Y N* 2017;30:159–67. doi:10.1002/ca.22802.
- [9] Johnson EO, Charchanti AV, Troupis TG. Modernization of an anatomy class: From conceptualization to implementation. A case for integrated multimodal-multidisciplinary teaching. *Anat Sci Educ* 2012;5:354–66. doi:10.1002/ase.1296.
- [10] Scott KM, Charles AR, Holland AJA. Clinical embryology teaching: is it relevant anymore? *ANZ J Surg* 2013;83:709–12. doi:10.1111/ans.12213.
- [11] Holterman, Mark J., Ashiru, Oladapo, Abdulla, Ra-id, Blew, Gregory, Sundararajan, Suresh, Rao, Seema, et al. Clinically relevant embryology: new approaches to education 1999.
- [12] Salamon E. Mechanisms of knowledge learning and acquisition. *Med Sci Monit Int Med J Exp Clin Res* 2002;8:RA133-139.
- [13] Moris C, Bransford J, Franks J. Levels of Processing Versus Transfer Appropriate Processing n.d. [https://sci-hub.tw/10.1016/S0022-5371\(77\)80016-9](https://sci-hub.tw/10.1016/S0022-5371(77)80016-9) (accessed May 18, 2018).
- [14] Baddeley AD, Thomson N, Buchanan M. Word length and the structure of short-term memory. *J Verbal Learn Verbal Behav* 1975;14:575–89. doi:10.1016/S0022-5371(75)80045-4.
- [15] Alsaid B. Slide shows vs graphic tablet live drawing for anatomy teaching. *Morphol Bull Assoc Anat* 2016;100:210–5. doi:10.1016/j.morpho.2016.05.003.
- [16] Sweller J. Cognitive load during problem solving: Effects on learning. *Cogn Sci* 1988;12:257–85.
- [17] Ruiz JG, Cook DA, Levinson AJ. Computer animations in medical education: a critical literature review. *Med Educ* 2009;43:838–46. doi:10.1111/j.1365-2923.2009.03429.x.

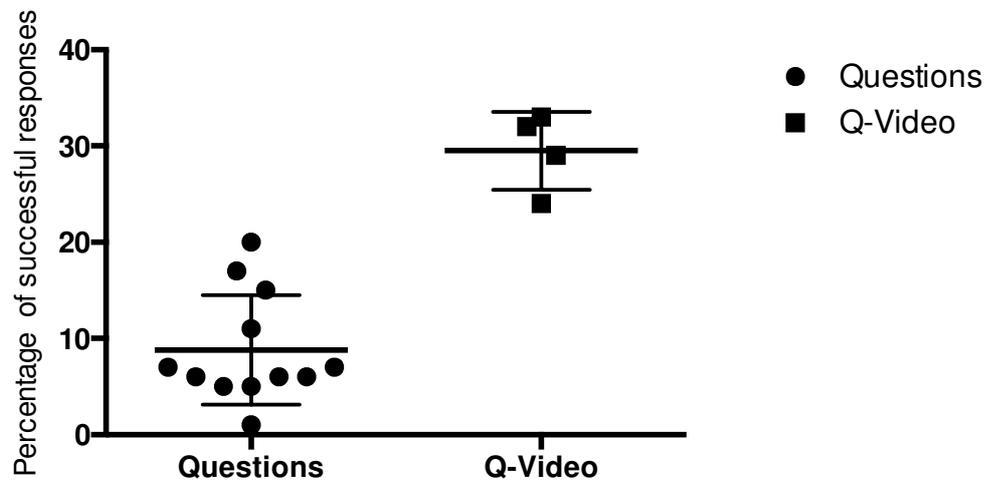
- [18] van Leeuwen T, Manalo E, van der Meij J. Electroencephalogram Recordings Indicate That More Abstract Diagrams Need More Mental Resources to Process. *Mind Brain Educ* 2015;1.
- [19] Moreno R. Optimising Learning from Animations by Minimising Cognitive Load: Cognitive and Affective Consequences of Signalling and Segmentation Methods. *Appl Cognit Psychol* 2007;21:765–81.
- [20] Rodriguez V, Solis S. Teachers' Awareness of the Learner–Teacher Interaction: Preliminary Communication of a Study Investigating the Teaching Brain. *Mind, Brain and Education* 2013;7:161–9.
- [21] Beale EG, Tarwater PM, Lee VH. A retrospective look at replacing face-to-face embryology instruction with online lectures in a human anatomy course. *Anat Sci Educ* 2014;7:234–41. doi:10.1002/ase.1396.
- [22] Ainsworth S, Prain V, Tytler R. Science education. Drawing to learn in science. *Science* 2011;333:1096–7. doi:10.1126/science.1204153.
- [23] Van Meter P, Garner J. The Promise and Practice of Learner-Generated Drawing: Literature Review and Synthesis. *Educational Psychology Review* 2005;17:285–324.
- [24] Paas F, Van Gog T. Cognitive Load Theory: New Conceptualizations, Specifications, and Integrated Research Perspectives. *J Educ Psychol Rev* 2010;22:115–21.
- [25] Prinz A, Bolz M, Findl O. Advantage of three dimensional animated teaching over traditional surgical videos for teaching ophthalmic surgery: a randomised study. *Br J Ophthalmol* 2005;89:1495–9. doi:10.1136/bjo.2005.075077.
- [26] Hoyek N, Collet C, Di Rienzo F, De Almeida M, Guillot A. Effectiveness of three-dimensional digital animation in teaching human anatomy in an authentic classroom context. *Anat Sci Educ* 2014;7:430–7. doi:10.1002/ase.1446.
- [27] Lowe R. Extracting information from an animation during complex visual learning. *Eur J Psychol Ed* 1999;14:225–44.
- [28] Brisbourne MAS, Chin SS-L, Melnyk E, Begg DA. Using web-based animations to teach histology. *Anat Rec* 2002;269:11–9.
- [29] Marsh KR, Giffin BF, Lowrie DJ. Medical student retention of embryonic development: Impact of the dimensions added by multimedia tutorials. *Anat Sci Educ* 2008;1:252–7. doi:10.1002/ase.56.



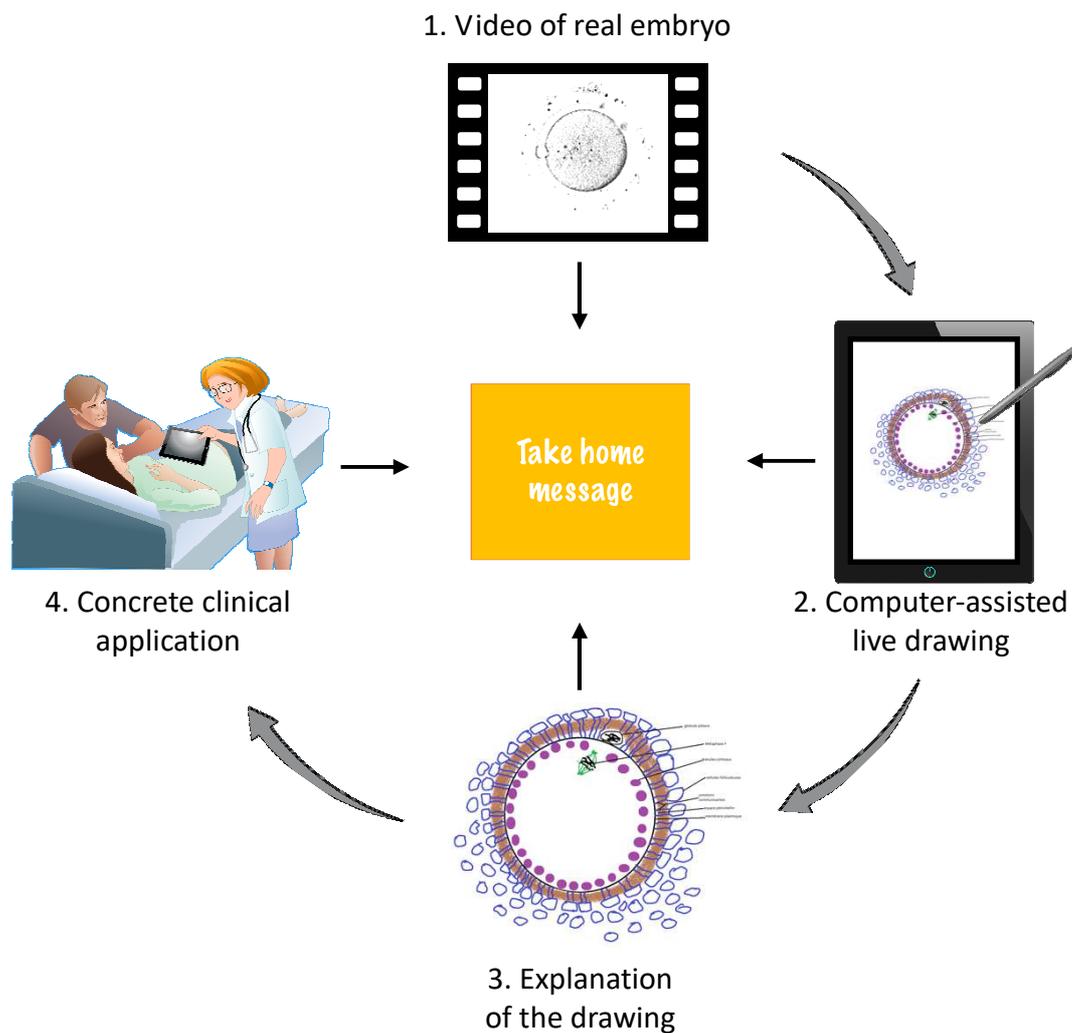
**Figure 1: Responses to the satisfaction survey of the first step of study.** The questions are related to A- Comprehension, B- Memorization, C- Interest for embryology, D- Time devoted to embryology, and E- Future interest to practice in embryology. Likert scale: 1- absolutely not, 2- perhaps, 3- certainly, 4- enormously. Number of students: total = 190; Freshmen, = 131; Repeaters = 59



**Figure 2: Rate of successful answers to embryology questions of the final exam (step 2) compared over the past 5 years.** The teacher providing the magisterial course changed over the years (and so did the questions and their difficulty in the exam) which constitutes an important bias for the comparison of the results over the years.



**Figure 3: Answers to questions of embryology in the final exam (step 2).** The percentage of successful responses to the embryology questions is presented for both years. The item Questions is related to the 14 questions not related to a video content. The item Q-Video regroups the questions related to a video content.



**Figure 4: For an efficient embryology take home message, we propose an association of the four following elements.** 1- Calling the attention of the students by presenting a real embryologic event in a movie; 2- Unhurriedly, explain the mechanisms as comments of a real-time drawing with 3- Computer assisted animations (if pointing an element is relevant), 4- Finally, presentation of a human clinical application to come back to the concrete reality.