ISSN: 2710 - 0936 | ISSN-L: 2710 - 0936

Alternancia – *Revista de Educación e Investigación*

https://doi.org/10.37260/alternancia.v7n12.11

www.revistaalternancia.org

Vol. 7. Issue 12 | January – June 2025 | Pages 12 - 21

Theoretical foundations for teaching manual skills in health technologies. The case of histology technicians

Fundamentos teóricos para la enseñanza de competencias manuales en tecnologías en Salud. El caso de los técnicos de histología

Rosa Alicia Araoz
araozalicia53@gmail.com
https://orcid.org/0000-0003-4085-2307
University of Buenos Aires, Buenos Aires, Argentina

Article received date: September 18, 2024 / Peer-reviewed date: October 13, 2024 / Accepted date: November 20, 2024 / Published date: January 5, 2025

ABSTRACT

Various technological specializations in health care are operator-dependent who work under stress to optimize the final result, so training needs to include not only skills but also other knowledge that reduces uncertainty for students. Histotechnologists, among other functions, are characterized by their cutting ability, which has evolved from the use of knives to mechanical systems, adding the concept of tools to laboratory activity. For a long time, it was considered that after a manual skill had been enhanced, that ability no longer required the voluntary action of individuals, becoming automatic. In this work, we wish to present theories that offer a different path for organizing and justifying the technical teaching-learning process and how complex cognitive adaptations are produced, far from simple automaticity. We will highlight Cognitive Load Theory (TLC), which has been analyzed in various technological activities involving eye-hand coordination.

Keywords:
Health technologies; Motor learning; Skills; Tools; TLC

RESUMEN

Distintas especializaciones tecnológicas en salud son operario dependiente que trabajan bajo estrés en la optimización del resultado final, por lo que la formación necesita incluir además de las destrezas otros conocimientos que reduzca la incertidumbre en los estudiantes. Los/as histotecnólogos/as se caracterizan entre otras funciones por la habilidad de corte, que evolucionó desde el uso de cuchillos hasta sistemas mecánicos, sumándose el concepto de herramienta a la actividad del laboratorio. Durante largo tiempo se consideró que después de potenciada una habilidad manual, esa destreza no requería de la acción voluntaria de los sujetos, pasándose a realizar automáticamente. En este trabajo se desea mostrar teorías que ofrecen un camino diferente para organizar y fundamentar el proceso de enseñanza-aprendizaje técnico y de cómo se producen adecuaciones cognitivas complejas alejadas de la simple automaticidad. Destacaremos la TLC (teoría de la carga cognitiva) que fue analizada en distintas actividades tecnológicas de coordinación óculo-manual.

Palabras clave:
Tecnologías en salud; Aprendizaje motor; Habilidades; Herramientas; TLC

INTRODUCTION

What is motor learning?

Motor skills

Currently, some studies on human labor focus on gross motor skills for the care of factory personnel in general, analyses that include to a lesser extent the skills necessary for certain occupations (Castaño Gaviría , 2009). On the other hand, fine motor skills, which involve more precise movement, are analyzed from the perspective of education in general (writing) and especially by physical education and sports (Krakauer, 2019).

From other areas linked to health and the pathologies of this expression of the human body, with different objectives, there are general specialties associated with medicine such as physiotherapy, kinesiology, and neuroscience.

For this work, we will adopt definitions from education, which identify gross motor skills as actions that involve the largest muscles and bones to perform vigorous movements. Examples include walking, jumping, bending, etc.

While fine motor skills are determined by the coordination of muscles, bones, and nerves for the action of small and precise movements such as picking up a small item with the index finger and thumb (León Castro, 2021).

This last motor skill is also called oculo-manual due to the coordination of the fingers in combination with the eyes to perform fundamentally precision actions. Through this characteristic, tests can be carried out to evaluate the level of basic skills achieved through development and education, e.g. these tests are exercises with pencil and paper (drawing lines, making mandalas, writing with different types of letters), organizing objects, cutting, tearing and pasting, collage, etc. (Rosario-Rodríguez, 2023). This definition is limited because it considers the visual system as the main source of information and connection with the outside world and does not contemplate cases of diminished or null vision (Bayarri, 2014).

The importance of initial testing is that any improvement in performance that depends on practice and experience can be understood as motor learning.

These terms differ in relation to the environment where motor learning takes place, with the concept of practice reserved for controlled environments, while experience is achieved through adaptation to variable and less predictable environments.

Another more complete definition of motor learning is suggested from neuroscience by Krakauer (2019), who divides it into two parts: one is the acquisition of skills that allow the selection of the appropriate movement to achieve a specific objective in a particular context, where that choice corresponds to the sensory stimulus received from the environment, with that action being exact and precise (effective). This leads to the need for learning to be carried out in a practical way in controlled environments.

While the second part, according to this author, involves the ability to maintain these capabilities and performance levels and adapt them to different contexts, concepts that can be linked within cognitive theories to working memory and long-term memory. These theories were developed relatively recently and deserve to be illustrated.

The beginnings of research in visual-motor skills

The modern human brain has a strong system for controlling motor skills, and different areas of knowledge are dedicated to analyzing these possibilities from different perspectives.

Within the broad scope of physical anthropology, there are at least two beliefs about technical development. The oldest approach considers tool used to be solely a matter of tool manipulation, i.e., hand-tool interaction. While a more recent approach recognizes that people reason and create a representation of the solution to a practical problem—i.e., tool-goal thinking—but they ignore the necessary motor skills that depend on that representation.

A third hypothesis includes, in addition to knowing how to use tools, the ability to choose and select suitable materials and even build new objects for use, that is, it integrates the capacity for creativity and innovation (Osiurak, 2021).

There is broad agreement that technical reasoning is based on physical skills such as percussion, cutting, and levers, so we will have to look for their origins and, consequently, the choice will fall on the evolutionary theories of learning these skills. From these arises the widespread assumption that they were originally acquired for basic, routine use and that they are reused and transferred to other, more complex activities while still fulfilling those original functions (Osiurak, 2021).

In this sense, around 1874, from a physiological perspective, WB Carpenter (1813-1885) early on proposed the concept of the ideomotor principle, which held that a mental idea somehow found expression at the muscular level. In this way, he established a relationship between the physiology of the senses and the mind that went beyond the interpretation of perceptions and could intervene in the production of other sensory states. His research was primarily focused on differentiating automatic actions from those performed voluntarily (Hale, 1982).

It wasn't until 1931 that E. Jacobson (1888-1983) took up this approach again, conducting experiments that showed that when he asked test subjects to visualize an arm-bending movement, a power indicator connected to them indicated increased activity in the eye, not in the muscles. When the same subjects imagined themselves performing the action, the activity was observed in the biceps muscles and much less in the eyes.

In 1967, A. Richardson (1872-1976) and in 1972 C.B. Corbin rethought this experiment under the name of neuromuscular feedback theory and proposed that both executing and imagining a controlled action involving a muscle produced stimulation of that muscle. The corollary of the experiment was that thought first activated the premotor area of the cortex and that this acted as an inducer of future movement (Hale, 1982).

M.J. Mahoney (1942–2006) and M. Avener (1977) used this theory with athletes and categorized the visual-motor response into internal and external, depending on the degree of internalization of the action. Thus, if the person feels they are experiencing the action, the stimulus is said to be internal, while in the case of an external stimulus, the person is a spectator of the action (Hale, 1982).

Abraham (2020) recently worked with these theories to explain the complexity of the relationship between cognition, morphological activation of the brain, and motor action, which, although more accepted and studied, remains unknown in many aspects.

All of these works established both the morphological changes produced in different regions of the brain and those located at the muscular level.

The brain regions activated were those of the neocortex, which, from an evolutionary perspective, is the human region, the most recently configured in human physical and mental development. This research contributed to the idea that creating a tool required a mental activity distinct from using that instrument. It also included the need and ability to perceive the best elements for making them (whether by texture, color, hardness, etc.).

This attitude of choosing materials with which to make tools are also studied evolutionarily in human beings, considering their contact with the environment and the way in which they do so through their senses and how auditory, tactile, olfactory, and taste intervene, highlighting the importance of the visual, which then translates into the selection of the manual action that corresponds to that object (Hikosaka, 2013). Therefore, there is a relationship between tools and technology that shows the level of complexity that human beings have achieved evolutionarily compared to other species.

Bruner (2018) argues that through touch we access limited information while our vision expands the data field and that tools therefore produce different cognitive and neural responses when they are out of reach of the body (extrapersonal space) that is, beyond arm's length or when they are placed within the range of physical interaction, within reach of the hand (peripersonal space). The important thing is that tools are incorporated into body schemas when they are touched or manipulated: the brain would interpret an object that is manipulated as an extension of the body, which is the basis of prosthetic interpretation (Parente, 2010). This theory can be applied to mechanical or nonmechanical supplements of parts of the human body, because current biomechanics differentiates those elements that expand the radius of action of the human hand and calls them orthoses and not prostheses as a replacement for it (Salinas Castro and Cohí). Riambau, 2009) and the term would not correspond to the use of production devices or mechanisms.

The evolution of laboratory work is characterized by the selection of elements, and more specifically, the development of histological techniques from the very beginning, when different materials were gradually incorporated into the process in the quest to optimize the final product. Today, numerous components that did not initially exist are available and have become essential for modern laboratories.

As explained by historians of technology, at some point in the Neolithic, someone grabbed a heavy stone to hit a flint stone and thus the mace emerged, the hand tool that uses the basic primary mechanism: the vertical blow (Borràs, 2010).

For this reason, their classification is useful, starting precisely with hand tools, which are defined as those work tools that require only human motor power for their operation.

Recent research on the skills required for tool use suggests expanding the field of analysis to include studies of combined skills, e.g. analyzing shear and leverage together (Osiurak, 2021).

Tools, materials and skills

From another scientific discipline, physical anthropology, which studies human communities from the perspective of temporal (vertical) and spatial (horizontal) development (Laguna Rodríguez, 2002) with the help of archaeology, the relationship between tools and evolutionary abilities was raised, despite the difficulty in finding definitive answers. The study of tool remains from early humans raised the question of why so much time elapsed between the simplicity of the most remote flakes or laminated fragments of stone for different uses and the complexity of a double-sided laminate (Faisal, 2010).

The responses obtained support the hypothesis that the change was due to brain expansion brought about by sensorimotor adaptation and the perception of environmental possibilities, that is, the recognition of different materials, rather than the acquisition of strategic complexities, conceptualizations, or abstractions. These flakes are recognized as tools or examples of the most primitive techniques, rather than hominid technologies that had not achieved brain morphological change.

For this reason, a chronological scheme of the tools and the corresponding skills required for their manufacture was developed, which, in themselves, imply an evolutionary change.

The classification consists of three groups of primitive tools with their corresponding skills: percussion, cutting, lever (Borràs , 2010).

First family, percussion: These are, like the mace, tools based on vertical impact. The mace (a wooden block or stone attached to the end of a handle) and the club are the oldest representatives of this first family, from which we develop the different types of hammers.

Second family, cutting: These are the cutting tools, among which the punch and the needle are the oldest and predecessors of the knife, which in turn gave rise to cutting weapons (swords, daggers, foils, etc.) and among the tools, properly speaking, generated scissors (a combination of two knives) and with the addition of teeth to the edge that increased its penetration capacity when cutting, it was the predecessor of saws.

Third family, lever: lever tools belong to the simplest of machines and their origin also dates back to some point in prehistory, but their everyday use, in the form of a crankshaft, is documented from the third millennium BC, in cylindrical seals found in Mesopotamia (Borràs , 2010).

Once the tools have been described, the next question is how their use arose from what is organic and instinctive in humans, distinct from the manipulation that some animals also perform with some basic artifacts.

The answer comes from a paleontological theory that holds that the first skills developed by hominids were grasping and percussion.

The first allowed the handling of different materials without applying force to them, while the second skill was developed along with the possibility of shaping the first flakes obtained by percussion and thus achieving greater force in the blow. Leroi-Gourhan (1993) classifies three different types of percussion:

1) Supported percussion.
2) The thrown percussion.
3) Percussion supported by hammer

Supported percussion is the oldest form and consists of placing the piece directly on the material and striking it with muscle power. This is how knives, rakes, and scrapers for everyday use emerged.

The other two forms radically change the idea of tools by adding a handle or holder. Among them, the hammer stands out as an example of percussion supported by a firing pin. While thrown percussion is exemplified by harpoons and arrows.

Paleontology thus explains how the evolution of early hominids, through an adaptation measured through geological divisions, went from the joint action of hand and tool to distancing itself from the action itself, with humans finally becoming the independent motor operator of the tool.

The laboratory and technology

In the case of laboratories, and more specifically in histological research—that is, the study of organic tissues—manual skills were fundamental. The use of needles and knives to dissect and dissect human, plant, and animal anatomical specimens was necessary from the beginning and exemplifies the use of tools.

The microscope and stereoscopic magnifying glasses also serve as an example of the fine-ocular motor relationship, as the hand acts as a millimetric adjustment regulator for viewing and moving the slides on the stage.

Since the beginning of this discipline, innovative criteria were applied and allowed the development of procedures in the search and adaptation of different materials (it must be remembered that the first liquids used were oils, then alcohols, until the appearance of formaldehyde and xylene).

Tissue cutting is considered a distinctive skill, and from the use of simple knives, it evolved into simple to complex mechanical systems called microtomes. Initially called cutting machines, these devices involve levers and blades actuated by human motive power. Currently, some automatic and semi-automatic models exist, but they are still operator-dependent, as seen in Figure 1.

There are many other skills that use the oculomotor system in the histotechnology laboratory and this can be seen in the precision in the lifting of the thin sheets of material on the slides once suspended in the water of the thermal bath when they have a thickness of 5 μ (1 mm = 1000 μ) and they must be handled carefully as shown in Figure 2 or also for the handling of tools such as tweezers, scissors, etc. Also the final assembly with the coverslip requires delicate and rapid handling, as shown in Figure 3. To then take them to the optical microscope, as suggested in Figure 4.

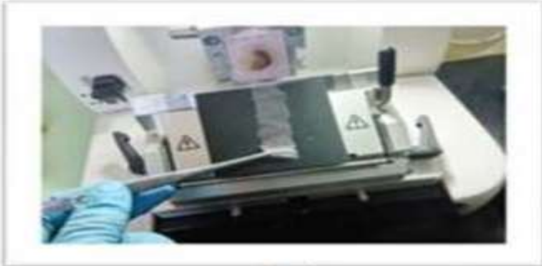

Fig. 1
Paraffin sections on a microtome.

Fig. 2
Lifting sections in a thermal bath (diagram).

Fig. 3
Final mounting with coverslip.

Fig. 4
Optical microscopy observation.
Own edition

But the most obvious example of these basic human skills is seen in the manufacture of glass blades for ultramicrotomy, which consists of marking the glass rod and subsequent precise striking to obtain right-angle triangular wedges.

This discovery emerged when the use of resins for embedding had already become widespread and cuts were made with steel blades that were not very effective, but it remained unknown because it was considered to diminish the importance of the research.

The little-known story goes that H. Latta (1918-2007) arrived at the MIT lab one day with a glass milk bottle and mentioned that he was going to make glass blades, which caused some skeptical expressions among those, present. Latta went to the workshop, broke the bottle and took a fragment and then, with J.F. Hartmann (1910-1993), began to make the first fine sections of resin inclusions with the ultramicrotome (Bechtel, 2006).

Latta and Hartmann published their work on obtaining glass blades for electron microscopy sections in 1950, where they schematized, as shown in Figure 5, the glass rod and the sections made. There were numerous adaptations as shown in Figures 6, 7 and 8 (Sevéus, 1985) and it is still in use today and there are also devices to make them.

This example also demonstrates innovation and the ability to search for different materials to find the fracture point and use the lever (tweezers) or the combination of fracture point with percussion (gently with a hammer) and rolling (a variant of the wheel, a simple machine, which serves to displace force and decreases friction) and the way in which basic motor skills are present in laboratory research.

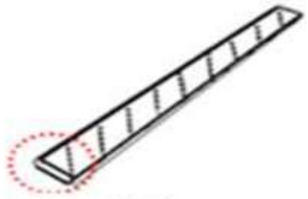

Fig. 5
Latta and Hartmann (1950) marked parallel lines at a 45° angle, and after cutting, they obtained 60 to 80° blades. Sevéus, 1985

Fig. 6
Hall (1956) introduced 45° blades after cutting glass squares. Sevéus, 1985

Fig. 7
Gelber (1957) fractured with angles close to 90°. Sevéus, 1985

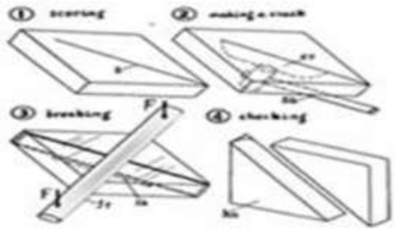

Fig. 8
Tokuyasu and Okamura (1959) improved the process with outlining, gentle hammering, and the use of a roller. Thus, with less but constant pressure, they obtained an optimal fracture.

Sevéus 1985

And in the histotechnology laboratories, there is diversity: the materials received. From fragile, millimetric materials (biopsies) to hard materials like bones or fibrous ones like the uterus, it is necessary to evaluate them according to different degrees of difficulty to choose the appropriate procedure. This is the first skill that must be developed in future technicians, who, in addition to using the tools, need judgment and suitability for laboratory tasks.

This concept used for teaching technical skills in the laboratory can be defined as suitability of actions, which according to Aguilar- Ozejo (2022) includes the support of internal factors, such as knowledge of the action and positive attitudes towards problem solving.

To acquire suitability or be competent in the action, this author presents a set of aspects that can be considered as final objectives of the technical teaching process:

a) Knowing how to understand a situation or problem in reality and find a solution

b) Compare the problem situation with other problems surrounding it.

c) Being able to have a calm and serious attitude towards the situation, which will have an impact on the responsibility for correct action.

d) Progressively expand skills and abilities to act with increasing confidence.

e) Know how to recover previous factual knowledge and experiences in respect to the situation.

f) Perceiving different alternative actions will make the situation be seen from a different perspective.

g) Distinguish the best course of action in each situation

These attitudes imply that the teaching of motor skills to technical students is partially structured because studies on the subject fail to explain how the execution of an action allows for long-term improvement. However, what could be determined with the use of neuroimaging is that practice time actually impacts the cognitive components of action located in the human brain (Krakauer, 2019).

It is at this point where cognitive research models found that some skills take longer to be acquired because multiple variables come into play that give rise to different scenarios and the person must learn to evaluate these contingencies and choose the best strategy based on their knowledge (skills, motor acuity, precision and speed) or adapt (adaptation) and create a new one (experience).

And it is in this last case where one's own executive capacities (motor acuity), memory and more general cognitive control (inhibition of external noise) would come into play (Krakauer, 2019) because what is expected of students is that they transform their initial suitability into expertise and be able to respond to situations that are not predetermined by teaching.

However, it is necessary to clarify in defense of sequential teaching that as the predetermined objective-action process is repeated, motor and executive quality will progressively improve because it allows the recognition of the correct response and provides the period of adaptation and incorporation of skills (Krakauer, 2019).

Recognizing that more complex actions will be required in the real-life work environment, preparation for these contingencies must be a teaching objective, since focusing only on correct actions without understanding the ultimate objective will not impact learning sufficiently to solve unforeseen problems.

The topic is relevant because it aims to highlight that in short-term programs such as health technical programs focused solely on responsible actions, the balance between theoretical knowledge and practical time must be optimized in the study programs.

In this way, work proposals originating from historical factory schools such as Taylorism and Fordism, with their efficiently optimized time and assembly lines, respectively, and outside the subject involved, should be replaced by new research from different disciplines such as data science and educational psychology.

An approach to working memory and long-term memory

As mentioned, the visual system induces motor action, and current cognitive sciences and their data analysis theories consider it a powerful tool for understanding the complex relationships between data components. It also contributes to the decision-making function. Therefore, it also intervenes in the process of acquiring new knowledge (Meyer, 2010). The acquired skills have a greater solidity in professional actions and production, even over motivation, understood as the impulse to act professionally (Hikosaka, 2013).

So far, it can be said that the learning process of practicing technicians has generally been directed toward perceptual inference, which is based on data without considering other conscious elements of the subjects (e.g., beliefs, tastes, etc.). Although cognitive specialists and those who study visualization processes continue to discuss how the incorporation of new knowledge or insight occurs, for the purpose of this article, we will follow this second line, which contributes a couple of definitions:

1) Insight is a moment of illumination
2) It can have a broader meaning that implies an advance in knowledge or adding a piece of information to the subject's scheme (Meyer, 2010).

If we consider that skilled technical skill is characterized, unlike assembly line capabilities, by the ability to multitask, and that to achieve this, technical personnel need to automate some movements because in this way cognitive capacity is freed up to perform other actions, it means that there is a relationship between this release of memory and knowing how to make good use of our skills. An example of this process is automated and fluid writing that frees up the cognitive resources necessary to think about the conceptual distribution of the writing (Hikosaka, 2013). And in the case of histotechnologists, the usefulness of practice allows them to acquire precision, speed and less stress in material cutting tasks.

The relationship between the acquisition of new knowledge that is useful at the moment and will not be required again immediately, but that does not have to be discarded from our cognitive apparatus to remain latent until the situation requires it, receives different names according to the discipline that studies it.

Cognitive theories generally work with animal models, but we highlight the proposal from educational psychology, where the cognitive load theory (CLT) designates working memory as the moment in which knowledge is acquired and defines long-term memory as the stabilization process in the cognitive structure.

This theory, which is only intended to be presented in this work, was initiated by J. Sweller, who built on the work of J. Piaget's (1928) constructivist theory and his concepts of human cognitive architecture and mental schemata. For Sweller (2002), working memory has limited capacity and duration and uses relatively separate visual and auditory channels, while long-term memory is infinite and contains numerous schemata, each with a different level of automation.

As Sweller argues, the importance of this theory lies in its application in teaching to achieve optimal levels of learning in new material, the process of systematization and fixation in cognitive architecture.

There is literature with various applications of this theory in different courses and in the case of laboratory technicians, specifically histotechnologists who must acquire the characteristics and expertise specific to this specialization, both theoretical and visual-motor, in the development of short courses, recognizing the dynamics of the stages that the TLC proposes, results in an interesting way to analyze and optimize teaching.

CONCLUSIONS

Although, as indicated, the human species has its own qualities that give it the capacity to perform multiple gross and fine motor actions, these can be increased and this is the aspect that was proposed to consider the training and education of health technicians in general and histotechnologists as an example.

Technical knowledge maintained for quite some time the old model of differentiating the “know-how,” which refers to an automatic act distinct from the “know-why” of the action, and in this difference both competencies and skills take on meaning, becoming established and reinforced through action and direct experience in reality. But unlike that old separation of individuals with different kinds of knowledge, anthropological and evolutionary studies indicate that the cognitive activity required for the coordination of the eye-motor system was configured in the development of the entire human species, endowing them with their own characteristic, global (or basic) and unique capacities.

Other disciplines and theories contribute to improving or correcting these uniquely human skills and competencies. These seek to understand the learning process in order to leverage the feedback from different experiences that provide the framework or framework for transferring that knowledge to different situations, while also providing the ability to effectively execute them when required, especially if they are motor skills.

The old differentiation between knowing how to do things and knowing why things are done has been clearly surpassed, and the application of theories such as TLC in education and continuous training can contribute to the education of health technicians in general. This theory deserves attention and future analysis.

REFERENCES

Abraham, A., Franklin, E., Stecco, C. y Schleip, R. (2020) Integrating mental imagery and fascial tissue: A conceptualization for research into movement and cognition. Complement Ther Clin Pract, 40:101193

Aguilar-Ozejo, J. y Mujica-Bermúdez, I. (2022) La competencia motriz, un potencial educativo para el contexto actual. Revista Digital: Actividad Física y Deporte, 8 (2) e2054.

Borrás, X. (2010) Evolución histórica de las herramientas manuales. De la piedra de sílex a la batería de litio. Recuperado de: https://www.interempresas.net/Construccion/Articulos/43391-Evolucion-historica-de-las-herramientas-manuales.html

Bechtel, W. (2006) Discovering Cell Mechanisms: The Creation of Modern Cell Biology. Cambridge University Press.

Bruner, E., Spinapolice, E., Burke, A. y Overmann K. A. (2018) Visuospatial integration: Paleoanthropological and archaeological perspectives. En L. V. Di Paolo, F. Di Vicenzo y F. De Petrillo (Eds.) The evolution of primate social cognition (pp. 299-329). Springer.

Castaño Gaviría, R. (2009) El cuerpo productivo y sus efectos sobre la motricidad. Educación Física y Deporte, 27 (2) pp. 11-23.

Hale, B. D (1982) The effects of internal and external imagery on muscular and ocular concomitants. Journal of sports Physiology, 4:379-387.

Faisal A, Stout D, Apel J, Bradley B (2010) The manipulative complexity of lower paleolithic stone toolmaking. PLoS ONE 5(11): e13718

Hikosaka, O., Yamamoto, S., Yasuda, M. y Kim,

F. H. (2013) Why skill matters. Trends Cogn Sci. 17 (9) pp. 434-441.

Krakauer, J. W., Hadjiosif, A. M., Xu, J., Wong, A. L. y Haith, A. M. (2019) Motor learning. Comprehensive Physiology, 9: 613-663.

Lagunas Rodríguez, Z (2002) La antropología física: qué es y para qué sirve. Revista Ciencia, pp. 12-23.

León Castro, A. M., Mora Mora, A.L. y Tovar Vera, L. G. (2021) Fomento del desarrollo integral a través de la psicomotricidad. Revista Dilemas Contemporáneos: Educación, Política y Valores, 1 (33).

Recuperado de: http://www.dilemascontemporaneoseducacionpoliticayvalores.com/

Meyer, J., Thomas, J., Diehl, S., Fisher, B. y Keim, D.A. (2010) From Visualization to Visually Enabled Reasoning. Scientific Visualization: Advanced Concepts. 1, pp. 227-245.

Osiurak, F., Crétel, C., Uomini, N., Bryche, C., Lesourd, M. y Reynaud, E. (2021) On the neurocognitive co-evolution of tool behavior and language: insights from the massive redeployment framework. Topics in Cognitive Science 13, pp. 684-707.

Rosario-Rodríguez, J. L. (2023) Actividades Óculo-Manuales para Desarrollar Habilidades de Motricidad Fina en Estudiantes de Licenciatura en Educación Física. Revista Dominio de las ciencias, Vol. 9 (3) pp. 159-184.

Sevéus, L. y Tarras-Wahlberg, C. (1985) The glass knife in ultramicrotomy. Scanning Electron Microscopy, Vol. 4 (1) 129-130.

Salinas Castro, F y Cohí Riambau, O (2009) Introducción a la biomecánica, en Zambuido Periago, R. (Ed.) Prótesis, Ortesis y Ayudas Técnicas. Editorial Elsevier Masson.

Sweller, J. (2002) Visualisation and instructional design. Proceedings of the International Workshop on Dynamic Visualizations and Learning, pp. 1501-1510.