Towards a Consensual Definition of Learning: Insights from the Aristotelian Philosophy

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Abstract

What is learning after all? Being the cornerstone of educational psychology, this question has not lost its appeal since there still is no consensus over it. What makes providing a careful definition of learning important is that such definitions carry important pedagogical implications which might not be equally beneficial. This theoretical paper, therefore, has tried to define learning by a novel interdisciplinary approach through connecting educational psychology to philosophy. It has started with the dilemma of a lack of consensus over the definition of definition itself and the necessity for holding a theory of definition. Consequently, Aristotle's definition theory has been chosen. To be impartial, it has been contrasted with that adopted by Karl Popper- Aristotle's major critic. Then, mainstream leaning definitions have been investigated. Their inadequacy has been attributed to their non-adherence to a tenable definition theory. The paper recommends a framework for learning definition studies established by adopting Aristotle's definition theory and other points discussed. Such a framework constitutes guidelines for future studies. These guidelines give future definition studies direction and coherence and allow us to move away from idiosyncrasies reflecting personal bias and, as such, they can direct us towards developing a consensual definition.

Keywords: Aristotle, definition theory, educational psychology, learning definition, philosophy

Introduction

What is learning after all? As a vexed question obsessing human beings ever since antiquity, this question has not lost its appeal. What makes this question more challenging is its epistemological nature. And as such, the answer to this question is not only the cornerstone of educational psychology but also an integral part of all sciences because "every science is a response to two questions: first the question *an est*, if a thing exists: second, the question *quid est*, of what nature is it" (Maritain, 1937, p. 67, italics in the original). Yet not only is there generally a lack of consensus over the definition of learning, but also even within the ardent advocates of the same learning theory there is no agreed-upon definition, even though they might claim unanimity. In fact, there are many cases when "researchers talk about the same term, [but] they had totally different conceptualizations and therefore measurements" (Sell, 2018, p. 10). Such different conceptualizations of learning a) threaten the validity of studies measuring learning, b) carry different pedagogical implications which might not be equally fruitful, and c) deter us from devising a clear and feasible plan for reaching our objectives. The third millennium heralds a new era in education with overriding objectives, such as learning to learn and lifelong learning. Yet, though undoubtedly grandiose by name and in nature, such targets cannot be achieved if no attempt is made to arrive at a consensus over the definition of learning in the very first place.

Myriads of definitions provided for learning are not only indicating a lack of a consensus over the definition of learning, but also have proven it to be one of the most enigmatic concepts to define. And quite ironically, what makes offering a learning definition even more

challenging is that there is no consensus about the definition of definition itself. This paper, therefore, has made an attempt to pave the way for developing a consensual definition of learning. To do, it has tried to conceptualize learning with the help of philosophy. It has started with discussing the status of definition and the dilemma of a lack of consensus over the definition of definition itself. Therefore, acknowledging a plethora of idiosyncrasies about not only the definition of learning but also the definition of definition itself, the authors believe that measures should be taken to reduce such idiosyncrasies. It is only then that we can hope to get close to some consensus. In their view, one way to do so would be to hold a theory of definition because such a theory establishes a framework for "the structure, roles, and goals of definitions and their usefulness" (Kublikowski, 2009, p. 231). Consequently, Aristotle's theory of definition has been chosen in this study as a framework for learning definition studies. Reasons have been provided for choosing this theory, especially in view of its potentials to provide inclusive and exclusive definitions (i.e., definitions which have the ability to not only include all different cases of the term to be defined but also distinguish that term from other phenomena). To further defend why Aristotle's theory has taken priority over other theories and to be impartial, it has been contrasted with that proposed by Karl Popper-Aristotle's major critic. It has been argued that Popper's theory of definition is inadequate and the criticisms that he has made against Aristotle's theory are invalid. In defense of Aristotle, countercriticisms have been provided. Then, the major constituents and rules of a formal Aristotelian definition have been discussed. Following that, the paper has investigated the inadequacy of some of the mainstream definitions of leaning in educational psychology not only in terms of the scientific aspects of learning but also in view of their incongruence with the Aristotelian approach. This inadequacy has been attributed to a scarcity of studies on learning definition made by educational psychologists, of course, as far as adherence to a theory of definition is concerned. The paper has, therefore, recommended a framework for definition studies which can be established, in part, by Aristotle's definition theory. It is a novel approach which tries to connect educational psychology to philosophy through a theory of definition. It is novel because although adopting philosophical approaches has been recommended in educational psychology, but there are no studies in this field (to our knowledge) attempting to investigate learning definition based on a classical theory of definition. To be comprehensive, this framework should also include epistemology, a theory of learning, and interdisciplinarity along with other points discussed.

Such a framework constitutes guidelines for future studies. These guidelines give future definition studies direction, coherence, and above all comparability because they help us to study definition in systematic and scientific way. Consequently, they allow us to move away from idiosyncrasies reflecting personal bias and, as such, they can direct us towards developing a consensual definition.

The Status of Definitions

Ever since ancient times, philosophers have been intrigued by definitions (Gupta, 2019). Socrates's (470 – 339 B.C.) frequently quoted sentence: "the beginning of wisdom is the definition of terms" (Policano, 2018, para. 1) highlights the importance of definitions. To him, the possession of knowledge of moral properties is contingent upon the ability to define them. This doctrine, which shows the importance of definitions to Socrates, is referred to as the Priority of Definition principle ascribed to Socrates (Firey, 1999). It was "Plato and Aristotle [who] introduced basic principles of definition" (Veltman, 2004, p. 15), yet definitions play a central role not only in philosophy but also "in all sciences and [they are] … a fundamental tool in logic, philosophy of ideas and semantics" (Sager, 2000, p. vii). In fact, since "[i]nsightful understanding often depends on definitions" (Vaneechoutte, 2000, p. 429), the need for unanimous and carefully defined concepts is strongly felt across all disciplines. But since "[a]n important first step in a paper about definition is a definition of a definition" (Sell, 2018, p. 10), prior to making any attempts to provide a careful definition of learning or any other concept, we have to find out what the definition of definition is. Doing so requires holding a theory of definition.

Theories of Definition

Theories of definition are a sub-discipline of the philosophy of science (Cattrysse, 2014). Such theories are "strongly linked to the field of logic" (Hebenstreit, 2009, p. 12). The major concerns of a theory of definition are the structure, roles, and goals of definitions and their utility (Kublikowski, 2009). Therefore, holding such a theory allows us to investigate definitions in a systematic and scientific way and, as such, it can help us to move away from our idiosyncrasies reflecting personal bias. Such a theory is so important that scholars like Fetzer (1991) have seen a philosopher's theory of definition as coming close "to qualifying as that philosopher's conception of methodology in philosophy. [Therefore,] There can be little doubt of its importance for philosophy today" (Fetzer, 1991, p. 3). Yet such theories "differ greatly …

[to the extent that] it might be said that there are no two modern logicians with the same theory about definitions" (Sager, 2000, p. 199). So the first step to be taken in defining definition and then defining learning would be choosing a theory of definition.

Historically, there are four main theories of definition, one of them being the Aristotelian essentialism and its successors to date[1] (Dubislav, 1931). Of course, there are also modern theories "and there is an obvious distinction between the classical and the modern theories" (Hebenstreit, 2009, p. 12). But "Socrates' and Aristotle's views [still] continue to influence modern theories of definition" (Pilkington, 2019b, p. 31) and "Aristotle and the Aristotelian definition is still the prototypical form of definition" (Hebenstreit, 2009, p. 12, italics removed). Moreover, while little modern work has been done on the subject of definitions, the old theories of definition offer some good practical advice (Walton, 2005). The same idea is held by Dubs (1943) who believes that the contribution made by the classic medieval Aristotelian logic to the issue of definition is greater than that made by modern thinkers. Therefore, for this reason and other issues to be elaborated, in this study an attempt has been made to define the concepts of definition and learning based on Aristotle's definition theory.

Aristotle's Views on Definition

To initiate a fair discussion about Aristotle's stance towards definitions, his viewpoints have been presented here in contrast to those held by Karl Popper, his major critic and opponent. These two scholars differ on their ideas about definitions and the role played by them in science. And the ideas of both of them have been influential. Aristotle's definition theory "has been more widely adopted, and less often reviled, than any other part of the original theory of logic drawn up by [him]" (Robinson, 1965, p. 1) and Popper "is not only widely regarded as one of the greatest modern philosophers, but many readers of his works tend to take his views as a final word in the philosophy of science" (Büttemeyer, 2005, p. 25). For example, von Mettenheim (1999) believes that Popper's definition theory is entirely convincing as opposed to that proposed by Aristotle.

Aristotle believed that the main target of science is finding and describing the essence of things (Büttemeyer, 2005). And "[a] definition is a phrase signifying a thing's essence" (Aristotle, trans. 1984, p. 385). Therefore, Popper (2013) has called Aristotle's methodology 'essentialism' and his definitions 'essentialist definitions'. Consequently, in Aristotle's view "definitions are the principles from which all our knowledge is derived; they thus contain all our knowledge" (Popper, 2013, p. 231). But while essentialist definitions are of prime importance in Aristotle's essentialism, playing a vital role in science (Popper, 2013), Popper (2013) believes that definitions used in science are not essentialist definitions rather they are what he refers to as 'nominalist definitions' and nominalist definitions do not play a significant role in science. Nominalist definitions are "shorthand symbols or labels … introduced in order to cut a long story short" (Popper, 2013, p. 230). Some of the major differences between Aristotle's and Popper's views on definition, as mentioned by Popper (2013) are as follows:

1. Reading direction

In essentialist view we read a definition from the left to the right, i.e., from a short label to the defining formula.

e.g., a puppy → a young dog.

Here we are asking 'What is a puppy?' which is an essentialist question since we are asking about the essence of a puppy. But Popper (2013) believes in the opposite, i.e., a definition must be read from the right to the left; starting with the defining formula and asking for a short label.

e.g., a puppy ← a young dog

Here we are asking 'What shall we call a young dog?' So here we are trying to find a shorthand label or a name to refer to 'a young dog'. Therefore, Popper (2013) has called his definition nominalist.

2. Eliminability

To Aristotle, definitions used in science are essentialist definitions containing all our knowledge, and hence ineliminable (Popper, 2013). But Popper (2013) believes that the language of science should include nominalist definitions which are eliminable because the only effect of their elimination would be "upon our language, which would lose, not precision, but merely brevity" (Popper, 2013, p. 231). Therefore, in his view, "all definitions can be omitted without loss to the information imparted" (Popper, 2013, p. 234). Popper (2013) believes that the development of science depends on our ability to get rid of Aristotle's definition theory as it has exerted a destructive influence on disciplines using it, leaving them "arrested in a state of empty verbiage and barren scholasticism" (Popper, 2013, p. 226). Yet, according to Büttemeyer (2005), while Popper (2013) has severely criticized Aristotle's essentialist definition, his critical remarks themselves are neither quite clear nor comprehensive. For example, Popper (2013) has criticized the epistemological function of essentialist definitions, i.e., their function of conveying knowledge. To solve this issue (which to him is a problem), he has introduced knowledge-free nominal definitions with brevity as their sole function. Yet, according to Büttemeyer (2005), at the same time he is trying to relate an epistemic role to nominalist definitions. Therefore,

the same criticism can be applied to his own method. Moreover, his demand for the arbitrariness of nominalist definitions and his demand for their unambiguousness are jointly incompatible (Büttemeyer, 2005). And above all, Popper's idea that only nominalist definition should appear in science is unjustifiable because his recommended nominalist definitions do not provide us with any method of clarification of concepts (Büttemeyer, 2005). Furthermore, "[n]ominalist definitions based only on exemplified or ostensive terms are not sufficient for the constitution of a workable scientific language" (Büttemeyer, 2005, p. 24). All these issues point to the inadequacy of Popper's (2013) nominalist definitions in meeting the requirements of scientific language. Therefore, because of these issues and because "Aristotle and the Aristotelian definition is still the prototypical form of definition" (Hebenstreit, 2009, p. 12, italics removed), Aristotle's definition theory has been chosen in this study. Also, more reasons have been provided in view of this theory's potentials to provide inclusive and exclusive definitions. Because two of the requirements of a formal definition are that it should be both inclusive and exclusive. That is, such a definition should encompass all the individual cases under its purview but, at the same time, establish a borderline between those cases and everything else (Hermans, 2013).

Aristotle's Definition Terminology

To understand Aristotle's approach some relevant terminology should be clarified here. The object of the definition is referred to as 'definiendum', and the definition's explanatory content as 'definiens' (Hebenstreit, 2009). Following his essentialist approach, "Aristotle considers the term to be defined [i.e., definiendum] as a name of the essence of a thing, and the defining formula [i.e., definiens] as the description of that essence" (Popper, 2013, p. 227). To Aristotle (Aristotle, trans. 1984), the main sources through which we can get the knowledge of a thing are its principles, causes, and elements. And the best way to reach such knowledge would be to advance from universals to particulars. Aristotle believes that this movement from universals to particulars is also observable in a child learning its mother tongue when a child at first calls all men father, and all women mother, but distinguishes each of them later on. So, to Aristotle, the same movement from universals to particulars should be used for definitions. Therefore, he holds that definitions are "representing both universal (genus) and particular (differentia/difference) features of the object they define" (Pilkington, 2019a, p. 585) and "[t]here is nothing in the definition except the first-named genus

and the differentiae" (Aristotle, trans. 1984, p. 3524). Consequently, in his view "[t]he *definiens* has two obligatory constituents: the *genus proximum* (the nearest superior concept) and the *differentiae specificae* (the characteristics that make it possible to distinguish between the *definiendum* and its *genus*)" (Hebenstreit, 2009, p. 12, italics in the original). Put simply, genus is the 'class' and differentia is the 'difference' (Pilkington, 2019b). "For Aristotle, a formal definition is technical and uses technical terminology, and it is expressed in terms of generic nature and differentiae" (Husain, 2002, p. 47). Therefore, to him, a formal definition has three parts: the term to be defined, genus, and differentia/e. Pilkington (2019b) has mentioned the following example from du Sautoy (2011) as an instance of a prototypical Aristotelian definition based on the class and difference:

"The place-value system ... is a way of writing numbers so that the position of each digit corresponds to the power of 10 that the digit is counting" (Du Sautoy, 2011, p. 20).

Here the class/genus "is represented by the phrase 'a way of writing numbers,' which gives you very general information about the subject (the place-value system). The difference—the end of the definition—provides more specifics" (Pilkington, 2019b, p. 31). "And it is easier to define the particular than the universal—that is why one should cross from the particulars to the universals"[2] (Aristotle, trans. 1984, p. 365).

Aristotle's Rules for Definition

When defining terms based on Aristotle's theory, certain rules should be observed. An Aristotelian definition should:
1) state the essential attributes of the term, 2) not be circular[3], 3) not be too broad or too narrow, 4) not be unclear or figurative, 5) be stated positively if possible, and 6) be of the same part of speech as the term ("*Introductory logic*", 1997, p. 35).
Aristotle "insists that the defining formula must give an *exhaustive* description of the essence or the essential properties of the thing in question" (Popper, 2013, p. 227, emphasis added). At the same time he believed that "[a] definition should not be too broad nor too narrow" ("*Introductory logic*", 1997, p. 34). These two Aristotelian beliefs indicate that a definition "should be both inclusive and exclusive" (Hermans, 2013, p. 75). But how can we make sure that an Aristotelian definition is both inclusive and exclusive? This is where the principle/law of non-contradiction (PNC) can play a significant role.

Aristotle has introduced this principle[4] in his Metaphysics (Aristotle, trans. 1984). "There are

arguably three versions of … [PNC] to be found in Aristotle: an ontological, a doxastic and a semantic version" (Gottlieb, 2019, "1. Three Versions of the Principle," para. 1). But its "first version … is usually taken to be the main version of the principle" (Gottlieb, 2019, "1. Three Versions of the Principle," para. 1), and it is as follows: "It is impossible for the same thing to belong and not to belong at the same time to the same thing and in the same respect" (Aristotle, as cited in Gottlieb, 2019, "1. Three Versions of the Principle," para. 1). Its third version[5] states that "opposite assertions cannot be true at the same time" (Aristotle, as cited in Gottlieb, 2019, "1. Three Versions of the Principle," para. 7). It should be mentioned that "the idea that opposite assertions cannot be true at the same time suggests that this third version is better interpreted as a variant of the first formulation" (Gottlieb, 2019, "1. Three Versions of the Principle," para. 7). Put simply, PNC "says that *a statement cannot be both true and false*" ("*Introductory logic*", 1997, p. 4, italics in the original).

PNC is "the foundation for all other logical principles, [and] its truth must be presupposed for any subsequent rational thought" (Karuzis, 2010, p. 231). "[F]ormal definitions and the statements that define them are captured, very simply, by [this principle]" (Sell, 2018, p. 10). To Aristotle, "[a] definition is a phrase signifying a thing's essence" (Aristotle, trans. 1984, p. 385). And a necessary condition for such a definition is PNC (Hudry, 2013). So, with PNC in view, "[a] definition of any term, x, is a formal definition if and only if it frames what is necessary and sufficient for the identification of x and not x" (Sell, 2018, p. 10). PCN can, therefore, set a limit on what something "means and what it does not mean" (De Praetere, 1993, p. 357). Therefore, Aristotle through applying this principle and using genus and differentia in the definition has made an effort to make definitions both inclusive and exclusive.

Towards a Formal and Consensual Aristotelian Definition of Learning

Defining concepts in a satisfactory way is an onerous task. This problem gets graver for concepts that are broad and abstract, such as the concept of learning (De Houwer et al., 2013). To avoid such difficulties, some scholars have tried to define learning from just one vantage point. For example, De Houwer et al. (2013) have tried to define learning not in terms of mental mechanisms but rather exclusively at functional levels. To do so, they defined "learning as ontogenetic adaptation—that is, as changes in the behavior of an organism that result from regularities in the environment of the organism" (De Houwer et al., 2013, p. 631). Yet

learning is complex and multifaceted; therefore, adopting a monolithic approach to its definition is too simplistic. This makes defining learning an arduous task. Consequently, in spite of myriads of definitions developed so far, still there is no consensus on its definition. Chronological citations of all these definitions would be interminable and hence beyond the scope of this study. Thus, mainstream definitions have been discussed here.

In most learning definitions, including that offered by De Houwer et al. (2013), the element of 'change/s in the behavior' can be seen. In fact, mostly, learning has been defined as "a relatively permanent change in behavior brought about by practice or experience" (Lachman, 1997, p. 477). This definition shows an orientation towards behavioral learning theories and it is problematic on several accounts. First, it is flawed because, according to Lachman (1997), changes in behavior are not necessary for learning to occur, i.e., the products of learning are not limited to changes in behavior. For example, in the classical conditioning the behavior remains constant (e.g., salivation) but it is brought about by a new (conditioned) stimulus (e.g., a tone) (Lachman, 1997). In the same vein, as far as the Aristotelian approach is concerned, it can be argued that such definitions are flawed since in them genus[6] (i.e., change/s in behavior) is not broad enough; therefore, such definitions are not inclusive of all different kinds of learning (e.g., conditional learning). Second, it can be argued that such definitions are invalid since learning can happen without practice as is the case with 'one-shot learning', which refers to learning from single exposure to a stimulus or a single training instance. This type of learning "is very different from incremental learning, in which new knowledge is acquired gradually through trial and error" (Weaver, 2015, p. 1). Yet it is a kind of learning which can be observed not only in humans but also in animals. In fact, as shown by Teyke (1995), even snails are capable of one-shot learning.

Later, in an attempt to apply the ideas of both behavioral and cognitive psychologists, learning was defined as: "Process through which experience causes permanent change in knowledge, or behaviour" (Woolfolk et al., 2003, p. 196). The inclusion of 'knowledge' has made this definition advantageous over the previous behavioristic definition. Yet, it can be argued that, the recognition that this change may neither be necessarily *completely* permanent nor limited to changes in knowledge and behavior resulted in modifications to be made to the definition of learning as: "Process through which experience causes a relatively permanent change in knowledge, attitudes, skills, or behavior" (Woolfolk & Margetts, 2013, p. 219). Lachman (1997) believes that a comprehensive

definition of learning should consider learning a process. Therefore, it can be argued that this definition, like its predecessor offered by Woolfolk et al. (2003), is advantageous over the behavioristic definition mentioned by Lachman (1997) because both of them consider "learning a process not to be confused with the products of learning" (Lachman[7], 1997, p. 479). Also both of them are advantageous because genera in them (i.e., 'knowledge, or behavior *change process*' and 'knowledge, attitudes, skills, or behavior *change process*' respectively) are rather more inclusive of different types of learning (in comparison to the behavioristic definition mentioned by Lachman, 1997). Yet these two latter definitions are still flawed on several accounts. First, it can be argued that both of them are beset with the same two problems raised by Lachman (1997), i.e., a) the inability to include all different types of learning (e.g., conditional learning) and b) the inability to distinguish "learning from other phenomena, such as sensory adaptation, muscular fatigue, the effects of injury, and the effects of maturation" (Lachman, 1997, p. 479). Therefore, such definitions are flawed since they are neither inclusive nor exclusive. Lachman (1997) believes that a comprehensive definition of learning should distinguish learning from other phenomena. Therefore, it can be argued that he concurs with Aristotle in the need for '(a) distinguishing element/s in a definition' or, to put in Aristotle's terms, 'differentia/e'. Yet although these two definitions have differentiae, they are not well-chosen. For example, both differentiae in Woolfolk and Margetts' (2013) definition (i.e., 'relatively permanent' and 'experience-induced') are inadequate on several accounts. First, the phrase 'relatively permanent' is itself vague as "[i]t is debatable how long changes must last to be classified as learned … [Even though] most people agree that changes of brief duration (e.g., a few seconds) do not qualify as learning" (Schunk, 2012, p. 4). Moreover, terms such as 'experience' and 'practice' are vague (Lachman, 1997). Furthermore, it can be argued that considering these terms as the causative factors responsible for learning is flawed since learning can happen without both practice (as already explained) and experience.

Learning can happen without experience. To prove such a claim, we have to first establish what is meant by experience. If we accept Dewey's (1934) definition that "[e]xperience is the result, the sign, and the reward of that interaction of organism and environment which, when it is carried to the full, is a transformation of interaction into participation and communication" (Dewey, 1934, p. 22), then 'interaction of organism and environment' is the requirement for experience, and hence necessary for those definitions of learning which are experience-dependent, such as those mentioned here.

But, in view of Dewey's (1934) definition of experience, it can be argued that learning can happen without experience because there are subjects/disciplines which can be learnt totally, or at least in part, in an *a priori* fashion, (i.e., without experience). For example, both mathematics and logic are *a priori* (Lewis, 1923). In fact, "[s]ince Greek times it has been accepted almost universally that mathematics is an *a priori* science, that is to say, a science in which all the propositions can be established without appeal to experience" (Kneale & Kneale, 1971, p. 444, italics in the original). As a matter of fact, *a priori* learning plays a crucial role in the learning of new mathematical issues (Quigley, 2016). Such recognitions, consequently, "led philosophers to conceive the possibility of learning without experience" (Kneale & Kneale, 1971, p. 444). Therefore, using the term 'experience' in the definition of learning is not justifiable. Moreover, even if we define experience in other ways, still using this term in learning definition would be problematic. For instance, Schunk (2012) has referred to "practice, [and] observation of others" (Schunk, 2012, p. 4) as examples of experience. Therefore, apparently he has considered experience as a superordinate term which includes practice and/or observation of others. In that sense, again it can be argued that learning can happen without experience because learning can happen a) without practice (as already discussed), and b) without observation of others, e.g., *a priori* learning.

Schunk (2012) believes that "[l]earning involves acquiring and modifying knowledge, skills, strategies, beliefs, attitudes, and behaviors" (Schunk, 2012, p. 2). But this definition (if we accept this sentence as an attempt to define learning) is also problematic. Following Aristotle's definition theory, it can be argued that it has not provided any differentia for learning. Therefore, it does not distinguish learning from other incidents (see also Lachman, 1997).

In an effort to provide an improved definition, Lachman (1997) defined learning as "the process by which a relatively stable modification in stimulus-response relations is developed as a consequence of functional environmental interaction via the senses … rather than as a consequence of mere biological growth and development" (Lachman, 1997, p. 479). Although the second part has tried to distinguish learning from other incidents, such as the effects of maturation (Lachman, 1997), but following Aristotle's theory, it can be argued that this definition is still problematic. Of course, it has both genus and differentiae but they are not well-chosen. Following the Aristotelian traditional[8] approach, genus can be construed as 'stimulus-response relations *modification process*'. Such a genus, like that in the mainstream behavioristic definition mentioned by

Lachman (1997), is not broad enough, because it limits the cases of learning to the *modification* of *already established* stimulus-response relations while learning can also involve the formation of *new* stimulus-response relations (such as those involved in a child on the path of development). Moreover, the possibility of encountering totally new stimuli and responses and formation of brand new stimulus-response relations in later life is not remote. Furthermore, differentiae (i.e., 'relatively stable' and 'environmental interaction-induced') are also not well-chosen. First, because using unclear words, such as 'relatively stable', has also made this definition vague. And second, because attributing all the causative factors of learning to external factors (i.e., functional *environmental* interaction) excludes *a priori* learning, such as that involved in mathematics. Consequently, all definitions discussed are neither inclusive (because of choosing not broad enough genera) nor exclusive (because of choosing non-distinguishing differentia/e or lack of differentia/e).

Discussion and Conclusion

Although myriads of definitions have been provided for learning, still there is no consensus over it. Developing a consensual definition of learning would be an arduous task, yet such difficulties should not deter us from undertaking this enterprise. It will not succeed overnight or with one article. But from each academic work we can take lessons which can pave the way for approaching a consensual definition. In line with this objective, the following lessons can be drawn from the issues raised in this paper.

1. In Order to Reach a Consensual Definition of an Abstract Concept, Such as Learning, We Have to Abide by a Theory of Definition.

Attempts to reach a consensual definition of an abstract concept without rules and guidelines would be doomed to failure because definitions of such concepts "will inevitably be influenced by personal circumstances and experience" (Porte, 2002, p. 30); the definition of learning is no exception. One way to reduce the number of idiosyncratic definitions and get close to some consensus would be to adopt a theory of definition because such a theory establishes a framework for "the structure, roles, and goals of definitions and their usefulness" (Kublikowski, 2009, p. 231). Consequently, it will give our studies direction, coherence, and above all comparability. In this study we have abided by Aristotle's definition theory.

This approach to investigating definition based on a philosophical theory of definition is novel in the field of educational psychology. It can be used not only for the definition of learning but also for the definition of other abstract concepts across different disciplines. There are many studies which have investigated definition without resorting to a theory of definition (e.g., Vaneechoutte, 2000). This non-adherence to a definition theory is even observed in studies which are not negligent of the importance of considering philosophical aspects in their investigation (e.g., Luk, 2010). To investigate definitions in a scientific way and to be able to defend our adopted approach in a way that it cannot be criticized as being idiosyncratic and biased, this study recommends adopting a theory of definition along with other guidelines discussed.

2. To Choose a Theory of Definition, We Have to Search for Those Espousing Widely-held Objectives (Unless Otherwise Proven).

Although there are numerous definition theories, most of them follow (or wish to follow) similar objectives. For example, nearly all Aristotelian definition rules, e.g., those prohibiting the use of too broad, too narrow, circular, and vague definitions ("*Introductory logic*", 1997) are widely-held as they can be found in many logic books (e.g., Hurley & Watson, 2018). So we have to narrow down our definition theories to those espousing widely-held ideas, unless we have sufficient reasons for choosing an unorthodox theory. Then, we can choose one theory as framework but we have to provide compelling reasons for considering it as being advantageous over others. Also, when establishing objectives, we have to consider feasibility issues. Take, for instance, the widely-held idea that definitions should not be vague. As mentioned by Büttemeyer (2005), in line with the traditional theory of definition we can try to reduce ambiguities in our definition by using other words that are less vague or unambiguous. Yet we have to remember that we cannot define *all* words because, quite ironically as admitted by *both* Aristotle and Popper, such attempts would lead to an infinite regress (Büttemeyer, 2005). So while attempting to provide a scientific definition, we should not allow the term 'scientific' to entangle us in an infinite regress. Because, as explicitly stated by Aristotle, "all our scientific knowledge presupposes a (non-scientific) starting-point, the νους ˜ which enables us to formulate our definitions in the first instance … [hence] we cannot look for a definition for everything, especially not for the first parts of things" (Büttemeyer, 2005, p. 21, italics in the original).

3. Learning Is a Function of Both Nature and Nurture; Hence Learning Definition Should Include Both These Factors.

One of the problems with solely experience-based definitions of learning is that such definitions do not distinguish learning from other incidents, such as sensory adaptation, muscular fatigue, the effects of injury, and the effects of maturation (see also Lachman, 1997). Of course, to Shunk (2012) a definition of learning which includes experience as a causative factor is exclusive of behavioral changes chiefly regulated by heredity, like maturational changes in children (e.g., crawling, standing). But even he himself has accepted that "the distinction between maturation and learning often is not clear-cut. People may be genetically predisposed to act in given ways, but the actual development of the particular behaviors depends on the environment" (Schunk, 2012, p. 4). So that normal development enables children to crawl and stand, but the environment should also be reactive and let these behaviors happen. Children whose movements are forcibly stunted do not follow a normal path of development (Schunk, 2012). Therefore, it can be inferred that Schunk (2012), in line with the modern learning theories, believes that learning is a function of both nature and nurture; hence it can be argued that learning definition should include both these factors.

4. Adopting a Monolithic Approach to Defining Complex and Multifaceted Concepts, Such as Learning, Is Simplistic and Futile.

The boundaries between different disciplines were originally established to be used as mental scaffolding (Author). Scaffolding refers to "a system of *temporary* guidance offered to the learner by the teacher, jointly co-constructed, and then *removed* when the learner no longer needs it" (Boblett, 2012, p. 1, emphasis added). So disciplines boundaries were originally established because of the limitations of human beings' mental capacities; being far away from omniscience to delve into all disciplines simultaneously. "Yet this removal phase or the 'handover principle', as Bruner (1983) calls it, has usually been neglected in many mono-disciplinary studies" (Author). So disciplines boundaries are useful as long as long as they help us deal with one aspect of a concept. But for complex concepts, which are inextricably connected with others, disciplines boundaries are an inhibitor rather than a scaffolding technique.

The definition of learning, as a multifaceted concept, therefore, requires an interdisciplinary approach. In fact, as put by the Nobel Laureate, Richard Ernst: "There is no fruitful science without interdisciplinarity" (Grayson, 2010, p. S3). Therefore, to answer the question of what learning is, we have to consider the increasing merger of different fields trying to answer this question from different perspectives. These different fields are independently contributing to developing a multidimensional understanding of the concept of learning (Uncapher, 2019). It can be argued that the growing recognition of this need led to the emergence of a new interdisciplinary discipline called "[l]earning sciences [which] was born in 1991" (Sawyer, 2008, p. 46). "Learning sciences is an interdisciplinary field that studies teaching and learning" (Sawyer, 2008, p. 45). It includes "cognitive science, educational psychology, computer science, anthropology, sociology, information sciences, neurosciences, education, design studies, instructional design, and other fields" (Sawyer, 2008, p. 45). "[T]he collaboration among these disciplines has resulted in new ideas, new methodologies, and new ways of thinking about learning" (Sawyer, 2008, p. 45). Such new insights from many different disciplines are merging to establish a new science of learning which may revolutionize educational practice (Meltzoff et al., 2009).

5. In Line With Favouring an Interdisciplinary Approach to Defining Multifaceted Concepts, Other Disciplines' Terminologies Can Be Used in Their Definitions.

Adopting an interdisciplinary approach leaves no room for avoiding definitions which are using terminologies from diverse disciplines. It does not imply a disciplinary bias towards those disciplines whose terminologies have been given priority in our definition rather it means no strict abidance to a specific discipline when its present terminology is not capable of providing better definitions. This approach is not only orthodox but also is getting more increasingly conventional and rather inevitable. For example, decades ago using philosophical, psychological, sociological, medical, or cognitive science terms in applied linguistics would sound unorthodox. Yet nowadays terms, such as agency, operant conditioning, critical theory, aphasia, neural networks, respectively coined/used in these disciplines, are neither unfamiliar to nor unpracticed by applied linguists. In fact, applied linguistics could not have been so booming without the valuable contributions made in other disciplines. The definition of this field as a discipline which "uses information from sociology, psychology, anthropology, and information theory as well as from linguistics in order to develop its own theoretical models" (Richards & Schmidt, 2010, p. 29)

is reflecting this view. So future learning definitions might use unfamiliar technical terms.

6. Although We Have to Make Collective Effort to Improve Conceptual Definitions of Learning, Operational Definitions Should Also Be Given the Same Emphasis.

Constructs may be defined in two ways: 1) constitutive/conceptual definition, and 2) operational definition (Ary et al., 2010). Although constitutive definition "helps convey the general meaning of a construct, but it is not precise enough for research purposes" (Ary et al., 2010, p. 36). In fact, there are many cases when "researchers talk about the same term, [but] they had totally different conceptualizations and therefore measurements" (Sell, 2018, p. 10). Such different conceptualizations of the same term make clear replication problematic (Sell, 2018). Therefore, especially in quantitative research and as one of the means of achieving validity (Riazi, 2016), operational definitions which ascribe "meaning to a construct by specifying operations that researchers must perform to measure or manipulate the construct" (Ary et al., 2010, p. 36) are needed.

7. Defining an Abstract Concept, Such as Learning, Requires Not Only a Theory of Definition but Also a Theory of That Concept.

Definitions are theory-dependent. They can be analyzed and evaluated most favorably in the context of the theory of the concept being defined (Zins, 2007). The same holds true for both conceptual and operational definitions[9]. So learning definition should be theory-dependent; prior to developing a learning definition we have to choose a learning theory. But developing such a theory in the field of humanities is difficult because "[h]uman nature is much more complex than the sum of its many discrete elements, even if they could be isolated and identified" (Best & Kahn, 2006, p. 7). Nevertheless, such a difficulty should not deter us from choosing a theory. To do so, first, we have to "recognise the philosophical underpinnings of all theories of learning" (Jarvis, 2006, p. 3) because one of the key concepts upon which a learning theory is based is epistemology (Harasim, 2012). And, put simply, epistemology refers to the philosophy of knowledge or the way we come to know something (Harasim, 2012). Therefore, prior to developing a learning definition we have to specify our "particular view of knowledge or epistemology that sets the context for the theory. Is knowledge a form of "truth" as objectivists claim, or does knowledge undergo changes over time through scientific debate and new

information, as constructivists content?" (Harasim, 2017, p. 1).

All in all, it has to be added that aside from the Aristotelian ideas about the importance of definitions, considering them as principles from which all our knowledge is derived (Popper, 2013), formal definitions are assumed to play a pivotal role. To put in Sell's (2018) words, such "definitions are the foundation for formal theories, but … even if you are a postmodernist who is suspicious of the whole scientific enterprise, formal definitions are important vehicles for advancement" (p. 8). Developing consensual formal definitions is important in all disciplines because different conceptualizations of the same concept reflect idiosyncrasies and personal bias. With blurring the hypothetical boundaries between different disciplines and interdisciplinarity movement (Author) this need is getting more and more axiomatic and when it comes to the key concept of learning it is even much more strongly felt.

This study has tried to demystify the concept of learning by establishing a connection between educational psychology and philosophy, yet its findings can be generalized to different concepts across different disciplines. Moreover, although this study is encouraging using Aristotle's definition theory as part of a framework for definition studies, it is not biased since it does not consider this theory as the only option. Surely, Aristotle's theory has its own critics. Theories are fallible since, by nature, they are not definitive. So if future studies can find some shortcomings in Aristotle's theory, they can either modify this theory or recommend a more comprehensive theory (if they can develop or find such a theory). The same holds true for learning theories. So this study gives future researchers some leeway to make their own choices, of course, as long as they can justify the advantages of their choices over other theories. Therefore, the major intention of this study is establishing a framework to be used as a *blueprint* for future definition studies. This framework is not foolproof, and it does not avoid challenge. Using a framework for definition studies, though, is more probably foolproof. In fact, future studies should compete to provide the most comprehensive framework possible. All in all, we have to keep in mind that "although an 'unbiased' [and non-idiosyncratic] science may be impossible, there are many mechanisms scientists can adopt for protecting their reasoning against undesirable forms of bias" (Reiss & Sprenger, 2017, "7. Conclusions," para. 3). Adhering to the guidelines developed in this study or similar guidelines is one of such mechanisms. It is only then that we can claim we are on the right track; not lost in the barren of our

personal bias and idiosyncrasies. Otherwise developing a consensual definition would be implausible.

Notes

Dubislave's (1931) four main theories of definition, as summarized by Dewey and Bentley (1949), are: the Aristotelian essence and its successors to date; the determination of concepts; the fixation of meanings, historical and juristic; and the establishment of new signs.

Some have considered this sentence to be in contradiction to Aristotle's idea that "we must advance from universals to particulars" (Aristotle trans., 1984, p. 700). "This is the contradiction, or apparent contradiction, between what Aristotle says here … and what he says [elsewhere] …as to whether the universal is the first thing we grasp or comes later in the process of acquiring understanding" (Philoponus trans., 2006, p. 3). It still remains a puzzle although some ancient philosophers, such as Philoponus, have tried to offer solutions to rescue Aristotle's consistency (see Philoponus trans., 2006).

It means "[t]he word being defined should not be used as part of the definition" ("*Introductory logic*", 1997, p. 34).

It should be noted that although this principle has been conceptually established by Aristotle, "the expression 'principle of non-contradiction' … is nowhere to be found in Aristotle's works" (Hudry, 2013, p. 51).

The second version of PNC states: "It is impossible to hold (suppose) the same thing to be and not to be" (Aristotle, as cited in Gottlieb, 2019, "1. Three Versions of the Principle," para. 2). This version is doxastic and ambiguous (Gottlieb, 2019), therefore, it is not the concern of this study.

It should be mentioned that learning definitions investigated in this study have not originally been offered based on Aristotle's theory; therefore, they do not "accord well with Aristotle's preferred method of defining kinds in terms of a genus and a differentia. For it is not [perfectly] clear what in the definition serves as the genus and what serves as the differentia" (Studtmann, 2008, p. 45). Nevertheless, whenever possible, the traditional Aristotelian approach for distinguishing genus and differentia has been adopted. In this approach "genus and differentia are generally given a substantival and an adjectival form respectively" (Prior, 1949, p. 14). Therefore, 'change/s in behavior' has been considered as the genus. And the differentiae are the adjectives qualifying this substantive, i.e., a) relatively permanent, b) practice-induced, and c) experience-induced.

Of course, it should be noted that Lachman's (1997) criticisms have been made against a behavioral view of learning, i.e., viewing it as "a relatively permanent change in behavior brought about by practice or experience" (Lachman, 1997, p. 477). Nevertheless, some of them, like this one, can be attributed to both behavioral and cognitive views.

Again here the traditional Aristotelian approach for distinguishing genus and differentia (Prior, 1949) has been adopted. Therefore, 'stimulus-response relations *modification process*' has been considered as the genus. And the differentiae are the adjectives qualifying this substantive, i.e., a) 'relatively stable', and b) 'environmental interaction-induced' (to be precise, 'sensually and functionally environmental interaction-induced').

Conceptual definitions are also referred to as constitutive or *theoretical* definitions. Therefore, as their names suggest, they are theory-dependent and so are operational definitions. As stated by Best and Kahn (2006), "[t]o be useful … operational definitions must be based on a theory that is generally accepted" (p. 10).

References

Ary, D., Jacobs, L. C., & Sorensen, C. (2010). *Introduction to research in education*. Wadsworth, Cengage Learning.

Best, J. W., & Kahn, J. V. (2006). *Research in education* (3rd ed.). Pearson Education.

Boblett, N. (2012). Scaffolding: Defining the metaphor. *Teachers College, Columbia University Working Papers in TESOL & Applied Linguistics, 12*(2), 1-16. https://tesolal.columbia.edu/article/scaffolding-defining-the-metaphor/

Bruner, J. (1983). *Child's talk: Learning to use language*. Oxford University Press.

Büttemeyer, W. (2005). Popper on definitions. *Journal for General Philosophy of Science, 36*(1), 15–28. http://dx.doi.org/10.1007/s10838-005-6037-2

Cattrysse, P. (2014). *Descriptive adaptation studies: Epistemological and methodological issues*. Garant.

De Houwer, J., Barnes-Holmes, D., & Moors, A. (2013). What is learning? On the nature and merits of a functional definition of learning. *Psychonomic Bulletin & Review, 20*(4), 631-642. http://dx.doi.org/10.3758/s13423-013-0386-3

De Praetere, T. (1993). The demonstration by refutation of the principle of non-contradiction in Aristotle's metaphysics, book IV. *Logique & Analyse, 36*(143-144), 343-358.

Dewey, J. (1934). *Art as experience*. Perigree Books.

Dewey, J., & Bentley, A. F. (1949). *Knowing and the known*. Beacon Press.

Dubislav, W. (1931). *Die definition* (3rd ed.). F. Meiner.

Dubs, H. H. (1943). Definition and its problems. *The Philosophical Review, 52*(6), 566-577. http://dx.doi.org/10.2307/2181259

du Sautoy, M. (2011). *The number mysteries: A mathematical odyssey through everyday life*. Palgrave Macmillan.

Fetzer, J. H. (1991). Aspects of the theory of definition. In J. H. Fetzer, D. Shatz, & G. N. Schlesinger (Eds.), *Definitions and definability: Philosophical perspectives* (pp. 3-20). Springer Science.

Firey, T. A. (1999). *Socrates' conception of knowledge and the priority of definition* (Master's thesis). https://pdfs.semanticscholar.org/4038/e92063aa564512dbf2b76dd815b3a5502a56.pdf

Gottlieb, P. (2019). Aristotle on non-contradiction. In E. N. Zalta (Ed.), *The Stanford encyclopedia of philosophy*. https://plato.stanford.edu/archives/spr2019/entries/aristotle-noncontradiction/

Grayson, M. (2010). Introduction: Curiosity aroused. *Nature, 467*(7317), S2–S3. https://doi.org/10.1038/467S2a

Gupta, A. (2019). Definitions. In E. N. Zalta (Ed.), *The Stanford encyclopedia of philosophy*. https://plato.stanford.edu/archives/fall2019/entries/definitions

Harasim, L. (2012). *Learning theory and online technologies*. Routledge.

Harasim, L. (2017). Learning theories: The role of epistemology, science, and technology. In J. M. Spector, B. B. Lockee, & M. D. Childress (Eds.), *Learning, design, and technology: An international compendium of theory, research, practice, and policy* (pp. 1-39). Sprinter International Publishing.

Hebenstreit, G. (2009). Defining patterns in translation studies: Revisiting two classics of German translationswissenschaf. In Y. Gambier, & L. van Doorslaer (Eds.), *The metalanguage of translation* (pp. 9-26). John Benjamins Publishing Company.

Hermans, T. (2013). What is (not) translation?, In C. Millán & F. Bartrina (Eds.), *The Routledge handbook of translation studies* (pp. 75-87). Routledge.

Hudry, J. -L. (2013). Aristotle on non-contradiction: Philosophers vs. non-philosophers. *Journal of Ancient Philosophy, 7*(2), 51-74. http://dx.doi.org/10.11606/issn.1981-9471.v7i2p51-74

Hurley, P. J., & Watson, L. (2018). *A concise introduction to logic*. Cengage Learning.

Husain, M. (2002). *Ontology and the art of tragedy: An approach to Aristotle's poetics*. State University of New York Press.

Introductory logic: The fundamentals of thinking well (5th ed.). (1997). Canon Press.

Jarvis, P. (2006). *Towards a comprehensive theory of human learning*. Routledge.

Karuzis, J. (2010). The principle of non-contradiction in Aristotle's metaphysics. *International Journal of Arts and Sciences, 3*(16), 231-254.

Kneale, W., & Kneale, M. (1971). *The development of logic*. Oxford University Press.

Kublikowski, R. (2009). Definition within the structure of argumentation. *Studies in Logic, Grammar and Rhetoric, 16*(29), 229-244.

Lachman, S. J. (1997). Learning is a process: Toward an improved definition of learning. *The Journal of Psychology: Interdisciplinary and Applied, 131*(5), 477-480. http://dx.doi.org/10.1080/00223989709603535

Lewis, C. I. (1923). A pragmatic conception of the a priori. *The Journal of Philosophy, 20*(7), 169-177. http://dx.doi.org/10.2307/2939833

Luk, R. W. P. (2010). Understanding scientific study via process modelling. *Foundations of Science, 15*(1), 49–78. https://doi.org/10.1007/s10699-009-9168-9

Maritain, J. (1937). *The degrees of knowledge* (B. Wall & M. R. Adamson, Trans.). Geoffrey Bles.

Meltzoff, A. N., Kuhl, P. K., Movellan, J., & Sejnowski, T. J. (2009). Foundations for a new science of learning, *Science, 325*(5938), 284-288. http://dx.doi.org/10.1126/science.1175626

Pilkington, O. A. (2019a). Definitions of scientific terminology in popular science books: An examination of definitional chains. *Science Communication, 41*(5), 580-601. http://dx.doi.org/10.1177/1075547019861397

Pilkington, O. A. (2019b). *The language of popular science: Analyzing the communication of advanced ideas to lay readers*. McFarland & Company, Inc., Publishers.

Policano, D. (2018). The beginning of good data is the definition of terms. *Stanford Social Innovation Review*. https://ssir.org/articles/entry/the_beginning_of_good_data_is_the_definition_of_terms

Popper, K. (2013). *The open society and its enemies*. Princeton University Press.

Porte, G. K. (2002). *Appraising research in second language learning: A practical approach to critical analysis of quantitative research*. John Benjamins Publishing Company.

Prior, N. (1949). Determinables, determinates and determinants. *Mind, LVIII*(229), 1-20. http://dx.doi.org/10.1093/mind/LVIII.229.1

Quigley, S. C. (2016). *Improving opportunities for mathematical learning amongst students identified as having behavioural, emotional and social difficulties within a special school environment* (Doctoral dissertation). http://sro.sussex.ac.uk/id/eprint/69052/

Reiss, J., & Sprenger, J. (2017). *Scientific objectivity*. In E. N. Zalta (Ed.), *The Stanford encyclopedia of philosophy*. https://plato.stanford.edu/archives/win2017/entries/scientific-objectivity/

Riazi, A. M. (2016). *The Routledge encyclopedia of research methods in applied linguistics: Quantitative, qualitative, and mixed-methods research*. Routledge.

Richards, J. C., & Schmidt, R. (Eds.). (2010). *Longman dictionary of language teaching and applied linguistics*. Pearson Education Ltd.

Robinson, R. (1965). *Definition*. The Clarendon Press.

Sager, J. C. (2000). *Essays on definition*. John Benjamins Publishing Company.

Sawyer, R. K. (2008). Optimising learning: Implications of learning sciences research. In OECD (Ed.), *Innovating to learn, learning to innovate* (pp. 45-65). Centre for Educational Research and Innovation.

Schunk, D. H. (2012). *Learning theories: An educational perspective* (6th ed.). Pearson Education.

Sell, J. (2018). Definitions and the development of theory in social psychology. *Social Psychology Quarterly, 81*(1), 8–22. http://dx.doi.org/10.1177/0190272518755335

Studtmann, P. (2008). *The foundations of Aristotle's categorial scheme*. Marquette University Press.

Teyke, T. (1995). Food-attraction conditioning in the snail, Helix Pomatia. *Journal of Computational Physiology A, 177*(4), 409–414. http://dx.doi.org/10.1007/BF00187477

Uncapher, M. R. (2019). From the science of learning (and development) to learning engineering. *Applied Developmental Science, 23*(4), 349-352. http://dx.doi.org/10.1080/10888691.2017.1421437

Vaneechoutte, M. (2000). Experience, awareness and consciousness: Suggestions for definitions as offered by an evolutionary approach. *Foundations of Science, 5*(4), 429–456. https://doi.org/10.1023/A:1011371811027

Veltman, K. H. (2004). Towards a semantic web for culture. *Journal of Digital Information, 4*(4), 1-87.

von Mettenheim, C. (1999). The problem of objectivity in law and ethics. In I. Jarvie, & S. Pralong (Eds.), *Popper's open society after fifty years: The continuing relevance of Karl Popper* (pp. 110-126). Routledge.

Walton, D. (2005). Deceptive arguments containing persuasive language and persuasive definitions. *Argumentation, 19*(2), 159-186. http://dx.doi.org/10.1007/s10503-005-2312-y

Weaver, J. (2015). How one-shot learning unfolds in the brain. *PLOS Biology, 13*(4), e1002138, 1-2. http://dx.doi.org/10.1371/journal.pbio.1002138

Woolfolk, A. E., Winne, P. H., & Perry, N. E. (2003). *Educational psychology* (2nd ed.). Pearson Education Canada Inc.

Woolfolk, A., & Margetts, K. (2013). *Educational psychology* (3rd ed.). Pearson Australia.

Zins, C. (2007). Conceptual approaches for defining data, information, and knowledge. *Journal of the American Society for Information Science and Technology, 58*(4), 479-493. http://dx.doi.org/10.1002/asi.20508