Chapter 13
Knowledge Building Conceptualisation within Smart Constructivist Learning Systems

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Abstract This chapter focuses on the meeting of Constructivism (as a learning theory) and Smart Learning and, thus, theorises Smart Constructivist Learning. The main field of research is Smart Learning Environments. Relying on the phenomena of 'meaning construction' and 'meaningful understanding production' in the framework of smart constructivism, we will focus on analysing Smart Constructivist Knowledge Building. Accordingly, we will analyse Learning-and-Constructing-Together as a smart constructivist model of learning. The outcomes of this chapter could support the developments of smart learning strategies.

Keywords Smart learning · Constructivism · Meaning · Understanding · Knowledge building · Collaborative learning · Philosophy of education

13.1 Introduction and Motivation

The process of knowledge building leads to changes in humans' minds. In the context of cognitive developmental psychology, conceptual change is a type of process that focuses on the conversion of a human's conceptions and the relationships between her/his old and new conceptions [1, 2]. Thus, the most salient effect of knowledge building could be recognised to be on conceptual change of the learners'/mentors' conceptions over the course of time. We begin this chapter with our special focus on the fact that knowledge acquisition (that is the most determinative process within knowledge building processes) is a reflective activity that enables learners and mentors to draw upon their previous (and accumulated) experiences and reflect on their background as well as existing knowledge [3]. The reflective activity of knowledge acquisition supports learners and mentors in reflecting on themselves, on their society, and on their environment. Knowledge

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acquisition enables learners and mentors to conceptualise and understand. Subsequently, it enables learners to evaluate both their present and past, so as to build up and shape their future actions (i.e., operations, practices, proceedings, movements, contributions and manners) as well as to construct and develop the construction of their latest pre-structured and pre-constructed knowledge. As described, 'understanding' has been recognised as the consequence of 'conceptualisation'. Our research [4, 5] has concluded that "an understanding could be realised to be a local manifestation of a global conceptualisation".

It is important to account for the fact that human beings become concerned with various construction processes over their pre-formed knowledge in order to obtain the opportunities necessary to develop their constructed knowledge and to produce their deeper understandings (i.e., meaningful comprehensions). Constructivist Learning (based on constructivist epistemology and constructivist models of knowing) has become the central framework of this research. Relying on this framework, our supposedly theoretical model of learning deals with how knowledge can assumedly be built by a learner/mentor. Through the lens of cognitive psychology, Piaget's developmental theory of learning says that constructivist knowledge acquisition, as well as knowledge building, is concerned with how an individual goes about the construction of knowledge in her/his own mental apparatus [6, 7]. Accordingly, for any learner or mentor, knowledge acquisition could be recognised as seeking knowledge regarding different objects, processes, events, and phenomena with regard to her/his background knowledge. As for the structural and existential characteristics of constructivism, the construction of knowledge is conceived of as a type of dynamic process. It can be informally described in terms of personal understanding in multiple actions. Consequently, constructivist learning is highly concerned with the active generation of personal understanding [5, 8].

This chapter focuses on 'Smart Constructivist Learning Systems', which are a specific sub-class of constructivist learning systems where 'constructivism' meets 'smart learning'. In accordance with the subject of this book, though, we look at the area of 'Smart Learning Environments'. According to [9], "smart education represents an integration of smart objects and systems, smart technologies, smart environments, smart features (smartness levels), smart pedagogy, smart learning and teaching analytics systems". Relying on the framework of smart education, we will focus on the development of a conceptual framework for analysing knowledge building in the framework of smart constructivism and over the flow of the learners' understandings. Correspondingly, we will characterise the main components of a smart constructivist pedagogy (and a smart constructivist model of learning). It may justifiably be assumed that the outcomes of this chapter will support designing and developing innovative learning and mentoring strategies as the products of smartness. We will conceptualise and prove that there are strong interrelationships between 'smart constructivist model of learning' and 'collaborative learning strategy'.

According to [9, 10], research in the area of smart learning systems should not only focus on software/hardware/technology features, but also on smart 'features' and the 'functionality' of smart systems. Furthermore, in order for smart learning systems to be effective and efficient for different learners, or mentors, there are certain smartness levels (smart distinctive features). The most significant feature in this research is analysing the phenomenon of 'smart learning' in the framework of constructivism. It focuses on acquiring new knowledge and building on existing knowledge. Also, this research aims to identify and recognise the concept of 'understanding' toward the awareness of learners. Therefore, this chapter will be highly concerned with the 'learning/self learning' feature. Additionally, our approach will rely on logical descriptions using, e.g., assumptions, implications, and different logical rules over conceptual analysis of the phenomenon of 'smart learning' and the concept of 'understanding'. Due to this, this research is effectively structured over logical reasoning processes and could support researchers' thoughts for the development of inferential and logical reasoning processes within smart learning systems.

Note that this research has been designed based on our own approaches to the analysis of 'meaning construction' and 'understanding production' processes [8, 11–13]. Our ideas have been based on a new scheme for interpretation based on semantics and interaction. Interaction consists of (i) interactions between learner and her/his self, (ii) interactions between learner and other agents (e.g., mentors, other learners, and smart programs), and (iii) interactions between learner and her/his environment.

13.2 Background of Thought

In this research, our conceptualised scheme for interpretation (based on semantics and interaction) will be analysed in the framework of smart constructivism. In our opinion, learning in the framework of constructivism is highly concerned with the active generation of personal meaningful understandings. This is based on personal constructed meanings and over personal mental objects. More specifically, we believe that the phenomenon of 'understanding' could be valid (and meaningful) based on learners' constructed meanings. In fact, this belief is the main building block of this research. This means that this chapter is specially concerned with 'meaning construction', 'meaningful understanding production', and 'knowledge construction' in the framework of smart constructivism. We strongly believe that there is a bi-conditional relationship between 'understanding production' and 'meaning construction' in the framework of smart constructivism. Accordingly, it shall be claimed that the phenomenon of 'understanding' could be valid and meaningful based on learners' and mentors' constructed meanings in the framework of constructivism and, in the context of smart learning environments.

13.3 Constructivist Learning Systems: Literature Review

This section conceptualises the most significant and supportive characteristics of constructivist learning. In our opinion, the following items are the most fundamental. These can be shared by Constructivism and SmartNess:

a. Understanding the learner's understanding;
b. Respecting the learner's background knowledge;
c. Paying attention to the learner's understanding of personal learning; and
d. Focusing on the learners' and mentors' reliable universal knowledge in the context of their interactions.

In fact, these items could both conceptually and epistemologically relate the concept of 'Constructivism' to the phenomenon of 'SmartNess'. This section totally focuses on the concept of 'Constructivism'. The next section, subsequently, will focus on the actuality of the junction between constructivist learning and smart learning systems.

13.3.1 Understanding the Learner's Understanding

The most fundamental point is the concept of 'understanding'. This concept is very complicated and sensitive in psychology, neuroscience, cognitive science, cybernetics, philosophy, and epistemology. There has not been any absolute, decisive, or independent description and specification of 'understanding'. It is important to note that (i) we can potentially describe our grasp (and our conceptions) of the concept of 'understanding', e.g., [14]. This is relying on the fact that it is possible to support the realization of understanding within various specific areas. Furthermore, (ii) we could describe 'understanding' in order to support its representation (e.g., [15, 16]). Finally, (iii) some descriptions could focus on specifying the components and constituents of understanding (i.e., from the perspectives of cognition and affects) [17–23]. We believe that the first item is the most crucial one. In addition, it shall be claimed that (ii) and (iii) could logically be subsumed under (i).

Let us now focus on our own realisation of the concept of 'understanding'. Assessing from the epistemological point of view, it could be concluded that there has always been a very strong bi-conditional relationship between 'understanding something' and 'explaining something'. The dependency between understanding and explanation is considerable in analytic sciences (e.g., mathematics, physics, chemistry, biology, computer science) as well as in the humanities and social sciences. The explanation or the actual explaining of a phenomenon (an object, event, or process) can shed light on the produced personal understanding of that thing. The relationship between understanding and explanation is bi-directional. Therefore, there is also a path from understanding to explanation. In fact, the well-understood phenomena could be explained more properly in order to be interpreted and realised by other agents (mentors and other learners). It is worth mentioning that there have been some descriptive models that focus on the concepts of explanatory proofs and explanatory systems along with their interrelationships with the concept of 'understanding' [24].

In our opinion, "a human being who tackles to understand something—directly or indirectly—becomes concerned with the taxonomy of various concepts relevant for that thing, and thus, she/he needs to move toward the chain of various related concepts in order to approach to the more specified concepts" [12]. Additionally, she/he must be able to propose strong explanations of those related concepts. We shall, therefore, say that 'concept' and 'generality' could be interpreted as the most significant ideas that could support the structuralist account of understanding and could support understanding the concept of 'understanding'. Consequently, constructivist learning (based on a constructivist epistemology and constructivist models of knowing) is highly concerned with an individual's knowledge building processes based on her/his own produced understandings. The constructivist learning systems make the learners and the mentors concerned with the understanding of more specific concepts with regard to the special focuses on their understanding of more general concepts. In fact, the constructivist learning systems focus on developing the concept of 'understanding of more specific concepts'.

13.3.2 The Importance of the Learner's Background Knowledge

Any background knowledge, by activation, becomes actualised and directed to the more-developed construction of knowledge. Living and experiencing different things are the first metaphorical teachers of all human beings. Additionally, in the context of learning environments, background knowledge could be defined as knowledge that learners have. This may come either from their previous learning environments and learning materials or from their own life experiences [25, 26]. Constructivist learning systems focus on knowledge building over learners' background knowledge. In fact, through the lens of constructivism, the concept of 'learning' is seen as the 'process of construction' over personal background knowledge. Furthermore, constructivism focuses on the individual learners' comprehensions of their own objectives with regard to insights based on their background knowledge. The theory of constructivism could also focus on the individual mentors' comprehensions of their own objectives with regard to insights based on their background knowledge and on knowledge of what will be taught.

13.3.3 The Learner's Understanding of Personal Learning

Here, the focus is on learners' conceptualisations and realisations of the phenomenon of 'learning' (e.g., [27–29]). More clearly, learners are concerned with (i) their own conceptions of the phenomenon of 'learning', as well as their conceptions of their personal learnings, and with (ii) the reflection of their personal learning on themselves and society. It shall be stressed that the most significant matter in constructivist learning is transforming the phenomenon of 'learning' into the constructions of knowledge. In fact:

- Constructivism focuses on transformation of the phenomenon of 'learning' into the learners' comprehensions of their personal constructed meanings.
- Constructivism focuses on transformation of the mentors' comprehensions of their personal constructed meanings into the phenomenon of 'mentoring'.

13.3.4 The Learner's and Mentor's Reliable Universal Knowledge in the Context of Their Interactions

Constructivist learning could work as an explanatory, heuristic, and developmental framework. It must be considered that there exists a kind of reliable global and universal knowledge between constructivist learners and constructivist mentors. It is constructed and developed by both groups. For example, this knowledge evolves in learners' and mentors' action-grounded conversational exchanges [30, 31]. According to our research in [8], the produced meanings by learners and mentors support the constructions of their own worlds. Subsequently, regarding Laurillard's conversational learning framework [32, 33], the learners' and the mentors' constructed worlds become interacted and the learner-mentor interactions manifest themselves between their constructed worlds. The outcomes of these interactions become reflected in the learners' and the mentors' conceptual knowledge that support their reliable universal knowledge. These processes express how the constructed meanings could be reflected in their constructed reliable universal knowledge.

13.4 Smart Constructivism: Research Project Objectives

This section, based on the identified concepts in the last section, investigates some conceptual and epistemological linkages between constructivist learning and smart learning systems. The conclusions could potentially express how educationalists and educators in smart learning environments could benefit from constructivist learning systems.

13.4.1 Smart Constructivism: Understanding the Learner's Understanding

As mentioned, we believe that comprehending the learner's understanding is the most crucial conception relevant to the concept of 'understanding'. According to [34], 'learning behaviour and learning pattern analysis' could be one of the most significant research issues of smart learning. It shall be taken into consideration that these outcomes are applicable to understanding learners' behaviours and learning patterns in the integrated real-world and virtual-world environments. Comprehension of learners' understandings, as the consequences, could support educationalists and educators in designing and developing more effective learning strategies. In fact, this issue is a very good example of grasping the idea of learners' understanding within smart learning environments.

In addition, we interpreted the concepts of 'concept' and 'generality' as the most significant concepts that could support the structuralist account of understanding and comprehending the concept of 'understanding'. Taking into consideration the concept of 'generality', the smart learning approaches must motivate deeper and more complicated levels of learners'/mentors' understandings. Accordingly,

- supporting any individual learner in producing her/his own deeper understanding of the world, and
- supporting any mentor in producing her/his own deeper understanding of the learners' understandings and of the problems of the learners

could be considered the most important objectives of smart learning systems. The most salient characteristic of smart constructivist learning systems is their special attention to the learners' understandings and, respectively, to the mentors' understandings, with respect to their own produced meanings and with regard to their own generated meaningful understandings. An individual's understanding of more specific concepts could be achieved with regard to her/his understanding of more general concepts. For example, a learner's understanding of the concept of 'InductiveLogicProgramming' is absolutely dependent on and supported by her/his understanding of the concept of 'LogicProgramming'. Therefore:

i. Smart constructivist learning systems must focus on explaining more general concepts, and, inductively, move toward explaining more specific concepts.

Also, similar to what [34] suggests for recording the details of the students' learning behaviours, we can conclude that:

ii. Since smart constructivist learning systems respect the learners' and mentors' produced understandings of the world, these learning systems can record the individuals' understandings of the world. This can provide good opportunities for educationalists to achieve valuable understandings of the learners' understandings. Note that the educationalists, educational psychologists, and learning theorists could also achieve valuable understandings of the learners' and the mentors' understandings. Furthermore, the long-term analysis of multiple levels of the learners'/mentors' understandings can definitely support researchers in knowing more about the efficiencies and productivities of any smart educational system.

13.4.2 Smart Constructivism: The Learner's Background Knowledge

In the framework of smart learning, any learner must be informed about the learning program's objectives. Subsequently, she/he could be able to identify her/his personal objectives. Accordingly, she/he

- activates her/his background knowledge,
- compares her/his own objectives with the program's objectives,
- focuses on processing different kinds of information, and
- works on self regulating and organising her/his self.

We shall claim that activating background knowledge is the most crucial process within these processes. Furthermore, referring to [35] and relying on constructivist theory of learning, one of the most important characteristics of an effective, efficient, and engaging smart learning environment is one that can adapt to the learner/mentor and can personalise instruction and learning support. This characteristic is highly relevant to (i) the wide variety of learners with different levels of prior knowledge, different psychological backgrounds, and different interests, and (ii) the attitudes and policies of mentors with their background knowledge of any learning environment, their background knowledge of any learner, and their knowledge of what they are going to teach/train. It shall be concluded that:

- Smart constructivist learning systems must respect the learners' and the mentors' background knowledge and attempt to construct, as well as develop, knowledge over their existing background knowledge. These systems do not destruct or destroy the pre-constructed knowledge of learners. Rather, they only focus on repairing, mending, and developing.
- Smart constructivism must produce and develop a kind of self-organisation process for any learner with respect to her/his own insights. This can be based upon her/his life experiences, her/his previous learning experiences, and her/his identified personal objectives.
- Smart constructivist learning systems can adapt to any learner in order to support her/his learning process by suggesting her/him the right learning strategies with regard to her/his background knowledge. The outcomes could, to a very high degree, support and advance the learners' lifelong learning.

- Smart constructivist learning systems can be adapted to the mentors, the adaptive teachers, and smart programs, as well as personalise their own instruction and teaching strategies with regard to the personalised learning environments and the conceptualised learners.

13.4.3 Smart Constructivism: The Learner's Understanding of Personal Learning

In smart learning environments, any learner transforms the phenomenon of 'learning' into 'demonstrations of understanding of what she/he is learning'. Accordingly, the learner reflects on her/his own learning strategy and promotes it over time.

Smart constructivism must consider the transformation of the phenomena of 'learning' and 'mentoring' into knowledge constructions. Smart constructivist learning systems must support learners/mentors in reflecting their own conceptions of 'what they assume they have to do as learners/mentors' on their learning/mentoring processes, respectively, on their knowledge constructions, and, consequently, on themselves and on their society.

13.4.4 Smart Constructivism: The Learner's and Mentor's Reliable Universal Knowledge in the Context of Their Interactions

Smart constructivist learning systems must aim at supporting learners and mentors in developing their universal conceptual knowledge. By taking into consideration

i. the learners' constructed worlds,
ii. the mentors' constructed worlds,
iii. the learners' conceptual knowledge, and
iv. the mentors' conceptual knowledge,

smart constructivist learning systems must support the development of their reliable universal knowledge. It shall be stressed that any learner and any mentor can try to adapt the universal conceptual knowledge to her/his own constructed world. This means there is always a bi-directional relationship between 'own constructed worlds' and 'the universal conceptual knowledge' in the form of 'reflections' and 'adaptations', respectively.

13.5 Smart Constructivism: Methods Used in Research Project and Their Outcomes

13.5.1 Learners' Developing Conceptions of Learning in Smart Constructivism

This section focuses on learners' conceptions of the phenomenon of 'learning' and, subsequently, on their conceptions of the phenomenon of 'smart learning'. Note that any learner's conception(s) of the phenomenon of 'learning' play(s) a fundamental role in her/his study behaviour [29, 36]. Regarding behavioural and cognitive analysis of human beings' qualitative interpretations of the phenomenon of 'learning', any learner observes, interprets, and evaluates the world through the lenses of her/his own conceptions. In fact, the amalgamation of her/his mental images of the concept of 'smart learning' and her/his mental representations of the words 'smart' and 'learning' in 'smart learning' are manifested in the form of her/his conceptions. Accordingly, they are expressed in her/his actualisations and interpretations that all support her/his own understandings of smart learning. [37] provides information about the amalgamations of 'mental images' and 'linguistic expressions' regarding the philosophy of mind and language.

Note that the design and development of any smart constructivist learning system must be learner-centered [38]. Considering the significant importance of learner-centered analysis of the concept of 'smart learning' and in order to propose more analytic descriptions of smart learning, we need to put ourselves into the learners' shoes and observe the phenomenon of 'learning' from their perspective. Regarding this requirement, we take into account the significant products of [27–29]. The model sketches on Säljö's seminal studies on learners' conceptions of 'learning'. In more proper words, this model—qualitatively—focuses on adult learners' experiences of (and thoughts about) the phenomenon of 'learning'. This model could be interpreted as a layered model (Fig. 13.1). Any of its inner/deeper layers are supported by its outer/shallower ones.

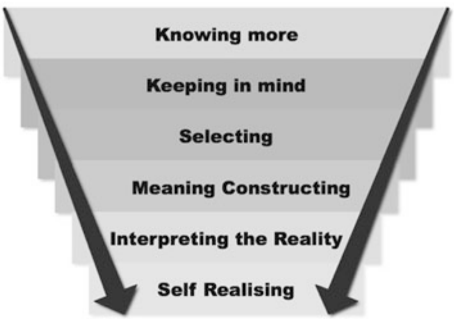


Fig. 13.1 Learners' developing conceptions of the phenomenon of 'Learning'

Let us describe and analyse them:

1. On the shallowest layer, the learner recognises that the phenomenon of 'learning' is equivalent to 'knowing more and knowing new things'. Such a learner is strongly dependent on her/his learning environment, learning materials, and teachers such as trainers, instructors, tutors, and mentors. This learner heavily needs ideas to be expressed, be explained, and be imparted explicitly. Furthermore, she/he needs her/his teacher/mentor to isolate and classify the flow of well-structured information into separated and individual facts. Such a learner needs the teacher/mentor to break down the procedures into isolated facts. In this layer, the learner needs to know more isolated and realisable facts. This learner needs to attain the abilities of 'naming' and 'identifying'. Identifying multiple facts prepare the learner for 'describing' facts and primary procedures.
2. The second layer could be identified by the concept of 'keeping in mind'. The concept of 'keeping' indirectly relates the learner to 'reusability' and 'reproduction'. In fact, she/he aims to memorize an acquired and known fact in order to apply and activate it regarding her/his own requirements and tasks. The one who attempts to keep something in mind is still trying to know more. Reusing and reproducing prepare the learner for 'describing' and 'combining' various facts, and, respectively, procedures.
3. The third layer is identified by the concept of 'selecting'. The ability of selection and refinement prepares the learner for pragmatism and for practical approaches. The learner expects her/his teacher to motivate her/him through selection processes. Selection and refinements connect the learner with 'comparing', 'contrasting', 'relating', and 'explaining'. Additionally, it indirectly makes a connection with 'justifying' and 'analysing'.
4. The fourth layer is identified by 'meaning construction'. She/he has become concerned with interpretation, analysis, justification, primary reasoning, and primary criticising. In our opinion, this layer is the most crucial one due to the fact that it makes a linkage between learners' fundamental and their advanced understanding of the concept of 'learning'. We shall focus emphasis on identifying this level by 'meaning construction'. It is not equivalent to ignoring the fact that meaning construction is an infinite process of any learner. The fourth layer is identified by 'meaning construction' because the process of meaning construction reaches its highest point and finds its most extreme significance in this layer. This layer provides a crucial interval for signifying the phenomenon of an individual learner's 'learning' within her/his learning processes.
5. The fifth layer makes the learner concerned with 'interpreting the reality'. Learning as an interpretative, explanatory, and expository process must be capable of supporting the learner in 'interpreting', 'explaining', and 'understanding' the reality of the world. This means she/he has become concerned with explaining the causes and reasons, criticising, formulating, and theorising. In this layer, many learners characterise 'learning' as the process of self-development.

6. The sixth layer is identified by ‘self realisation’. The learner has become concerned with ‘creation’, ‘generation’, and ‘reflection/mirroring’ when it comes to her/his self and society. It’s very important to know that learning, as the transcendental process of self-realisation and self-organisation, is continual, successive, and concatenated.

Regarding the described layers of learners’ conceptions, we can realise that any outer/shallower conception, whether logically, conceptually, or cognitively, supports its inner/deeper layer. Assessed by logics, the conjunction of the outer layers is subsumed under their inner ones. For instance, the conjunction of the concepts of ‘knowing more’, ‘keeping in mind’, and ‘selecting’ are subsumed under ‘meaning construction’. Then, through the lens of formal semantics, the provided logical model of ‘meaning constructing’ satisfy ‘knowing’, ‘keeping in mind’, and ‘selecting’. Informally, those who are concerned with meaning construction have previously been concerned with ‘knowing’, ‘keeping in mind’, and ‘selecting’. Accordingly, the succession of the layers’ contents from ‘knowing more’ to ‘self realising’ could represent the flow of the concept of ‘understanding’ in learners’ perspectives. In fact, there is a succession that could be considered as a flow of understanding regarding the expressed model. The succession could be described as: (1) knowing new isolated facts … (2) identifying them … (3) keeping them in mind … (4) describing them … (5) reusing them … (6) combining them … (7) selecting them … (8) comparing them with each other … (9) relating them to each other … (10) explaining them and explaining by applying them … (11) interpreting them and interpreting by using them … (12) analysing them and analysing other things using them … (13) justifying for their existences and justifying by employing them … (14) reasoning for [and based on] them … (15) criticising for [and based on] them … (16) theorising for [and based on] them … (17) developing them and developing other things based upon them … (18) reflecting on selves and on society (with regard to them).

An important question is “How could we establish a connection between a flow of understanding with regard to the learners’ developing conceptions of the phenomenon of ‘learning’ and the phenomenon of ‘smart learning’?” In other words, how could we characterise the concept of ‘understanding’ with regard to the learners’ conceptions of learning within smart learning environments? To answer these questions, we shall stress that any smart learning environment should be filled with available and well-organised learning materials and should also be aesthetically pleasing. Any smart learning environment must be ‘effective’ [35, 39, 40]. What is likely to make a learning environment effective, efficient, and engaging for a wide variety of learners with different levels of background knowledge, psychological backgrounds, and interests is one that can adapt to the learner, personalise instruction, and support learning. This suggests that appropriate adaptation is a hallmark of smart behaviour. The concept of ‘smart learning environments’ has been presented as one “… that makes adaptations and provide appropriate support (e.g., guidance, feedback, hints or tools) in the right places and at the right time based on 'individual learners' needs, which might be determined via analysing their learning behaviours, performance and the online and real-world contexts in which they are situated. …" [34]. Furthermore, [34] states that a smart learning environment is able to offer adaptive support to learners through immediate analyses of the "needs of individual learners from different perspectives". It shall be taken into consideration that any smart learning environment meets the personal factors (e.g., learning styles and preferences) and learning status (e.g., learning performance) of individual learners. In fact, all individual learners and their needs are the most central components and incorporators of smart learning environments. It is worth mentioning that IBM has also recognised smart educations as student-centric education systems [41].

Taking all the characteristics of smart learning mentioned here into consideration, any smart learning system utilized as a student-centric system must prepare a background for the learners' flow of understanding and support them within different aspects of their understandings. Also, as mentioned earlier, the most central focus of constructivist smart learning systems is on learners' understandings with regard to their own produced meanings and their generated meaningful comprehensions. At this point we shall state that smart constructivist learning systems must be developed over the individual learners' conceptions and requirements. These developments must be supported by the special focus on the flow of understanding of learners.

Let us take into consideration some significant results of our discussions with undergraduate students. A number of students wanted to know which facts would be required and helpful for them. We can transform this requirement into (i) 'How could a learner know the required and helpful facts?' Also, a few students told us that they know that they need to select facts in order to conceptualise them and to have a better understanding of them, but they don't know which facts must be selected. Again, we can transform this requirement of learners into (ii) 'How could a learner find the ability to select the rightful and beneficiary facts in order to construct meaning over them?' Also, a student wanted to know how she could let her mentor know about her constructed meanings. This question could be translated into (iii) "How could a learner announce her/his constructed meanings to their mentor or other learners?'. Questions such as (i), (ii), and (iii) are prevalent to any learner.

Smart constructivist learning systems must be able to provide a kind of requirement analysis and to suggest rightful choices to individual learners. In the beginning, the learning system, the learner, and the mentor should not look at each other, but should actually look at the same point and discover the appropriate facts together. Accordingly, the conceptions of the mentor could influence the learner and vice versa. Furthermore, the learner's and the mentor's conceptions could be influenced and modified with regard to what the system has suggested to them. Smart constructivism must be capable of locating the learner in her/his best position to go toward her/his production of meaningful comprehension. Respectively, the mentor must be guided to find her/his most appropriate position in relation to the learners' positions.

In order to express and analyse the concepts of 'meaning', 'meaning construction', and 'meaningful comprehension', our theoretical model needs to be supported by a proper educational and pedagogical model. This can provide an organized framework for representing different levels of learners' understandings. We need to employ a model of learning concerned with various complexities of understanding at its different levels/layers in order to support the conceptualised idea of 'understanding', to analyse the flow of understanding in experts'/educationalists' points of view, and to model it in smart constructivist learning systems.

13.5.2 Smart Constructivism and the Structure of Observed Learning Outcomes

The Structure of Observed Learning Outcomes (SOLO) taxonomy is a proper model that represents multiple layers of learners' understandings within learning and knowledge acquisition processes [42]. SOLO provides an organised framework for representing different levels of learners' comprehensions. It is concerned with various complexities of understanding at its different layers. In the framework of SOLO, learners are concerned with five levels of understanding (Fig. 13.2).

As an analytic example, we focus on a learner, Martin, who is learning Java Programming:

- Pre-structured knowledge: Martin does not really have any knowledge about Java. This kind of knowledge about Java has been constructed over his mental backgrounds and from his previous experiences, e.g., experiencing different products that are developed in Java, meeting Java's official and related websites, discussing with Java programmers, etc. The most important fact is that Martin does not have any special constructed knowledge about Java.
- Uni-structured knowledge: Martin has limited knowledge about Java and may know few isolated facts. Thus, he mainly focuses on identifying those isolated facts. For example, he knows that Java works based on classes of objects and

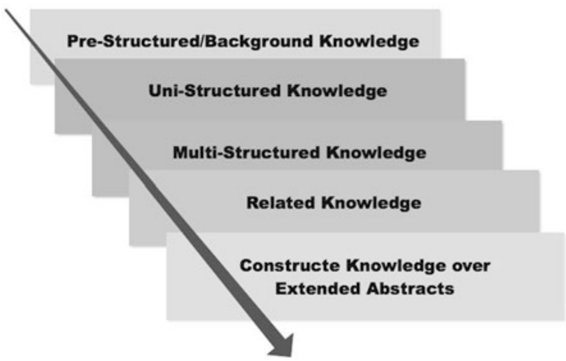


Fig. 13.2 SOLO taxonomy: levels of constructed knowledge and levels of produced understanding

that Java is an object-oriented language. He may know that Java derives its syntax from C. Based on this, Martin has a very shallow understanding of Java. The known facts are isolated and he is not able to either relate them together or apply them.

- Multi-structured knowledge: Progressing from the previous level to this level simply means that Martin knows a few facts about Java, but he is still unable to find logical and conceptual linkages between them. Martin (i) has extended the domains of his factual knowledge about the isolated facts, (ii) has become concerned with combinations of various isolated facts, and (iii) has become concerned with descriptions of the results of those combinations. For example, he knows about object-oriented languages, he knows that object-oriented programming is a paradigm based on the concept of 'objects' and 'things', and he knows that object-programming languages focus on 'objects' rather than 'subjects' and 'actions'. Martin has produced some mental combinations of these facts. He is preparing himself for producing logical and relational models based on his produced combined facts.
- Related Knowledge: Martin has started to move towards higher levels of conception about Java. He has also begun moving towards deeper levels of understanding of Java. At this level, he is able to link different facts together and explain several conceptions of Java. The important fact is that he has become concerned with analysis, argumentation, explanation, justification, comparison, and applications relevant to Java. Now, Martin can explain and analyse the elements of his factual knowledge and can relate them together. He can now relate the characteristics of object-oriented systems and Java programming. He knows why object-oriented paradigms are in favour of 'objects' and not in favour of other phenomena. He is able to explain and analyse the characteristics of Java as well as apply different methods to them.
- Extended Abstract: This layer is the deepest and the most complicated level of Martin's understanding. Here, Martin is not only able to link a huge number of related conceptions together, but he can also link them to other specified and complicated conceptions. Now, he is able to link multiple explanations and justifications in order to produce more complicated extensions relevant to Java. Martin has become concerned with theorising, hypothesising, creating, and criticising.

According to Fig. 13.2, the extended abstracts are the products of deeper realisations and understandings of relational structures and constructed related knowledge. Relational structures are the products of deeper comprehensions of multi-structures and constructed multi-structured knowledge. In a similar manner, the multi-structures are the products of deeper comprehensions of uni-structures and constructed uni-structured knowledge. Finally, the uni-structures are the products of deeper pre-structures and pre-structured background knowledge.

At this point, we need to focus on the HowNess of satisfaction of the flow of understanding from 'pre-structured and background knowledge' to 'constructed knowledge over extended abstracts' by smart learning development and design.

Smart constructivist learning systems must be able to support the development of knowledge constructions over any learner's background and pre-structured knowledge. The central idea is that smart constructivism must generate a kind of self-updating process for any learner with respect to her/his own insights based on her/his background knowledge in order to prepare her/him for her/his individual processes of semantic interpretation, meaning construction, and understanding production. Let us be more specific on the concepts of 'semantic interpretation' and 'meaning construction'.

As characterised earlier, one of the most significant features of smart constructivist learning systems is their special focus on the learners' understandings with regard to their own produced meanings and generated meaningful comprehensions. In addition, we have mentioned that there is a bi-conditional relationship between 'understanding production' and 'meaning construction'. Therefore, we shall stress that the following items have a logical bi-conditional relationship:

- The process of knowledge construction as "pre-structured knowledge → uni-structured knowledge → multi-structured knowledge → related knowledge → knowledge over extended abstracts"; and
- The learners' meaning construction.

At this point, we employ a linguistic approach to explain and analyse this bi-conditional relationship. This approach, in dynamic semantics, has considered meaning as a context-update function [43, 44]. You can also find one of its particular applications in [45]. Considering meaning as a context-update function, the input of the Meaning function is a context and the output is its updated form. Any context comprises different types and different numbers of conceptions. Terminologically, we can consider conceptions as the sub-class of contexts. Therefore, we describe any 'meaning' as a conception-update function like $Meaning: Conception \rightarrow Conception'$. This function iteratively organises itself in multiple loops and repetitions. It shall be claimed that the constructed meanings of any learner, based on her/his constructed knowledge over extended abstracts, are the updated forms of her/his constructed meanings within relational structures. Also, the constructed meanings in the ground of her/his related knowledge on mental relational structures are the products of her/his constructed meanings based on her/his multi-structured knowledge on mental multi-structures. In a similar manner, the constructed meanings, based on multi-structured knowledge and mental multi-structures, are the updated products of the constructed meanings based on uni-structured knowledge. Finally, the constructed meanings on uni-structured knowledge are the updated constructed meanings over mental pre-structures and pre-conceptions.

When it comes to semantic interpretations, our approach recognises the learner's semantic interpretation as the connector of her/his various levels of constructed meanings [46]. In other words, the interpretations semantically support the succession of the updated meanings. Relying on this conception, an interpretation could be known as the continually adjusted relationship between two things. It is quite important to consider the following when it comes to smart constructivism:

1. The learner's intention behind her/his conceptions, and
2. The learner's actual mental universe of her/his conceptions, which are based on her/his accumulated experiences.

As concluded earlier, smart constructivism must consider the fact that any individual learner transforms 'what she/he is learning' into "uni-structures of knowledge, multi-structures of knowledge, related structures of knowledge, and constructed knowledge over extended abstracts". In fact, any learner, based on her/his tasks and roles as a learner, increases the complexities of her/his constructed meanings in order to be closer to her/his own deepest understanding. Smart constructivist learning systems must be capable of supporting learners in reflecting their own multiple conceptions of a phenomenon. This occurs when it comes to mirroring the concatenation of the produced conceptions on their own learning as well as on different levels of their constructed knowledge.

13.6 Knowledge in Smart Constructivist Learning Systems: Analysis of Methods' Outcomes

Relying on the framework of constructivism, the current theoretical analysis of smart learning is not focusing on ontologies or the existence of knowledge. The central focus, though, is on the tenets of humans' knowledge construction and development. This involves the creation of mental models when encountering new, unusual, or otherwise, unexplained experiences [35]. We have taken into account that learners create their own mental representations in order to make sense of their experiences and learning tasks. By interpreting the phenomenon of 'learning' as the process of knowledge construction, we need to put any individual learner at the center of the proceeding of knowledge construction. The personal characteristics of any learner, the mental backgrounds, personal experiences, and the pre-structured and uni-structured knowledge all support the foundations of knowledge construction. This section deals with how multiple categories of knowledge can assumedly be constructed in the framework of smart constructivism.

13.6.1 Categories of Knowledge in Smart Constructivism

We adopt Bloom's taxonomy in order to clarify what we mean by 'categories of knowledge'. Bloom's taxonomy is a framework for classifying educational and pedagogical objectives. These could be interpreted as the statements of what educators and educationalists expect the learners to have dealt with [47, 48].

Considering Bloom's taxonomy and taking into account the constructivist theory of learning, we could express the view that the concept of 'knowledge' has a strong relationship with 'recognition' of multiple phenomena. In fact, knowledge construction is supported by any individual's insights, based on her/his own recognition of various materials, methods, procedures, processes, structures, and settings in the form of her/his conceptions. According to Cambridge dictionary [49], having knowledge about something or about some phenomenon could be realised as being related to the following items: (i) Having a piece of knowledge about that thing/phenomenon and (ii) judging about that thing/phenomenon based on personal experiences and information.

We shall claim that we are allowed to divide knowledge into separated classes (for example, into Class_1, Class_2, …, Class_n) if and only if we have aimed at clarifying and specifying the humans' conceptions of any of them (e.g., Class_i) and, respectively, of all of those separated classes (i.e., Class_1, Class_2, …, Class_n). In the end, we must consider the union of all classes as the phenomenon of 'knowledge'. Let us focus on analysing how Bloom has dealt with the phenomenon of 'knowledge'. Bloom's taxonomy categorises knowledge into multiple classes, e.g., distinct classes for knowledge of terminologies, knowledge of ways and means, knowledge of trends and sequences, knowledge of classifications and categorisations, knowledge of criteria, knowledge of methodologies, knowledge of quantifications, knowledge of principles, knowledge of generalisations and specifications, and knowledge of theories and structures. Since then, [48] has proposed a knowledge dimension in the revised version of Bloom's taxonomy. The revised taxonomy consists of (i) factual knowledge (e.g., terminological knowledge), (ii) conceptual knowledge (e.g., knowledge of theories, models and structures), (iii) procedural knowledge (e.g., knowledge of methods and algorithms) and (iv) meta-cognitive knowledge (e.g., contextual knowledge, conditional knowledge).

We strongly believe that these four classes could support us in clarifying and analysing the interconnections between the phenomena of 'learning (and knowledge acquisition)' and 'knowledge building'. We shall, therefore, claim that the phenomenon of 'learning' consists of a sort of transformations from constructed knowledge in the world (e.g., by experts, by theoreticians, etc.) into the sets of 'facts', 'procedures'. and 'concepts' in different 'contexts'. We believe that procedures are constructed over the chain of separated, connected, and related facts. Then, in our opinion, any procedure is just the concatenation of a number of facts. Therefore, learning provides multiple functions from constructed knowledge into 'facts' and 'concepts'. Learners need to deal with those facts and concepts while they need to construct their own knowledge with their insights based on what they construct over those facts and concepts. In [50], we have argued as following: "… In our opinion, there is a concept behind every fact. Then any factual knowledge can be supported by a conceptual knowledge. For instance, according to a fundamental characteristic of terminological knowledge (as a type of factual knowledge), we can represent terminologies by means of taxonomies. A taxonomy could be constructed based upon concepts. Then a terminological knowledge has been supported by a conceptual knowledge. Also, as another instance, we can define a body of the related elements and interpret it as a set of constructors for denoting various concepts and their interrelationships. That's how the concept languages and descriptive languages appear. Then, we could be able to represent knowledge over concepts, their instances and their relationships …". Thus, we shall claim that everything is translatable into, and mentally representable in the form of, a concept. Accordingly, concepts are manifested in the learners' conceptions and they could be declared in the learners' hypotheses. A concept might be interpreted to be a linkage or interconnection between the mental representations of linguistic expressions and the other mental images (e.g., representations of the world, representations of inner experiences) that a learner has in her/his mind [37].

It shall be concluded that the phenomenon of 'smart learning' must provide multiple transformations from 'knowledge', either 'received from outside' or 'experienced within inside', into concepts. Learners represent those concepts in their minds and propose their own conceptions of those concepts. Consequently, learners construct their own knowledge with insights based on their produced conceptions. It is a fact that learners' conceptions could elucidate others and could be shared with them through Internet, social networks, virtual classes, and media. Learners can propose/announce their own conceptions of what they have constructed in the form of texts, voices, videos, etc. The collection of these processes could be identified by 'construction of own packages of knowledge by learners' in smart constructivist learning systems.

13.6.2 A Conceptual Framework for Knowledge Building in Smart Constructivism

The main objective of this section is to propose a conceptual framework for representing the stream of understanding within knowledge construction processes in smart constructivist learning systems. First, we shall refer the readers to our research in [51], which focused on formal semantic analysis of interrelationships between multiple categories in learners' developing conceptions of the phenomenon of 'learning' [27–29]. We need to employ the results of that research. More particularly, that research has focused on the conceptualisation of the phenomenon of 'learning' within the top-ontology of adult learners' developing conceptions of learning. Self-realisation (and self-awareness) is the most excellent conception of learners. It can conclude all other conceptions within its lower categories. Assessed by logics, all conceptions of learners within lower categories of conceptions are subsumed under 'self realisation'. Relying on Description Logics, [51] has focused on discovering the main constructive concepts and their interrelationships under 'self awareness' as well as a semantic representation of adult learners' developing conceptions has been sketched out. Figure 13.3 represents a network that has been developed over an important piece of the proposed semantic representation in [51].

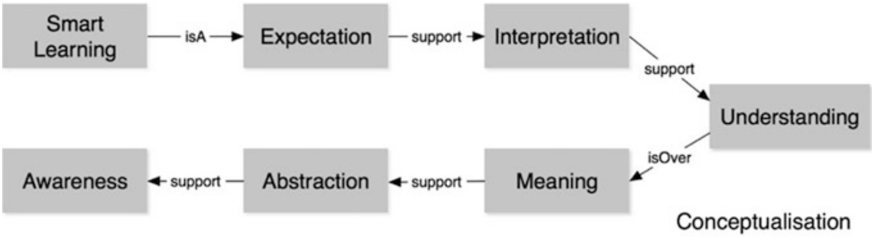


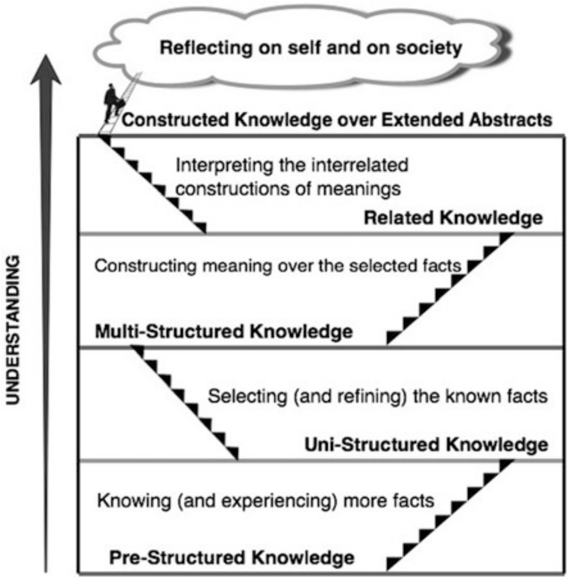
Fig. 13.3 A semantic representation of concept of 'Understanding' in smart learning environments

Figure 13.3 represents a structural analysis of 'smart learning' on the highest conceptual level and from the perspective of the most excellent learning conceptions; this semantic representation is meaningful in the context of 'conceptualisations'.

This network shows that the concept of 'smart learning' is a kind of expectation. In some cases, it is an 'outlook'. Smart learning, as an expectation, supports learners' interpretations and understandings of the world. In fact, by relying on individuals' interpretations, this expectation produces a strong belief that the phenomenon of 'smart learning' will be valid and meaningful. Furthermore, humans' interpretations support their personal understandings, making it is possible to say that any personal understanding is a kind of limited interpretation in the context of conceptualisations. Learners, through relying on their conceptualisations and by engaging their interpretations, explicate what they mean by classifying a thing, process, event, or phenomenon as an instance of a concept. The interpretations prepare learners for producing their personal meaningful descriptions over their own conceptions, and, in fact, over their constructed concepts. Therefore, an 'understanding' could be realised to be the sub-process of an 'interpretation'.

On the other hand, though, all interpretations are not necessarily understandings. In fact, all the interpreted concepts may not be understood, but all the understood concepts certainly have been interpreted, see our research in [5]. Then, understanding, in the framework of smart constructivism, is produced over 'interpretations' of things, processes, events, and phenomena as well as within smart learning environments. Additionally, as analysed, understanding could be considered as constructed over individuals' constructed meanings. Meanings on the deepest layers of understanding, as well as on highest floor of the constructed knowledge, support 'abstractions' and 'production of knowledge over the extended abstracts' by learners. These abstractions support individual meaningful comprehensions over individual constructed meanings. Figure 13.3 structurally and conceptually supports Fig. 13.4. Figure 13.4. represents a conceptual framework for 'knowledge creation' over the stream of learners' understandings within smart constructivist learning systems. It represents a conceptual description of 'knowledge building' toward 'deepest understanding levels of learners' within smart learning environments.

Fig. 13.4 A conceptual framework for knowledge building within smart constructivist learning systems



13.7 Conceptualising a Smart Constructivist Pedagogy: Testing of Research Outcomes

This section employs the outcomes of [52–58] in order to conceptualise a smart constructivist pedagogy based on the proposed model of knowledge building. According to Fig. 13.3, the phenomenon of ‘smart learning’ in the framework of constructivism is an expectation that is supported by any individual’s interpretations and meaningful understandings. Consequently, both learners and mentors are interpreters, organisers, and constructors within the process of smart constructivist learning and in the context of smart learning environments. In fact, they are the developers of a collaborative process of constructing. Therefore, it shall be emphasised that smart constructivism doesn’t assess the phenomenon of ‘learning’ as an outcome of a development. It does, however, recognise it as a development. Here, learners are inventors. They must be allowed to generate their hypotheses based on their own conceptions of the world. The main characteristics of these conceptions are as follows:

1. Conceptions are learner-centered (individual-centered).
2. Conceptions are central-organizing.
3. Conceptions are generalised across experiences and direct observations.
4. Conceptions require reorganisable pre-conceptions.
5. Conceptions make sense to communities by becoming shared.

In the framework of smart constructivist pedagogy, learners must have opportunities to announce their pre-conceptions, their presuppositions, their hypotheses based on their presuppositions, and their possible suggestions over them. Learners, as constructors of meanings, need to organise their experiences and, correspondingly, generalise and specialise the experiences into their personal hypotheses. Furthermore, mentors, adaptive teachers, and smart programs must be able to:

i. work on conceptual and logical analysis of learners' hypotheses,
ii. check the validity and definability of learners' hypotheses,
iii. find reasonable descriptions and specifications for denying and refusing the learners' hypotheses.

The third item could be done deductively based on rules or inductively based on different cases of study. In other words, in order to be disclaimed, learners' hypotheses must be illuminated and explored. Any kind of error, mistake, or inaccuracy would be assessed as an outcome of learners' misconceptions. The learners' misconceptions could be found and organised. Thus, their mistakes would be explored for themselves. Note that counterexamples are quite efficient in resolving learners' misconceptions and errors. It shall be concluded that smart constructivist mentoring focuses on:

i. discovering conceptions/misconceptions of any individual learner,
ii. discovering the common conceptions/misconceptions among a group of learners,
iii. conceptualising learners' conceptions/misconceptions,
iv. conceptualising and attempting to understand learners' understandings over their conceptions/misconceptions, and
v. motivating proper conceptions and resolving misconceptions.

It shall be stressed that smart constructivism could consider 'improvable and re-organisable conceptions of learners' as the main building blocks of its knowledge building pedagogy. [59] is in line with the conceptualised theory and has had a special focus on the learners' productive use of the principle of improving their conceptions within their relationships with their 'constructed knowledge'. At this point, we shall conclude that the presented conceptualisation of knowledge building has had a special attention to 're-organisable conceptions of learners within their connections with their collaborative constructed knowledge'. Table 13.1 is presented in order to itemise the most important components of Smart Constructivist Pedagogy and its significant characteristics. Later on, Fig. 13.5 schemes the conceptual interrelationships between those components and the phenomena of 'knowledge' and 'conception'.

Table 13.1 Main components of smart constructivist pedagogy

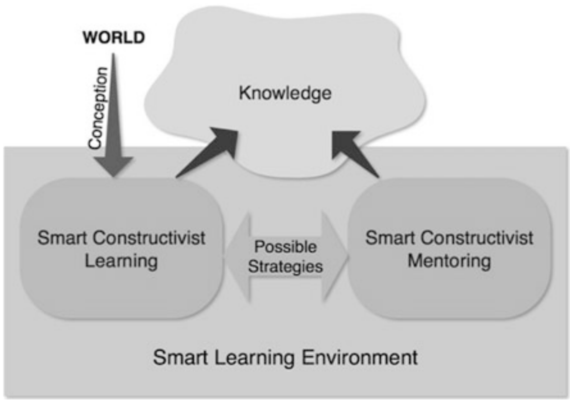
Components	Characteristics
Smart constructivist learning	• The phenomenon of 'learning' in the framework of smart constructivism is interpreted as a process of knowledge construction. The constructed knowledge is idiosyncratic • Smart constructivist learning is strongly concerned with self-regulation, auto-organisation, self-development and, finally, self-learning • Learning in the framework of smart constructivism is an active and dynamic (not passive) process • In the framework of smart constructivism, the constructed knowledge by any individual learner is not innate, passively absorbed, or invented, but it is 'constructed' and developable • In the framework of smart constructivism, learners interpret their world and, correspondingly, construct their own versions of the world based on their personal conceptions • The most significant objectives of smart constructivist learning are 'meaning construction' and 'meaningful understanding production' • Smart learning in the framework of constructivism proceeds toward developing constructed structures. • Experiences and prior understandings of learners play fundamental roles in smart constructivist learning • Smart constructivist learning encourages and motivates any individual learner to explore and discover the world by her/him self • Smart constructivist learning encourages any individual to make her/his own sense of the world • In the framework of smart constructivism, the phenomenon of 'learning' is situated in the context in which it occurs • Smart constructivist learning is strongly supported by social interactions and conversational exchanges
Smart constructivist mentoring (by human beings, adaptive mentors, smart programs)	• The phenomenon of 'mentoring' in the framework of smart constructivism is a process of knowledge construction. • Mentoring in the framework of smart constructivism is an active and dynamic (not passive) process • Smart constructivist mentoring conceptualises learners' conceptions of the world • In the framework of smart constructivism, the constructed knowledge by mentors is not innate, passively absorbed, or invented, but it is 'constructed' and developed by the mentor with regard to the learners' opinions, actions, transactions, questions, and answers • In smart constructivist learning systems, the mentor is an expert and advanced learner and has a special respect for learners' choices • In smart constructivist learning systems the mentor is an organiser around significant conceptions that could motivate learners • In smart constructivist learning systems, the mentor must get to know about any individual learner and her/his backgrounds • In smart constructivist learning systems, the mentor assists learners and links them with their background knowledge

(continued)

Table 13.1 (continued)

Components	Characteristics
	• In smart constructivist learning systems, the mentor mainly focuses on (i) constructing meanings for her/him self, (ii) giving feedbacks to learners with regard to their constructed meanings, and (iii) developing meaningful understandings for her/him self • In the framework of constructivism, smart mentoring conceptualises learners' understandings based on their conceptions of the world • In the framework of constructivism, smart mentoring builds a world of developed understandings • In the framework of constructivism, smart mentoring proceeds toward developing constructed knowledge structures • In the framework of smart constructivism, any learner must be driven by her/his mentor to understand the world and to change her/his understanding with regard to her/his misconceptions. In fact, smart mentoring discovers/recognises learners' misconceptions, mistakes, and errors • In the framework of constructivism, smart mentoring focuses on making senses. It's highly affected by the learners' senses of the world • In the framework of constructivism, smart mentoring is situated in the context in which the phenomenon of 'smart learning' occurs • In the framework of constructivism, smart mentoring is strongly supported by social interactions and conversational exchanges • In the framework of constructivism, an effective smart mentoring aims at presenting open-ended identifiable, describable, specifiable, justifiable, and analysable problems to learners

Fig. 13.5 The conceptual relationship between main components of smart constructivist pedagogy



13.8 Linking Smart Constructivism and Collaborative Learning Strategy: Verification of Research Outcomes

This section picks up the collaborative learning strategy that is highly relevant to smart education in order to focus on explaining its possible connections with ‘the smart constructivist model of learning’. This section describes why ‘collaborative learning strategy’ could cope with and could be furnished by the presented and conceptualised approach.

The central focus of this research has been on knowledge building. This means we need to take into consideration the phenomenon of ‘knowledge building’ in order to check the validity and reliability of the constructivist model of learning in conjunction with ‘collaborative learning strategy’ and smart learning environments. First, it seems useful to take a look at Popperian epistemology [60] in order to work on conceptual analysis of knowledge building in smart learning. More specifically, the concept of ‘knowledge building’ could be derived from an epistemology that treats conceptions of human beings as entities in their own right that can have properties, connections, and potentialities. Consequently, it’s quite important to be concerned with the concepts of ‘pervasive knowledge building’ and ‘knowledge of community’. In fact, we need to focus on the fact that in collaborative learning, or ‘Learning-and-Constructing-Together’, the constructed knowledge must be capable of becoming spread widely throughout a group of learners. In the context of collaborative learning, any individual learner constructs her/his own knowledge. This means she/he attempts to construct the universal knowledge and also develop the construction of the knowledge of her/his community.

This section (i) relies on [61] and its conceptual analysis of the phenomenon of ‘togetherness’ in learning environments, (ii) follows the analysed policies of [62–64], and (iii) uses the methodological notions of [65], to focus on conceptualisation of ‘Learning-and-Constructing-Together’ while it’s concerned with knowledge building within junctions of ‘smart constructivism’ and ‘collaborative learning’.

13.8.1 Essential Value 1: The State of Knowledge

Creative knowledge work could be interpreted as a work that advances the state of knowledge of a community. The ‘state of knowledge’ is an emergent collective phenomenon and might be interpreted for a group of people. According to the concept of ‘state of knowledge’, knowledge building pedagogy is supported by the premise that authentic creative knowledge work can take place in any learning environment or in any smart learning environment. The state of knowledge of a group of learners within a smart learning environment only indirectly reflects the knowledge of individual learners. This conclusion could be implicated by smart constructivism. In fact, relying on smart constructivism, the state of knowledge of an individual learner, based on her/his constructed meanings, could highly reflect the knowledge of the community and, inversely, the state of knowledge of the community could only indirectly reflect the knowledge of the individual learners. Then, learners could re-organise and update their constructed meanings. Therefore, it is reasonable to expect that individuals' achievements go along with developments and advancements of community knowledge. This conclusion seems to be in parallel with the proposed approach of Zhang and colleagues in [66]. This characteristic, based on the state of knowledge, could highly affect course-by-course, program-by-program, and semester-by-semester changes in plans and strategies of any smart learning environment. Note that the mentor, the adaptive mentor, or the smart program, is another member of any learning community and, therefore, her/his/its constructed meanings reflect the knowledge of the community. In addition, it shall be considered that the mentor's knowledge is, regarding the feedbacks and transactions of learners, developable.

13.8.2 Essential Value 2: The Phenomenon of 'Discourse'

According to [64], discourse could come from sharing knowledge as well as subjecting conceptions to criticism. For example, in online meetings, web conferences, webinars, and Massive Open Online Courses (MOOC), any individual learner could become concerned with a kind of discourse which could be interpreted as 'a filter that determines what could be accepted into the canon of justified beliefs' [67]. However, it could be argued that modern learning strategies must support any individual learner and, also, any individual mentor, in playing her/his own creative roles in order:

i. to improve her/his own conceptions, and
ii. to judge and to make decisions more rationally beside her/his manners of criticism.

We shall claim that this kind of discourse-based judgement and decision-making is the consequence of any individual's, and, consequently, of a community's construction of factual and conceptual knowledge. It can be labelled as 'Social Constructivism in the Framework of Smart Constructivism'. Relying on practical and empirical approaches, this kind of social constructivism would be more concerned with shared goals of advancing understanding beyond what is currently interpreted and understood. In fact, the practices could support the processes of meaning construction. Consequently, the produced social meanings, in the context of interactions and conversational exchanges between individuals within a smart learning environment, could be updated and be more organised.

13.8.3 Essential Value 3: Authoritative Information and Their Reliability

Smart constructivism in collaborative learning supports learners in:

i. using their own authoritative information that is achieved based on their own experiences, explorations, studies, etc. and
ii. bringing other authoritative information (e.g., from other individuals, from e-books and e-references, from learning applications) as evidences of their own authoritative information.

The latter supports the development and reorganisation of all individuals' constructions based on received authoritative information from others within their social interactions. It shall be claimed that the interconnections between (i) and (ii) elaborate the 'state of knowledge of community' in the long term. Accordingly, the interrelationships between (a) and (b) increase the state of knowledge of the community:

a. A learner's constructions based on her/his own authoritative information.
b. A learner's development of her/his constructions with regard to others' authoritative information.

13.8.4 Essential Value 4: Explanation and Understanding

The Organisation for Economic Co-operation and Development (OECD) has emphasised the importance of conceptual understanding as a basis for creative knowledge work of all kinds: "Educated workers need a conceptual understanding of complex concepts, and the ability to work with them creatively to generate new ideas, new theories, new products, and new knowledge" [68]. It might be assumed that any individual learner has to understand appropriately in order to develop her/his own knowledge constructions. Similarly, as discussed earlier, learners' understandings are strongly supported by explanations. Accordingly, it must be stressed that the development of knowledge building in smart learning societies is highly related to the phenomena of 'explanation' and 'understanding'.

Smart constructivism, as a theory of learning, must support the conceptual understanding of learners in different communities and organisations. Special attention must be given to guiding, instructing, and mentoring any individual learner. Any learner in such a framework must be guided in order to construct her/his own meanings and to support her/his society with her/his constructed meanings. In addition, the smart constructivist theory of learning within collaborative strategies focuses on developing the communities' understandings. In our opinion, a proper strategy must follow the conceptual framework presented in Fig. 13.4. In addition to this, smart constructivism must focus on developing 'knowing HowNess combined with knowing WhyNess' as 'explanatorily coherent practical knowledge'. A similar principle for practical knowledge has been analysed in [69].

13.9 Smart Constructivist Learning Communities: Validation of Research Outcomes

According to [70], smart learning communities must be sensible, connectable, accessible, ubiquitous, sociable, sharable, and visible/augmented. We shall claim that our research has interconnections with the features of 'being connectable', 'accessibility', 'being sharable', and 'visibility'.

At this point, we shall draw your attention to Vygotsky's theory of social constructivism [71–73]. In our opinion, Vygotsky's ideas are quite helpful in conceptualising smart constructivist learning communities. Vygotsky's theory, based on his ideas in human cultural and biosocial development, has supported the development of social constructivism. Vygotsky believed that 'social interaction' plays a fundamental role in the process of humans' cognitive development. In his opinion, an individual with stronger understandings and higher abilities in particular domains could be a so-called 'teacher'. He specified the concept of 'teacher' by defining the notion as an MKO (i.e., More Knowledgable Other). Additionally, Vygotsky defined ZPD (i.e., the Zone of Proximal Development) in order to express the concept of 'learning' by an individual learner under MKO's supervisions and/or in her/his collaborations with other individuals. Vygotsky believed that learners could learn in this zone. It shall, therefore, be concluded that we can have a similar conception of smart learning communities. In fact:

i. A mentor, an adaptive mentor, or a smart program is considered more knowledgable as an individual due to their stronger understandings and higher abilities in particular domains. They supervise learners.
ii. Learners have interactions and conversational exchanges with each other and develop their personal constructions of knowledge.
iii. The phenomenon of 'smart learning' occurs over actions, transactions, questions, and answers between any learner and mentor as well as between any learner and other learners.

13.9.1 Conceptualising Smart Constructivist Learning Communities

The fundamental characteristics of smart constructivist learning communities are as follows:

- Smart learning communities are communities using a discourse engaged in activity, reflection, interaction, and conversation.
- The main goals of any smart learning community are (i) Learning-and-Constructing-Together and (ii) producing the Collaborative Understanding.
- The main belief of any smart learning community is that the phenomena of 'smart learning' and 'development' are integrally tied to any individual's communicative and social interactions with other individuals.
- The second important belief of smart learning communities is that the use of information technologies (IT) and information communication technologies (ICT) is more likely to create a constructivist perspective towards the phenomenon of 'smart learning'.
- Smart learning communities must be given senses by (i) learners' made senses of the world based on their own experiences, explorations, and discovered key concepts and by (ii) their shared conceptions of the world.
- In the context of smart learning communities, any individual learner must be permitted to express, explain, defend, prove, and justify her/his conceptions of the world. Subsequently, all learners must be allowed to communicate their conceptions to each other as well as to their smart learning community.
- Smart learning communities must involve instructed interactions that guide any individual learner to recognise and resolve her/his conceptual inconsistencies and to modify conceptions through her/his interactions and conversational exchanges.
- In the context of smart learning communities, both interactions and conversational exchanges between two agents support bi-directional meaning constructions and collaborative understanding developments.
- In the context of smart learning communities, any constructed knowledge by an individual learner supports collaborative knowledge construction.

13.9.2 Smart Constructivist Learning Communities and Knowledge Building Technologies

In the context of smart constructivist learning communities, any conception is a building block of a knowledge construction. Any conception of an individual learner must be connected to and related to all others' conceptions. For example, any conception of a learner could be expressed in the form of her/his notes, paintings, sound clips, video clips, etc. Accordingly, the conceptions can be recorded and archived in the digital library of the relevant smart learning environment. Therefore, the smart learning environment must record a huge collection of conceptions. These could be represented by, e.g., data models, conceptual models, graphical models, statistical models, and concept maps. This can be seen in Fig. 13.6.

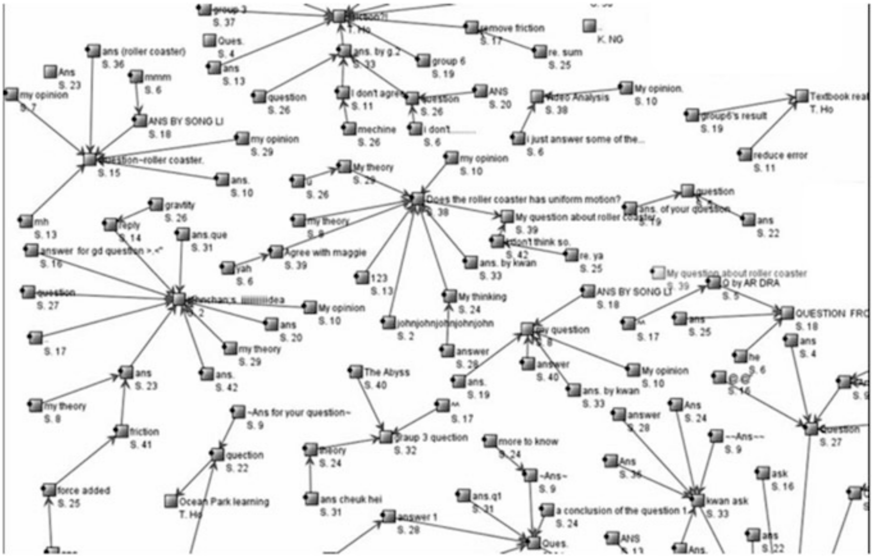


Fig. 13.6 Knowledge building view in knowledge building communities

Consequently, any conception would be viewable in multiple views as well as from different perspectives. For example, John's conception could be viewed from the perspective of Bob's and Mary's conceptions or from the perspective of their mentor's conception. In addition, there could be different possible interpretations for any linkage between two conceptions. These all could be recorded in the digital library. For example, Elizabeth may have an interpretation of John's conception, but she has observed and conceptualised John's conception from the perspective of Mary's conception. Accordingly, Elizabeth's interpretation, over the arc/line between John's and Mary's conceptions, could produce a new conception that could be recorded in the digital library.

The 'Knowledge Forum' [59, 62, 64, 74] is a proper knowledge-building environment. This multimedia knowledge-building environment could be recognised as a kind of smart learning environment. Such a smart learning environment focuses mainly on knowledge building. Knowledge Forum becomes organised by all of its users. All users are the constructors and developers of a huge collaborative knowledge construction. It might be assumed that such an environment can be an appropriate developable environment for 'knowledge building within smart constructivist learning communities'. Such a smart system can represent the advancing knowledge of any individual and of any community.

It's undeniable that smart learning communities are dependent on discourses engaged in activity, reflection, and interaction. We cannot deny that the most important objective of a modern learning community like Knowledge Forum is Learning-and-Constructing-Together. It must be taken into consideration that a smart constructivist learning community believes that 'smart constructivist learning' and 'knowledge development' are both integrally dependent on any individual's interactions and collaborations with other agents. Furthermore, we cannot ignore the importance of Collaborative Meaning Construction and Understanding Production in smart constructivist learning communities.

13.10 Discussion and Concluding Remarks

This research is focused on the area of Smart Learning Environments. Our theory has been presented (i) based on traditional constructivist theory of learning and (ii) by considering new requirements of learners in the digital age. It has—with special focus on 'constructivist epistemology' and 'constructivist models of knowing'—conceptualised Smart Constructivist Learning Systems.

In this research, knowledge acquisition has been recognised as the process of seeking knowledge [by human beings] about different phenomena, objects, processes and events with regard to their personal background knowledge. The concepts of 'knowledge building' and 'understanding production' have been the most sensitive terms in this article. More clearly, our theoretical model deals with (i) how knowledge may reasonably be assumed to be built by an individual, and with (ii) how her/his meaningful understandings could be assumed to be produced. The constructivist theory of smart learning, and, respectively, the smart constructivist theory of learning is a modern learning theory that is conceptualised over the phenomenon of 'smartness'. What we have offered has been a 'conceptual, logical and epistemological description' which has justified the importance of Smart Constructivist Knowledge Building Strategies. More specifically, this research has presented a specification of conceptualisation of:

a. smart constructivism,
b. smart constructivist learning,
c. meaning construction and understanding production in the framework of smart constructivism,
d. knowledge building in the framework of smart constructivism,
e. smart constructivist collaborative learning,
f. smart constructivist learning communities,
g. smart knowledge building environments, and
h. collaborative meaning construction and understanding production in the framework of smart constructivism.

As for the structural characteristics of smart constructivism, knowledge construction is conceived of as a type of active process, and it can be informally described in terms of personal understanding in multiple actions. Furthermore, it has been theorised that the phenomenon of 'understanding' could be valid and meaningful based on learners' [and mentors'] constructed meanings in the framework of constructivism and in the context of smart learning environments.

Accordingly, the concept of ‘knowledge building’ is interpreted as the consequence of ‘meaning construction’, ‘understanding production’ and ‘sense making’ by any individual learner.

Subsequently, this chapter has worked on designing a conceptual (and logical) framework for analysing knowledge building in the framework of smart constructivism and over the flow of learners’ understandings. Considering that framework, we have identified the most significant characteristics of a smart constructivist pedagogy. It has been assumed that the conceptualised theory must be able to support other learning/mentoring strategies as the products of the phenomenon of ‘smartness’. Accordingly, we have—relying on the characterised concept of ‘smart learning communities’—picked up the ‘collaborative learning strategy’ and worked on checking the validity of Learning-and-Constructing-Together (as a model of learning) within smart learning communities. Subsequently, the most fundamental characteristics of knowledge building within smart learning communities are conceptualised. We shall claim that smart constructivism—besides Learning-and-Constructing-Together—could support some strategies like, e.g., Learning-and-Constructing-by-Doing and Learner-based programs of study with variable structures adaptable to types of learners.

We strongly believe that the theory of smart constructivism, and, subsequently, the constructivist model of learning within smart learning environments can support subsequent developments of smart learning strategies. This theory could support renewed qualitative developments of knowledge building and understanding production within smart learning environments.

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