How Learning Styles Can Withstand the Demands of Mobile Learning Environments?

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Abstract—The contribution of learning styles is undeniable in the educational field. Several learning styles exist in the literature. Their use in the field of e-learning remains limited to certain learning styles only. With rapid technological development, their use in e-learning systems has proven its worth, particularly in terms of personalizing learning paths. But with the transition to mobile technologies, it has become necessary to study how much use can be made of these learning styles in a mobile environment. In this paper we spread out the most relevant learning styles, while putting the focus mainly on the Felder-Silverman learning style models, since they remain the most used ones in adaptive learning systems, and then we will answer an essential question concerning to what extent the adaptation according to the learning styles of Felder-Silverman remain possible in mobile environments.

Keywords—learning styles, mobile learning, Felder and Silverman learning styles

1 Introduction

Learning styles (LS) are a key component of the learning process according to researchers and educational theorists, and their incorporation into the classroom has the potential to facilitate learning. Felder [1] for example, contends that students who strongly favor one particular LS may experience learning challenges if the classroom setting does not support their desired LS [1], [2]. Theoretically we can state with confidence that the inclusion of LS makes learning considerably simpler and more effective. As a result, students that don't adhere to this paradigm may struggle with their academic progress.

With the appearance of adaptive learning systems, much attention has been paid to LS, since they are largely based on personalizing the learning process. Certainly these systems have been able to achieve the goal of personalizing learning paths, however we have recently witnessed a rapid evolution in mobile technologies, hence the need to ensure learning in these environments too. Thus the question that arises is to what extent is it possible to achieve personalization of learning paths based on LS in mo-

bile environments, knowing that the technical characteristics of mobile platforms may not be adequate with most of the LS dimensions.

The learning objects format and the didactic resources types are two factors that learning styles place a strong emphasis on. The format of the learning objects is where the issue is present. Since connectivity and battery life are the two factors that make mobile settings unique, we will inevitably encounter a problem where favoring battery life and connectivity will prevail over the recommendation of learning object according to the learning.

This paper is structured as follow: Section 2 discusses the most significant and used LS. Section 3 presents the adaptive learning systems which use LS as an element of adaptation. Later in section 4 we will be putting the focus on the context awareness learning, mainly in mobile environments. Then in section 5, we will analyze one specific LS which is the Felder-Silverman model. We'll investigate its applicability in a mobile setting as well. In section 6 we will discuss the finding of the study. Finally, we will make some judgments about the application of LS in mobile environments.

2 Learning styles

The LS area remains complicated since it is influenced by so many aspects, leading consequently to different concepts. Several LS exist in the literature; each one is offering multiple classifications of learning. The authors in [3] have identified 71 learning style models and classified 13 of them as the most relevant ones according to their impact and influence on the other models.

We mentioned earlier that a large number of models of LS exist in the literature. In an attempt to reflect the point of view of LS theorists, [3] has classified those models in five categories:

A first category is based on the fact that LS based on the four modalities: tactile, auditory, visual and kinesthetic.

A second category which details the properties of cognitive structure.

A third category refers to LS as a relatively stable element of a personality. In a fourth category, LS are described as being flexible and stable. A final category extends LS to approaches and strategies of learning. Here in the following table, is a classification of the different LS.

Table 1. A summary of learning styles, adapted from Cofield [3]

Classes	**C1**	**C2**	**C3**	**C4**	**C5**
Learning styles characteristics	**Type of personality relatively steady**	**Linked to approaches and to strategies**	**Complies with constitution**	**Flexible and stable**	**Structure cognitive**
Examples	Myers-Briggs	Entwistle, Grasha-Riechmann	Dunn et Dunn, Gregorc	Kolb, Honey et Mumford, Herrmann Felder and Silverman	Pask

In the Table 2, we will describe the dimensions related to the 9 most commonly used LS models. These models were chosen based on the work of [3], with an emphasis on their influence on other LS models. A crucial criterion has also been thought to be the usefulness of LS models in technology-assisted learning.

Table 2. The dimensions related to the different learning styles

Learning Style	Dimensions
Personality type according to Myer-Briggs [4],[5]	Sensing/intuitive, thinking/feeling, judging/perceiving, extrovert/introvert
Pask Model [6],[7],[8],[9],[10],[11]	Serialist learners - Holistic learners - Versatile learners.
The deep approach and the surface approach from Entwistle [12],[13],[14],[15]	Deep learning and learning surface
The Grasha-learning style model Riechmann [16]	Competitive – Cooperative - Avoidance-oriented Participative – Dependent - Independent
Dunn and Dunn's learning style [17],[18],[19],[20]	Environmental variable - The sociological variable The emotional variable - The physical variable The psychological variable
Gregorc's Mind learning style [21],[22]	The concrete-sequential style - The concrete-random style - The abstract-sequential style - The random abstract style
The learning style model of Honey and Mumford [24],[25],[26]	The pragmatic style - The reflective style - The theoretical style - The active style
Kolb's learning style model [23]	The diverger - The Assimilator - The Converger The accommodator
The FSLSM [27]	Sequential/Global - Visual/Verbal Sensory/Intuitive - Active/Reflective

2.1 Personality type according to Myer-Briggs

The MBTI indicator [4], is a psychological assessment tool determining the type of a subject psychology wise, following a method proposed in 1962 by Isabelle Briggs Myers and Katherine Cook Briggs. Other LS models are based on certain reflections from MBTI because it is not directly about learning but rather how the learner's personality influences his method of learning. As a result, the MBTI provides key elements for learning.

According to Jung [5], the MBTI differentiates a person's type based on 4 dichotomies: Extrovert / Introvert, Sensing / Intuitive, Thinking / Feeling and Judging / Perceiving.

All combinations that lead to a total of 16 types are conceivable.

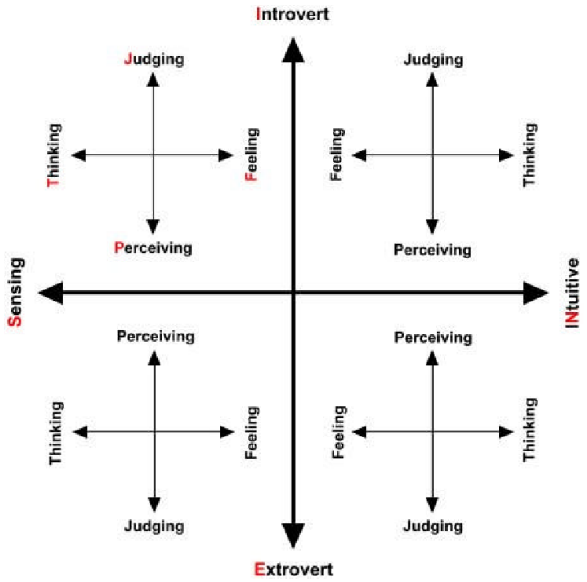

Fig. 1. The Myers-Briggs Type Indicator 4x4 Grid Structure

Extrovert / Introvert: it refers to the orientation of a person. An extroverted person's point of focus is things and people, whereas an introverted person prefers focus on ideas.

Sensing / Intuitive: it is concerned with how people perceive information. Sensing people detect and perceive data, using their 5 senses, but intuitive people prefer to perceive data from their unconsciousness.

Thinking / Feeling: The difference between thinking and feeling is based on how data is perceived.

Judging/Perceiving: People with the judgment dimension prefer step-by-step structures and approaches, while people with a perception dimension tend to be more flexible and spontaneous, while keeping all the options possible.

2.2 Pask model

In order to determine the various learning and thinking styles, Pask [6] looked at conversation patterns amongst individuals while establishing the text-conversation cycle theory. This theory states that a crucial procedure known as the teach-back technique, in which students teach their pairs, resulted in the classification of learners into three groups. [7].

Serialist learners: who promote the conversational progression of sequentially, through a precise structure? Prior to conceiving of a broad image, they have a tendency to concentrate more intently on specifics and procedures.

Holistic learners use a holistic learning approach, prefer to develop wide descriptions, concentrate on multiple facets of the subject at once, and employ intricate connections to link the data.

The majority of learning styles, if not all, can be learned by **versatile learners**. The Spy Ring History Test [8] and the Clobbits Test [9] are two tests that Pask has developed. A few years later, [10]-[11] created a self-report survey to help people choose between the serialist, holistic, or adaptable learning styles.

2.3 The deep approach and the surface approach from Entwistle

Research by Entwistle [12]-[13] distinguish between deep learning and learning surface. Deep learning corresponds to behaviors, where learners actively process information and use strategies elaboration and organization, rather than memorization strategies. Information processing support strategies such as strategies metacognitive, affective or managerial could favor or counter one or the other approach. The work of [14]-[15] also authorize this interpretation.

In an in-depth approach, learners develop and organize their knowledge. They are strongly emotionally involved and use more resources to learn. It is the opposite when they opt for a surface learning approach. Learners use coping strategies memorization and reproduction of knowledge, they have an instrumental interest for knowledge; they are not emotionally committed and use minimally the resources they have.

2.4 The Grasha- Riechmann LSM

The Grasha-Riechmann model developed by psychologists Grasha and Riechmann [16], classifies learners into six categories: competitive, cooperative, avoidance-oriented, participative, dependent and independent.

Competitive: This group includes learners who acquire knowledge, to perform better than other learners in the class. They believe they should compete with others to be rewarded. They like to be the center of attention and to be recognized for their accomplishments in class.

Cooperative: a typical category of learners who feel that they can learn, by sharing ideas and talents. They cooperate with teachers and enjoy working with others.

Avoidance-oriented: Learners show little enthusiasm for learn and attend classes. They do not participate with the teachers and other learners in classroom activities. They are not interested because they are overwhelmed by what is happening in the classroom.

Participative: good citizens in the classroom, these learners like to attend courses and take part in as many activities as possible organized in the framework of the course. In general, they are eager to get the maximum benefit from the course requirements, whether compulsory or optional.

Dependent: Students learn only subjects that are required of them and exhibit minimal intellectual curiosity. They look to the teacher and their peers for structure and support, and they anticipate that those in positions of power will establish the rules for how things should be done.

Independent: specific to learners who demonstrate autonomy of thinking and have confidence in their learning abilities. They prefer to acquire the knowledge they deem

important, they tend to work in an autonomous on course projects, rather than working with other learners.

2.5 Dunn and Dunn's learning style

The learning style model by Dunn and Dunn [17]–[18] was initially put forth in 1974, then it was improved upon and increased over time. Five variables, each depending on a number of variables, make up the model, which separates adults from children.

Environmental variable contains temperature, sound, design and light.

Factors linked to the choice for learning on one's alone, in a small group, or as a member of a team are included in **the sociological variable**. Parental and teacher motivation is a further consideration for kids.

The emotional variable involves the following factors: compliance / responsibility motivation, persistence and the need for structure.

The physical variable is composed of factors concerning the preferred mode perception of information (visual, auditory, tactile/external kinesthetic, internal kinesthetic).

Right or left hemisphericity, global/analytical preferences, and impulsive/reflective preferences are all included in **the psychological variable.**

To detect the preferences based on the style model Dunn and Dunn learning, different versions of questionnaires were elaborated. The Learning Styles Questionnaire [19] was established for children and exists in 3 versions.

2.6 Gregorc's Mind learning style

The model of Gregorc [21]-[22] is grounded around 2 dimensions bearing on preferences for perception and organization. When it comes to perception, individuals may prefer an abstract or concrete way to perceive. Perception refers to the aptitude to procedure information using intuition. Physical, On the other hand, refers to the capacity for sensory information processing. The dimension organization is interested of how a learner organizes, prioritizes and uses information in sequential, random or combination of the two.

The interviews conducted with students revealed two dimensions that characterize the behavior of learners and that they consider complementary: concrete-abstract and sequential-random. So the tool says the Gregorc Learning Style Delineator, assesses four learning styles defined from the relative position on these two dimensions: the style concrete-sequential, the concrete-random style, the abstract-sequential style and the abstract-random style.

The concrete-sequential style is characterized by a preference for what is practical, orderly and stable. It favors the gathering of information, in concrete and practical experiences.

The concrete-random style is characterized by a preference for an environment rich in stimuli and free from all restrictions. It is characterized also by a need to experiment with concepts and ideas by favoring a trial-and-error approach.

The abstract-sequential style is characterized by a preference for mentally stimulating, content-rich and organized presentations, as well as a force at the level of symbolic decoding, whether the latter is written, verbal or imaged.

The random abstract style is characterized by a preference for an unstructured learning atmosphere, leaving room for freedom of expression, by a strong awareness of human behavior and an ability to interpret it.

2.7 Kolb's learning style model

According to David A. Kolb published [23], there are four learning styles:

The diverger prefers the phases of concrete experience and reflection on this experience. He is interested in people and emotions. He has a sense of observation and he is adept at perceiving an object or problem from different angles. He enjoys innovative activities and has a fertile imagination and interests varied. He is interested in people and values feelings. He enjoys learning by experience.

The assimilator: he prefers phases of reflection and conceptualization, abstract and theory of an experiment.

The Assimilator likes to create patterns theoretical and is less interested than others in people and applications knowledge practices. They logically reorganize information and juggle ideas and theories. They appreciate the theoretical courses.

The Converger prefers the phases of abstract conceptualization and theory of the experience and application of the idea/action. Convergers like to be practical and tend to be unemotional. Moreover, they prefer to deal with things rather than people. They prefer to solve problems whose solution is unique. They have ease in tasks techniques and decision-making. They enjoy projects and activities self-managed.

The accommodator prefers the phases of concrete experience and implementation application of the idea based on this experience. Accommodators fit easily to new experiences and tend to find solutions. He learns manipulatively by performing tasks. He likes to be involved in the planning and carrying out activities, it works by trial and error rather only by logic; he tends to follow the thoughts of others rather than his own analysis. He easily accepts to take risks and he appreciates the small group exercises.

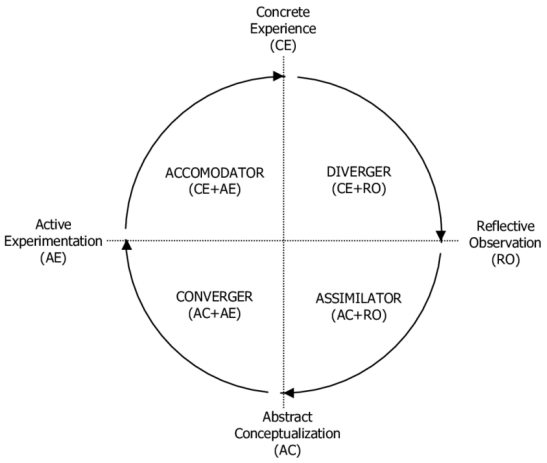

Fig. 2. David Kolb's Learning Styles

2.8 The Honey and Mumford LSM

Honey and Mumford [24] retain from Kolb [23] the idea of a four-phase experiential learning model that they name: the experience, the feedback on the experience, the formulation of conclusions and planning. According to them, each of the phases includes behaviors and own attitudes and is important to successfully complete the process of learning. But most people, through the successes and failures of behaviors in their attempts to learn, develop preferences which make them particularly "like" certain phases of the process.

To the extent that these phases are favored by individuals, they define four learning styles, each of which corresponds to "one of the descriptions of attitudes and behaviors that determine a preferred way of learning for an individual" [25]. In doing so, Bokoros [26] postulate the existence of four unipolar dimensions, rather than two bipolar dimensions as does Kolb [23]. This important difference between Honey [24] et Bokoros [26] in their ways of conceiving learning styles, could partly explain the weakness of correlations obtained by Bokoros [26] between learning scores Kolb's Style Inventory (LSI), first and second version and those in the Learning Styles Questionnaire (LSQ) of Bokoros [26].

The four learning styles according to Honey [24] are: the active learning style that describes the behavior of the person who privileges, the attitudes and behavior specific to the experience phase. The reflective style describes those of the return on experience phase; the theorist style describes those of the phase of formulation of conclusions and the pragmatic style that describes those of the phase of planning.

The active style is characterized by the taste for concrete involvement in an experience, to dive into activity here and now. This taste is particularly stimulated when the experience has an element of novelty or challenge and that there is an opportunity to play an active role in interaction with other people. The active style is also marked by the desire to engage with people, to confront their ideas with theirs and to take up

challenges or solve problems as a team. It is also characterized by the presence of invention of ideas in the absence structural constraints or standards.

The reflective style is characterized by the importance of hindsight and distance taken in relation to people and things. It is marked by prudence and careful thought before making decisions and acting. observation, listening, the exhaustive accumulation of data before issuing an opinion appear essentials, look back on events and review what happened are important behaviors. It is also characterized by the desire to take decisions without time constraints.

The theoretical style is characterized by the search for logic and coherence in the organization of the accumulated information. It is also characterized by the a taste for analysis and synthesis, an interest in basic presuppositions and the underlying principles, a valuation of the rational and objectivity. This taste is stimulated when it comes to understanding and explaining, exploring methodically, the links between ideas or by being confronted with systems, models or theories.

The pragmatic style is characterized by an interest in the application ideas, theories and techniques, with the explicit aim of validating operation. It is also characterized by a marked preference for realistic and practical solutions, by the desire to make useful decisions and to solve concrete problems. Respond to a well-identified immediate need, find concrete benefits and see practical advantages are considered as important dimensions of learning.

2.9 The Felder-Silverman LSM

Felder-Silverman [27] characterizes learners according to four dimensions. They show how learners prefer to process (Active/Reflective), perceive (Sensory / Intuitive), receive (Visual / Verbal) and comprehend (Sequential /Global) information.

In terms of learning styles, these aspects are not particularly novel, but the way they describe a learner's learning style may be. While the majority of learning style models with two or more dimensions, such as those by Briggs and Myers [4], Gregorc [21]–[22], Kolb [23], and Honey [24], statistically determine the types of learners represented by these dimensions. Felder and Silverman [27] use measures from 11 to -11 for each dimension to describe learning styles (Only odd values).

The accommodator dimension in Kolb's learning style model is comparable to **the Active/Reflective dimension**. Active learning involves actively engaging with, experimenting with, and applying the subjects being studied. Reflective learners love to ponder and reflect on their learning resources. They prefer to operate alone or in a small group with pals when it comes to communication.

The Sensory/Intuitive dimension is based on Briggs and Myers [4] and has similarities also with the accommodating style of the model Kolb [23]. Learners with a sensory learning style enjoy learning facts, using their sensory experiences as an essential source. They enjoy using conventional methods to solve issues and are frequently more detail-oriented.

The visual/verbal dimension relates to the preferred form of input and distinguishes between students who retain more textual representations, whether they are

written or spoken, and students who remember better what they have seen (such as drawings, diagrams, flow charts, etc.).

The fourth dimension, **Global/Sequential**, categorizes learners based on their modes of comprehension, either global or sequential. This dimension is based on the learning style model put forth by Pask [6], in which learners who study sequentially are referred to as serialist learners, while learners who learn globally are referred to as holistic learners. Sequential learners build their knowledge in discrete, logical phases.

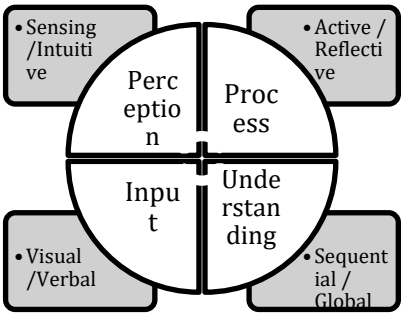

Fig. 3. Dimensions of Felder and Silverman Learning Style Model

3 Adaptive learning systems

Adaptive learning systems belong to a very important class of systems, namely adaptive hypermedia. They have the vocation of personalizing the learning process according to the learners' profiles. In order to achieve this personalization, it is necessary to collect information on the characteristics and preferences learning wise. Generally, there are two methods of collecting information, a first so-called implicit method [28]-[29]-[30]-[31]-[32] which consist in observing the learner's behavior during the learning phase and then building an adequate profile. The second method is said to be explicit [33]-[34]-[32]-[35]-[36] and consists of offering learners forms in which they are invited to express their learning preferences.

In this work we are only interested in systems that make use of explicit methods. In fact in the following table we summarize the most known adaptive systems which are based on the learning styles [37].

Most learning systems use Felder-Silverman learning styles. The reasons for the popularity of Felder's learning styles-Silverman are highlighted by Brown [38]-[39]. They justify this choice by the fact that the model fulfills most Criteria required by hypermedia systems, namely:

- Learning styles and model computations should be quantified by the model, as in the case of Felder-Silverman and the index (ILS).
- The model must have a high level of validity, reliability, and internal consistency in order to accurately measure the learning style.
- The model must be compatible with a web-based adaptive teaching system.

– The model needs to be simple for college students to use. As Sangineto [39] has pointed out, FSLSM has undergone thorough testing and validation on a population of engineering students. Additionally, while other models may have theoretically sound foundations, FSLSM offers practical suggestions helpful for tailoring training [39].

Table 3. Overview of ALS

System	Learning style
CS383	FSLSM
Manic	Combination of Learning styles
IDEAL	Determined by the tutor
Masplang	FSLSM
LSAS	FSLSM (Sequential /Global)
Iweaver	Dunn and Dunn
Inspire	Honey and Mumford
Tangow	FSLSM
AHA!	Determined by the tutor
ALS_CORR[LP]	FSLSM

4 Context awareness learning

In interactive applications, taking context parameters into consideration has become crucial, especially for applications whose context is dynamic. Similar to portable and widespread computing. We need a better understanding of what an application is and what context is in order to be able to leverage context more effectively and construct apps more quickly.

There are a number of definitions for the term "context," but the one adopted by [40] stands out as the most pertinent. It emphasizes that a context is any data that can be used to describe the circumstances of an entity, which can be a person, place, or thing, that is thought to be relevant to the interaction between a user and an application, including the user and applications themselves.

The following Context Perception Model (UCPM), which is based on Albrecht Schmidt's writings, emphasizes the concurrent perception processes occurring in the user and the system. If they disagree, we develop systems with an awareness mismatch, in which the system behaves differently than what the users would anticipate.

The context highlights four crucial components for learning systems, which are shown in Figure 4:

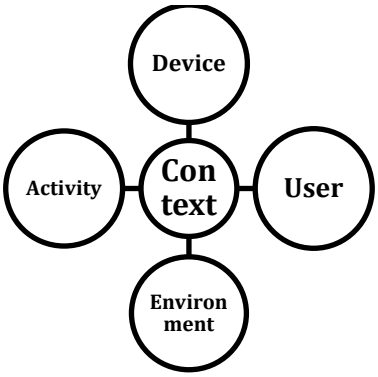

Fig. 4. The context elements

The context is built around four main components, as seen in the above diagram: the user, the device, the environment, and the activity. The primary characteristics of each element are illustrated in the following Table 4.

Table 4. The context element attributes

Context	User	Device	Environment	Activity
Attributes	Personal characteristics	Connectivity Battery	Localization Mobility	Learning objects Different versions of the learning objects Objective

In section 3, we have stated that most of the adaptive learning systems use the Felder-Silverman Learning styles. How adaptable are the LS of Felder and Silverman in a setting where the qualities are dynamically changing is the question that now has to be answered.

5 Felder-Silverman LS vs. Mobile environment

We are interested in this section at studying the relationship between the device attributes (Battery and Connectivity) and the FSLSM.

Table 5. Learning Object vs. Device requirement

FSLSM dimension	Corresponding Learning object	Device Requirement	
		Battery	***Connectivity***
Active	Assessment, Exercises	Low	Low
Reflective	Examples, outlines, summaries, result, pages	High	High
Sensing	Examples, explanation, facts, practical material	High	Low
Intuitive	Definitions, algorithms	Low	High
Visual	Images, graphics, charts, videos	High	High
Verbal	Text, audio	High	High
Sequential	Step by step exercises, link pages	High	Low
Global	Outlines, summaries	Low	High

Finally, the learning objects in the previous table bring us to the most pressing issues: to what extent can we follow the offered recommendations regarding learning style in a mobile environment? [42] Should we be forced to abide by the recommendation even when the battery is low, and the connectivity is not fully assured?

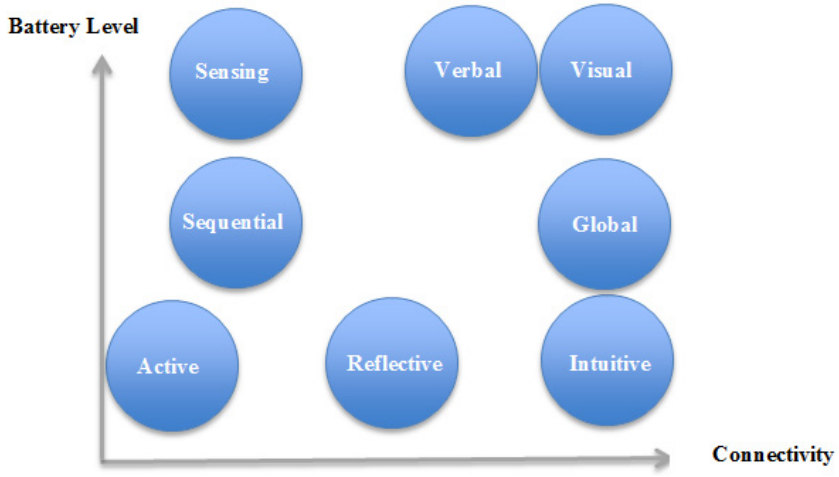

Fig. 5. Learning Object vs. Mobile attributes

6 Discussion

It is clear that the learning object recommendation based on learning styles in mobile environment [42], [43], [44], [45] has some limitations. Going back to the Felder-Silverman learning styles, we have found that the visual/verbal dimension presents a crucial criterion with regard to the recommendation of learning objects. There is a problem with projecting this dimension onto mobile environments: Both aspects of the visual/verbal dimension need an instantly available connection and a fully charged battery. That brings us to the conclusion that the adaptation of the Felder-Silverman learning style can only occur in particular circumstances. It is necessary to have a very good connection as well as a relatively full battery, other than that, we risk compromising the functioning of the device. If this is likely to happen, this will cause a problem with the recommendation. So in this case, the adaptation obviously will not take place and the system will switch to normal learning mode, namely the one size fits all paradigm, which considers learners as a single entity with the same learning preferences and obviously the same learning styles.

7 Conclusion

Although the learning styles have been proven in online learning environments, especially the Felder-Silverman learning styles because they satisfy several criteria

related to online learning. Their effectiveness has recently come up against the technical characteristics of mobile environments. We have seen how some dimensions of the Felder-Silverman learning styles, namely the visual / verbal dimensions, are not compatible with the technical characteristics, in particular those concerning the battery and connectivity. This allowed us to answer the question of how conflicting it is to adopt Felder-Silverman's learning styles in mobile environments. Which lead us to conclude that the adaptation of content according to FSLSM is only possible under optimal conditions.

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