

INTERNATIONAL
STANDARD

ISO/IEC
23126

First edition
2021-04

**Information technology for learning,
education and training — Ubiquitous
learning resource organization and
description framework**

*Technologies pour l'éducation, la formation et l'apprentissage —
Description de l'organisation et ressources d'apprentissage
omniprésent*



Reference number
ISO/IEC 23126:2021(E)

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Foreword

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This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 36, *Information technology for learning, education and training*.

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Introduction

Ubiquitous learning is becoming increasingly prevalent. Ubiquitous learning makes it possible for students to learn anything, at anytime, anywhere, using any learning device. To support ubiquitous learning for learners, a ubiquitous learning support model should be constructed to provide ubiquitous services. The model consists of four parts: user interface; sensor layer; educational cloud system; and learning resources and services ([Figure 1](#)). During the learning process, the user interface detects learners' learning status, logs, interactions and personal information in the real learning context through the sensor layer. Subsequently, the educational cloud system conducts computing and analysis before providing learners with adaptive learning resources and services (see [Annexes A, B and C](#)).

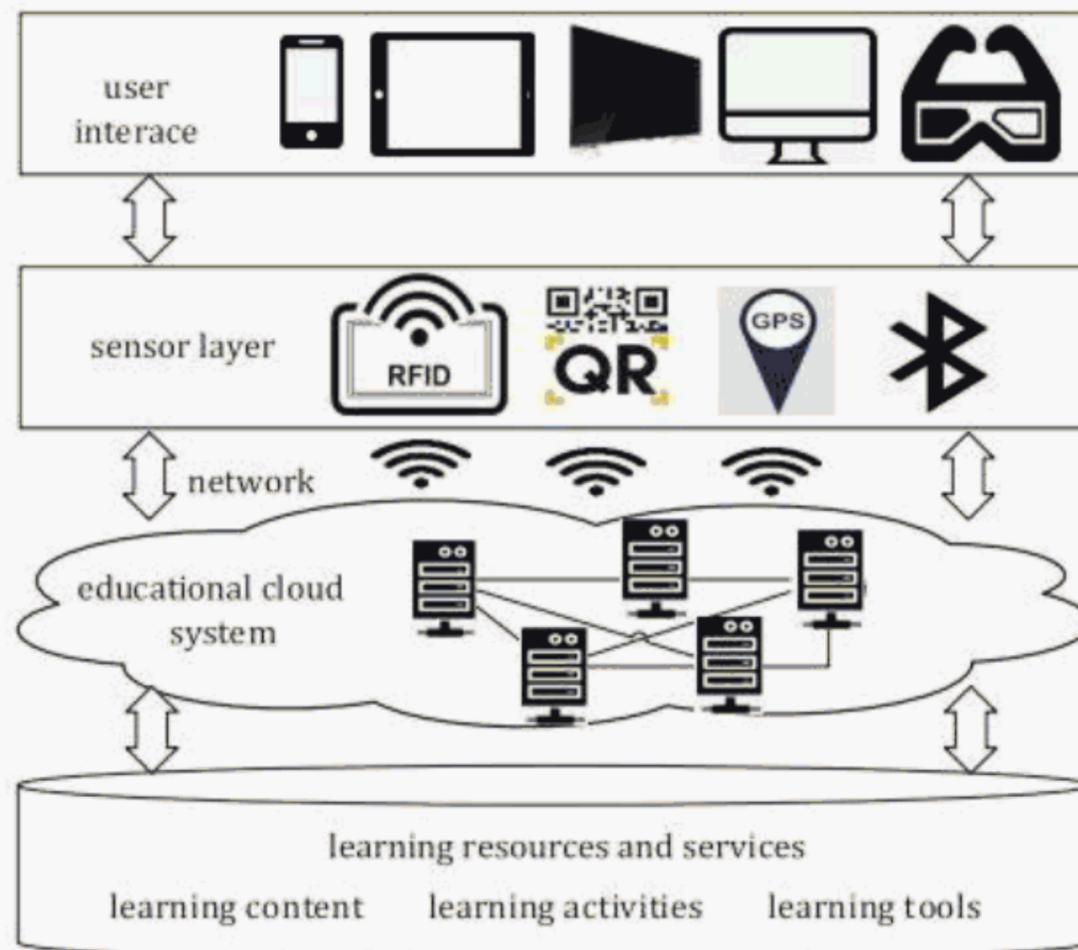


Figure 1 — Ubiquitous learning support model

Learning resources and services are central to learners' learning processes. However, learners' learning contexts can change as learners start and continue learning at different points across time and location. Under these circumstances, learners need adaptive resources and services to achieve effective learning. Traditional learning resources are designed and developed by experts for specific contexts. In some cases, the content is mostly static and cannot dynamically change to meet the diverse needs of learners who are accessing content in different environments. In addition, learners can encounter some difficulties as they learn specific topics. Related experts, peers or resources supporting the learning of the topic can be helpful for learners to expand their knowledge and knowledge-related connections. As time passed, learners can also contribute to current knowledge and thus promote the updating or evolution of knowledge while they achieve even higher-level knowledge. In order to make the learning process effective, it is important to provide learners with continuously evolving resources:

- a) Learning resources should have the ability to adapt to different learners' needs under different learning contexts.
- b) Learning resources should support the interactions not only between learners and resources, but also the interactions among learners and among resources.
- c) Learning resources should evolve according to the contribution of learners or new knowledge so that they can be continuously adapted for learners with diverse needs.

- d) In order to support personalized learning, dynamic and distributed resource aggregation service should be provided to learners with different learning requirements.

In summary, the ubiquitous learning support model needs to support diverse contexts, rich social interactions, continuous evolution and dynamic aggregation of knowledge. To that end, learning resources are the most important part for realizing the adaptation of the learning process. In order to support that adaptation, not only experts but also learners should be involved in the co-construction of learning resources. During the resource construction, resources should align with the contextual, social, evolvable and dynamic aggregated features. And in order to make the resources constructed by different contributors align with those features, a standardized guideline is needed for co-construction. However, existing standards for learning resources design and development focus on different aspects of static learning resources in terms of topic, description, related subjects, contributor and so on, and there is no description of the contextual, social, evolvable and dynamic aspects. In order to support these aspects, this document offers a ubiquitous learning resource organization and description framework, which is also referred to as a “learning cell framework”. This document provides a description of the main framework for ubiquitous learning resources. It does not provide detailed definition.

Information technology for learning, education and training — Ubiquitous learning resource organization and description framework

1 Scope

This document specifies a framework to describe and organize learning resources in ubiquitous learning. It provides features to enable dynamic aggregation of resources in different learning contexts, in which the social interactions are recorded to facilitate social learning. The features that reflect the evolutionary history of resources based on learners' contributions are also defined.

The framework includes an aggregation model, content organization, context-aware learning services, and learning cell service provider.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1

entity

any concrete or abstract thing that exists, did exist, or might exist, including associations among these things

EXAMPLE A person, an object, an event, an idea, a process, etc.

Note 1 to entry: Entity is a supportive element of identifier.

[SOURCE: ISO/IEC 2382:2015, 2121433, modified — domain of <databases> removed, notes to entry updated]

3.2

environment

<ITLET> context, surroundings or conditions in which a person learns, lives or operates

Note 1 to entry: Environment information includes time zones, geographical information, applicable norms and standards for telecommunication, technical implementation (firewalls, useable or allowed ports, bandwidth, file size restrictions, etc.), infrastructure support, current noise levels, and other environmental factors that may impact on delivery modes required by the learner.

3.3

identifier

sequence of characters capable of uniquely identifying an *entity* (3.1)

[SOURCE: ISO/IEC 19788-1:2011, 3.19, modified — notes to entry removed]

3.4

knowledge

human or organizational asset enabling effective decisions and action in context

Note 1 to entry: Knowledge can be individual, collective or organizational.

Note 2 to entry: There are diverse views on the scope covered within knowledge, based on context and purpose. The definition above is general as to the various perspectives. Examples of knowledge include insights and know-how.

Note 3 to entry: Knowledge is acquired through learning or experience.

[SOURCE: ISO 30401:2018, 3.25]

3.5

knowledge cloud

collection of *learning cell* (3.7) and *knowledge cluster* (3.6) aggregated semantically based on several related or similar topics to satisfy particular requirements for learning

3.6

knowledge cluster

collection of two or more *learning cells* (3.7) aggregated semantically based on a specific topic

Note 1 to entry: Knowledge cluster is a supportive element of knowledge cloud.

Note 2 to entry: Knowledge cluster can be involved in learning communities to support learners' learning.

3.7

learning cell

dynamic structure for ubiquitous *learning resource* (3.13), which defines the basic elements and their relations, and provides a personalized presentation [*learning cell entity* (3.9)] to support the diverse needs of learners based on a specific learning objective

Note 1 to entry: The structure is context adaptive, involves social factors to support social learning, realizes the evolution based on learners' interactions and contributions, and can dynamically aggregate content, based on the contextual, social and evolvable information and present learners with personalized *learning cell entity* (3.9).

Note 2 to entry: Learning cell has four characteristics: contextual, social, evolvable and dynamic aggregated.

Note 3 to entry: Learning cell is a supportive element of knowledge cloud and knowledge cluster.

Note 4 to entry: Learning cell can be involved in learning communities to support learners' learning.

3.8

learning cell container

space where *learning resource* (3.13) or *learning ingredient* (3.11) is extracted from different learning systems and managed according to specific topic or topics

Note 1 to entry: In this space, the resources or ingredients collected from the learning systems can be reorganized and retained in a well-structured manner.

3.9

learning cell entity

instance of a *learning cell* (3.7) that can be used in different learning contexts to support different learning needs

Note 1 to entry: A learning cell entity is a presentation of a learning cell within a specific context.

3.10

learning community

area in which learners with the same interests can interact, access, and share information using resources such as *learning cell* (3.7) and *knowledge clusters* (3.6) to achieve specific learning objectives or outcomes

3.11 learning ingredient

component that can be used to form a *learning cell* (3.7), such as content, activity, tools and metadata

Note 1 to entry: A learning ingredient is a supportive element of learning cell.

3.12 learning objective

description of a goal of training or learning in terms of the knowledge, skills or performance expected of a learner

Note 1 to entry: A learning objective may also be referred to as a learning outcome.

Note 2 to entry: A learning objective is often defined based on the requirements of a curriculum criterion or a set of criteria.

[SOURCE: ISO/IEC 2382-36:2019, 3.5.2, modified — notes to entry added]

3.13 learning resource

resource (3.17) used for learning, education and training

[SOURCE: ISO/IEC 19788-1:2011, 3.20]

3.14 obligation status

<attribute> indication of whether or not a value for the attribute is to be provided

[SOURCE: ISO/IEC 19788-1:2011, 3.20, modified — note to entry removed]

3.15 person person class

any *entity* (3.1) which is a natural or legal person

3.16 personal learning space

place for a learner to manage his/her learning profile, assignments, interactive data, evaluation and associated information generated during the learning process

Note 1 to entry: This personal space may be shared with learner's permission to instructor(s), other learner(s), and other systems to support further learning of the individual, other individuals, and the system itself. Learner data and interactions are private in the personal space and learner consent is required to share this data.

3.17 resource

entity (3.1) that can be identified and referenced by an unambiguous and stable *identifier* (3.3) in a recognized identification system

[SOURCE: ISO/IEC 19788-1:2011, 3.30]

3.18 resource class

set of *resources* (3.17) that can be identified by listing or description of boundaries and meaning and whose properties and behaviour follow the same rule

Note 1 to entry: A resource class has the following attributes:

- Identifier.
- Name.
- Definition.

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— SubclassOf [multiple inheritance].

— Note.

EXAMPLE Learning Resources (set of all learning resources), Persons (set of all Persons), Rights (set of all rights objects), and Documents (set of all documents).

[SOURCE: ISO/IEC 19788-1:2011, 3.31]

3.19 sharable learning cell description interface SLDI

interface to provide registration and open access for services and resources in different learning systems

3.20 social knowledge network SKN

network constituted by person, knowledge and their relations based on specific knowledge that supports learners' knowledge and peer discovery during the ubiquitous learning process

Note 1 to entry: A social knowledge network represents all the nodes that have a relationship with specific knowledge, and the nodes include person nodes and knowledge nodes.

3.21 ubiquitous learning

learning that is stimulated and supported through diverse channels and always readily accessible

[SOURCE: ISO/IEC TS 29140:2020, 3.15]

4 Abbreviated terms

LOM learning object metadata

MLR metadata for learning resources

ITLET information technology for learning, education and training

API application programming interface

5 Learning cell framework overview

5.1 General

The learning cell framework supports learners' ubiquitous learning. An overview of the ubiquitous learning model supported by the learning cell framework is provided in [Figure 2](#), which illustrates the process for learners to acquire ubiquitous learning services in different situations. In this model, the situations (classroom, home, bus station and so on) where learners' learning requirements rise are defined. In different situations, learners can interact with learning cells embedded in different devices.

During this process, the learning cell service will detect learners' personalized information and learning status with various sensors. Detected information will be sent to the educational cloud computing centre for analysis. The educational cloud computing centre conducts analysis and decides learners' current states and needs. The needs include several kinds of personalized services, such as knowledge network, social network, and other learning services (learning tools, learning activities, cognitive map and so on). These services will be dynamically collected, aggregated with the form of the learning cell and then present to learners with an adaptive presentation.

After these processes, learners can acquire adaptive learning support. With learners' further interactions, the learning cell can also be enriched. This document defines the core factors in a ubiquitous learning resource, and these constitute the organization and description framework.

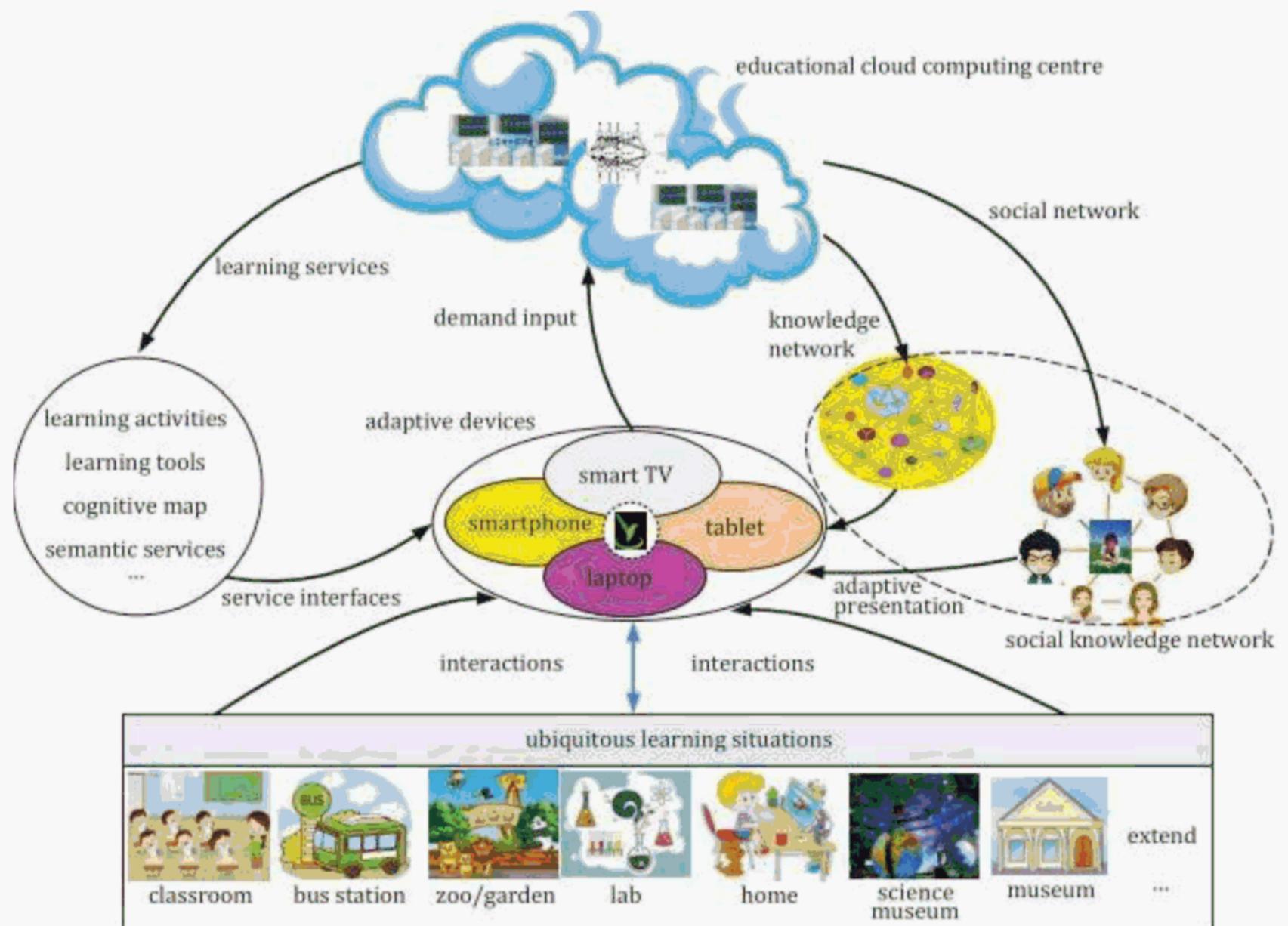


Figure 2 — Ubiquitous learning supported by the learning cell framework

The learning cell framework defines the characteristics of learning resources, in which different situations are supported for contextualized learning. At the same time, social knowledge network is used to support social learning and learning activities can be used to help the progression of the learners and learning resources. At last, the learning resources can be dynamically aggregated from different sources. Moreover, the framework also provides a detailed introduction of how these characteristics are represented with specific properties. Subclauses 5.2 and 5.3 define the characteristics and components of the learning cell framework.

5.2 Characteristics of learning cell

The learning cell has four essential characteristics: contextual, social, evolvable, and dynamic-aggregated. These characteristics can help realize the previously mentioned resource requirements

Contextual: The learning cell provides a changeable and dynamic structure that can adjust the elements and their organization in the structure so as to support learners' learning under different contexts. After that learners in different contexts can access resources that are aligned with their contexts both in terms of structure and display. This means that the presentation of the resource will match the learners' contexts.

Social: The learning cell provides social elements in its structure. The social elements are presented to learners with the form of social knowledge network, which contains person nodes, knowledge nodes, and the relations among these nodes. The nodes and relations in the social knowledge network are

created by learners' social interactions with different knowledge and related person nodes, such as other learners. The interactions will be retained as the SKN and used for computing and analysis.

Evolvable: The learning cell defines elements to record the interaction history and aggregation history of resources during the learning process. The interaction history is based on the contributions of different learners and promotes the learning cell transformation from insufficient to sufficient, low-quality to high-quality. The control of this process will be realized by algorithms. Also, when new resources are created, they will be classified semantically by algorithm, and thus cluster to a higher-level resource with higher quality.

Dynamic-aggregated: The learning cell defines the aggregate process how a learning cell entity can be formed and presented to learners dynamically. Contextual information is the basic condition for realizing the dynamic aggregation. A computing centre in the learning cell first conducts data analysis based on the contextual information and decides the elements involved in the learning cell entity. Then the sequences or structure of different elements will be computed, thus aggregating the elements together in a well-ordered manner. Also, when the context changes, the learning cell will detect the change and conduct re-aggregation dynamically. In this way, the resource is dynamically aggregated.

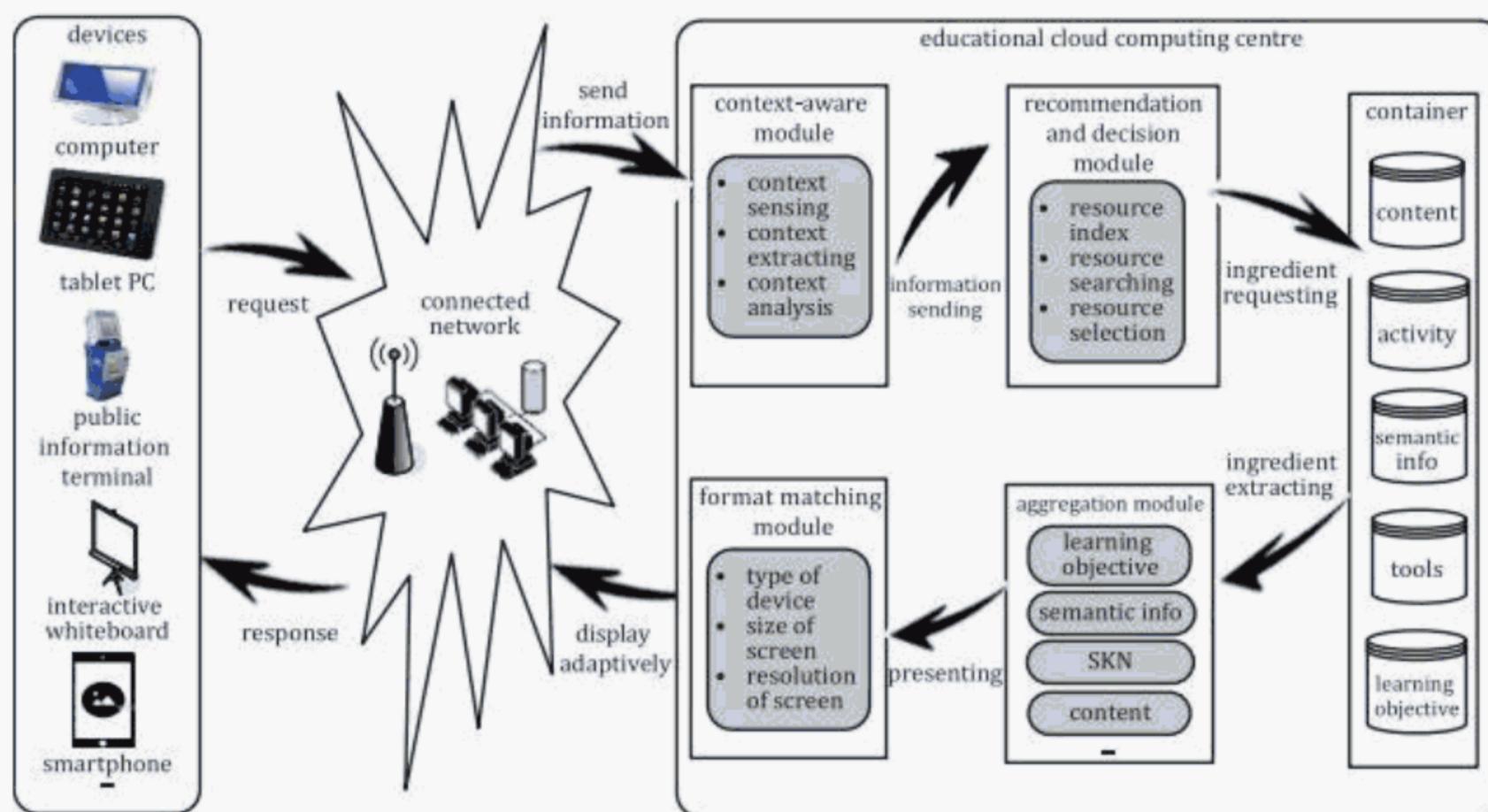


Figure 3 — Functions supported by learning cell framework

To realize these characteristics, this document defines how the system is supported by learning cell framework functions (see Figure 3). It includes three core elements: devices, connected network, and educational cloud computing centre. When ubiquitous learning begins, learners send their requirements through adaptive devices. Then the requests and related data collected by the sensors embedded in the environment are sent through the connected network to the educational cloud computing centre. After receiving the requested information, the context-aware module conducts analysis, and then transfers the analysed information to the recommendation and decision module. The recommendation and decision module are responsible for indexing, searching and selecting ingredients from the learning cell container, including learning objectives, content, activities, semantic information and cognitive network. Then the extracted ingredients are aggregated through the aggregation module into learning cell. Finally, the learning cell is displayed adaptively after format matching, such as matching type, size, and resolution of the device. Users can interact with the learning cell and promote the evolution of the learning cell.

5.3 Components of the learning cell framework

The components of the learning cell framework are shown in [Figure 4](#). The aggregation model defines the structure of a learning cell. The content organization provides detailed description for the elements and features in a learning cell. Context-aware learning services can support learners' situated learning based on the model and the organization, and finally the learning cell service provider can help the learning cell service be used by different systems or platforms:

- **Aggregation model:** The learning cell aggregation model defines the core elements and aggregation process of learning cell framework. With this model, learning systems which in line with the learning cell standard can conduct resource aggregation and provide learners with adaptive entities to different learners in different contexts.
- **Content organization:** The content organization defines the detailed semantic information and their organization which support the composition of the learning cell. The semantic information includes basic semantic information, contextual information, social information and evolvable information.
- **Context-aware learning services:** Context-aware learning services provide APIs for learners to access resource aggregation services for ubiquitous learning. The services are based on the learners' contextual information and personal profile. With the information authorized, the system can provide learners with adaptive learning services.
- **Learning cell service provider:** The learning cell service provider defines the process of how to realize learning cell services in different systems. It stores the service information and guidelines on how to register the services. Moreover, different systems can communicate with each other and with the registered services.

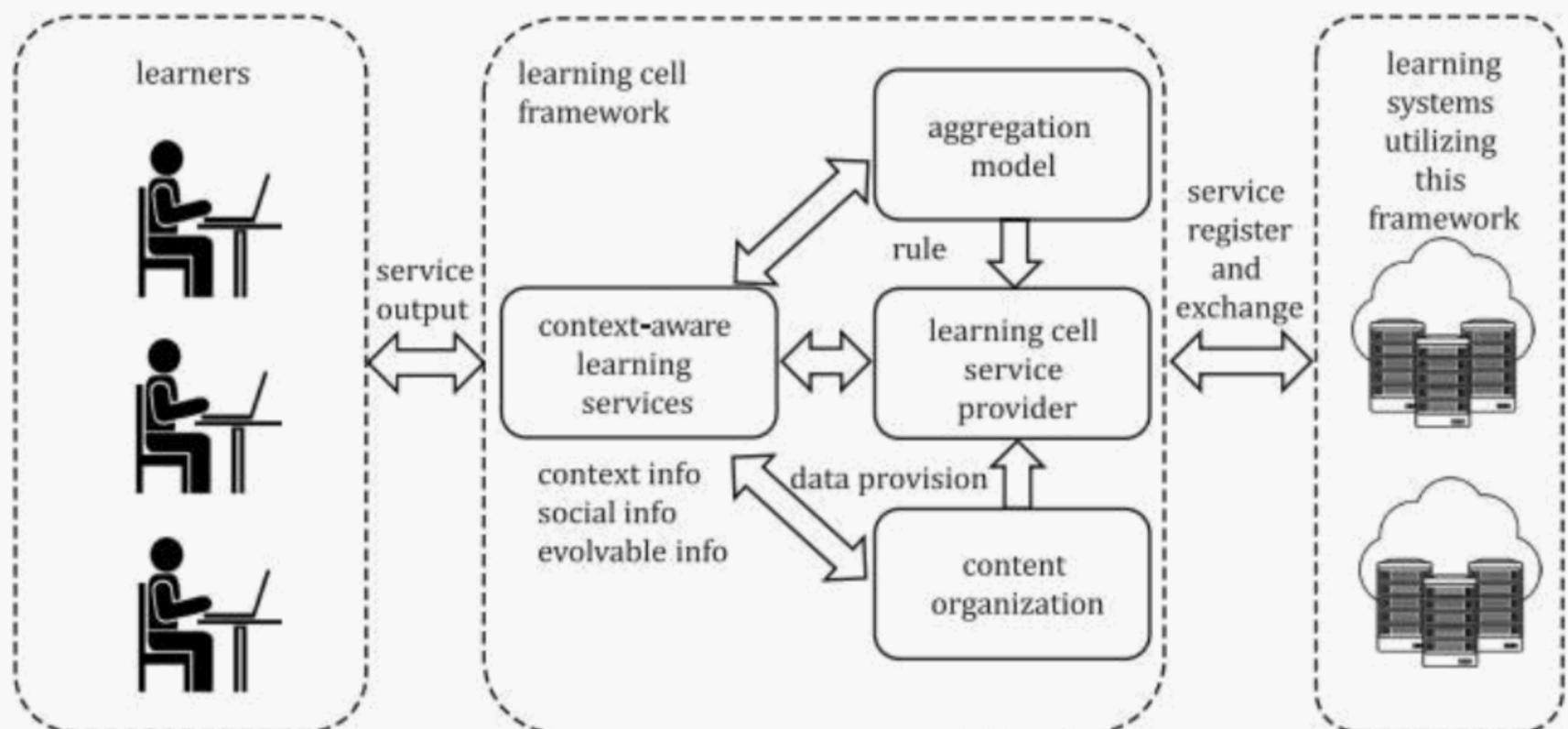


Figure 4 — Components of learning cell framework

6 Detailed description of the components in the learning cell framework

6.1 General

The four components of the learning cell framework play different roles during the ubiquitous learning. The aggregation model decides the structure of the ubiquitous learning resources. The content organization provides the detailed information regarding organization and structure. The context-aware learning services sense learners' information under different situations and help decide what

kind of resource or service learners need. Finally, the learning cell service provider provides open services among different learning systems or platforms.

6.2 Aggregation model

This component defines which elements constitute the learning cell and how to realize the aggregation process with the provided elements. With these elements, the detailed content can be aggregated dynamically if the context changes. The learning cell is a dynamic structure. It is organized based on specific knowledge and is related to one learning objective. At the back of the structure, there are large amounts of resources used to support the dynamic aggregation of the learning cell for learners based on the structure, environment and context. The aggregated learning cell can be represented to learners as a learning cell entity.

Elements of the learning cell aggregation model include: learning objective, semantic information, content, activity and SKN, as shown in [Figure-5](#). The learning objective, as an educational property, is the most important element of learning. It defines which learning level the learners are supposed to attain after the learning process. Semantic information will be used to differentiate learning cells. On one hand, it defines what topic the current learning cell is. On the other hand, it defines the organization of elements within this learning cell. Content and activity are the main parts of the learning cell. These elements represent the real resources (or learning cell instances) that learners get during the learning process. SKN describes the network of the current learning cell. It includes social relations and knowledge relations. With these relations, learning will become connected and helpful to learners' progress.

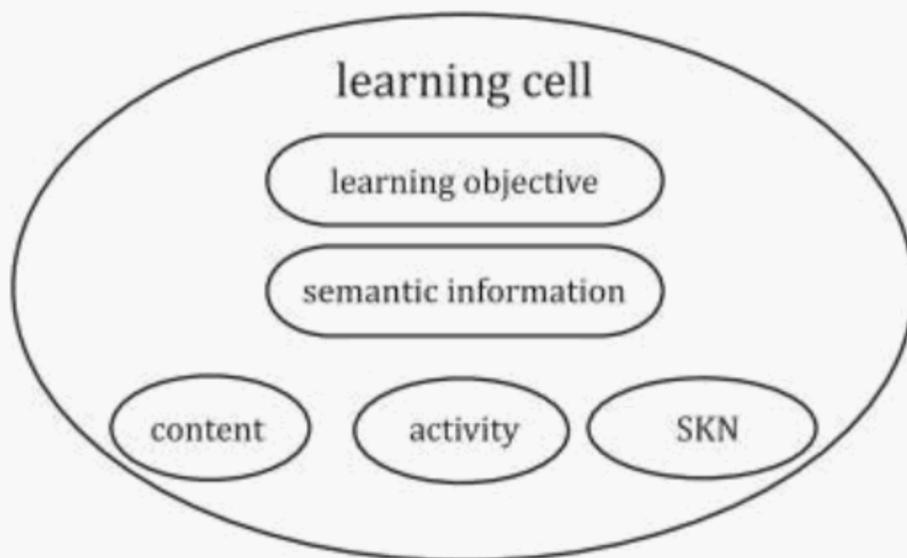


Figure 5 — Aggregation model

Regarding the aggregation process, there are three components: learning cell, knowledge cluster, and knowledge cloud. There are three levels of aggregation: aggregation of a single learning cell, aggregation from single learning cell to knowledge cluster, and aggregation from knowledge cluster to knowledge cloud.

For the aggregation of a single learning cell, all these processes are based on the aggregation model. It will search for related ingredients from the learning cell container and then output the learning cell entity with specific learning objective and organization.

After certain learning cells are aggregated, multiple learning cells with the same topic can be aggregated to a knowledge cluster. The learning cells in a knowledge cluster can be networked by different semantic relations. The knowledge cluster can also directly or indirectly help establish relationships between users and resources.

Similarly, knowledge clusters with similar themes or strong semantic relationships can be aggregated to the knowledge cloud, which can provide richer learning content with relevant themes for learners (see [Figure-6](#)).

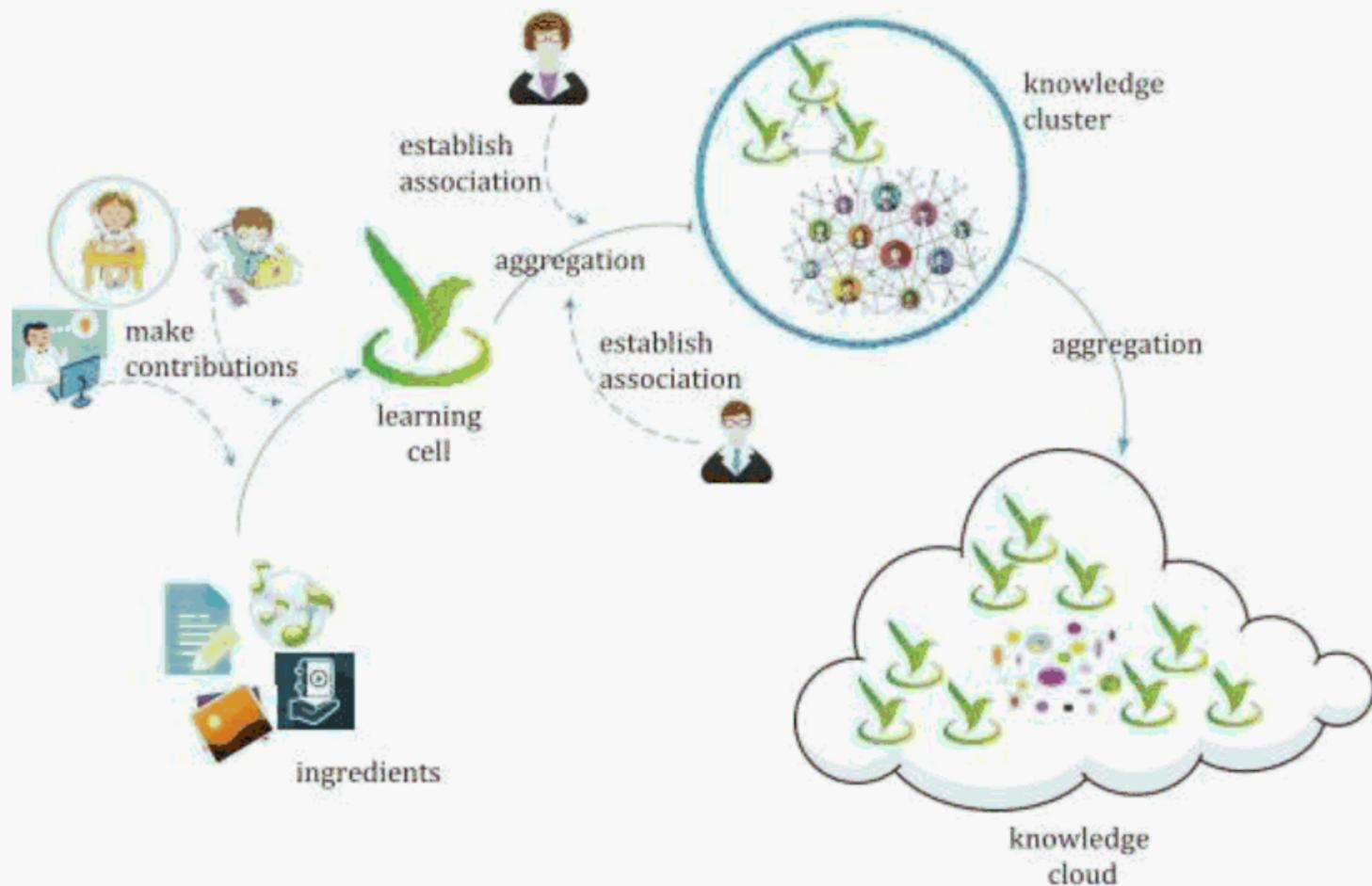


Figure 6 — Aggregation process for learning cells

6.3 Content organization

6.3.1 General

In order to satisfy the specific learning objective accurately, the learning cell is expected to have a well-organized structure. On one hand, some internal properties are required to describe the relationships between entities within the learning cell. On the other hand, some associated properties can be used to describe the relationships between different learning cells. To achieve this purpose, this framework specifies the content organization of a learning cell that contains both the learning ingredients, contexts and the descriptions of all of these relationships. All of these elements are supported by the learning cell container defined in the learning cell framework (see 6.4.1.2).

The content organization of the learning cell is described in Figure 7 and contains three parts: ingredients, resource contexts, and description of the learning cell information that reflect learning cell's characteristics (basic semantic information, contextual information, social information and evolvable information). Ingredients include multimedia resources, learning activities, learning tools, templates, evaluations and generative information provided by the learning cell container. Resource contexts describe the list of the provided context or situation in which the learning occurs. The description of the learning cell information defines information based on the learning cell's characteristics and contains four sub-parts: basic semantic information, contextual information, social information and evolvable information.

The basic semantic information is based on the metadata defined in IEEE LOM, Dublin Core, and MLR, and is the basic information which supports the dynamic aggregation. This document also makes some adjustments according to the ubiquitous learning needs. The other three descriptions are unique features of the learning cell and help realize the contextualization, socialization, and evolution characteristics in ubiquitous learning. The contextual information describes the most preferred context in which the learning cell can be implemented. The social information provides the rules and relations that make the learning cell a social entity. With the information, a network can be constructed, thus learners and learning cells can be located more easily. The evolvable information describes the dynamic state of a learning cell. In ubiquitous learning, the learning cell can dynamically change and evolve with

learners' learning process and emerging contents. Hence, it is necessary to record the version updates and interactions for the learning cell. Subclauses 6.3.2 to 6.3.5 specify the four descriptions in detail.

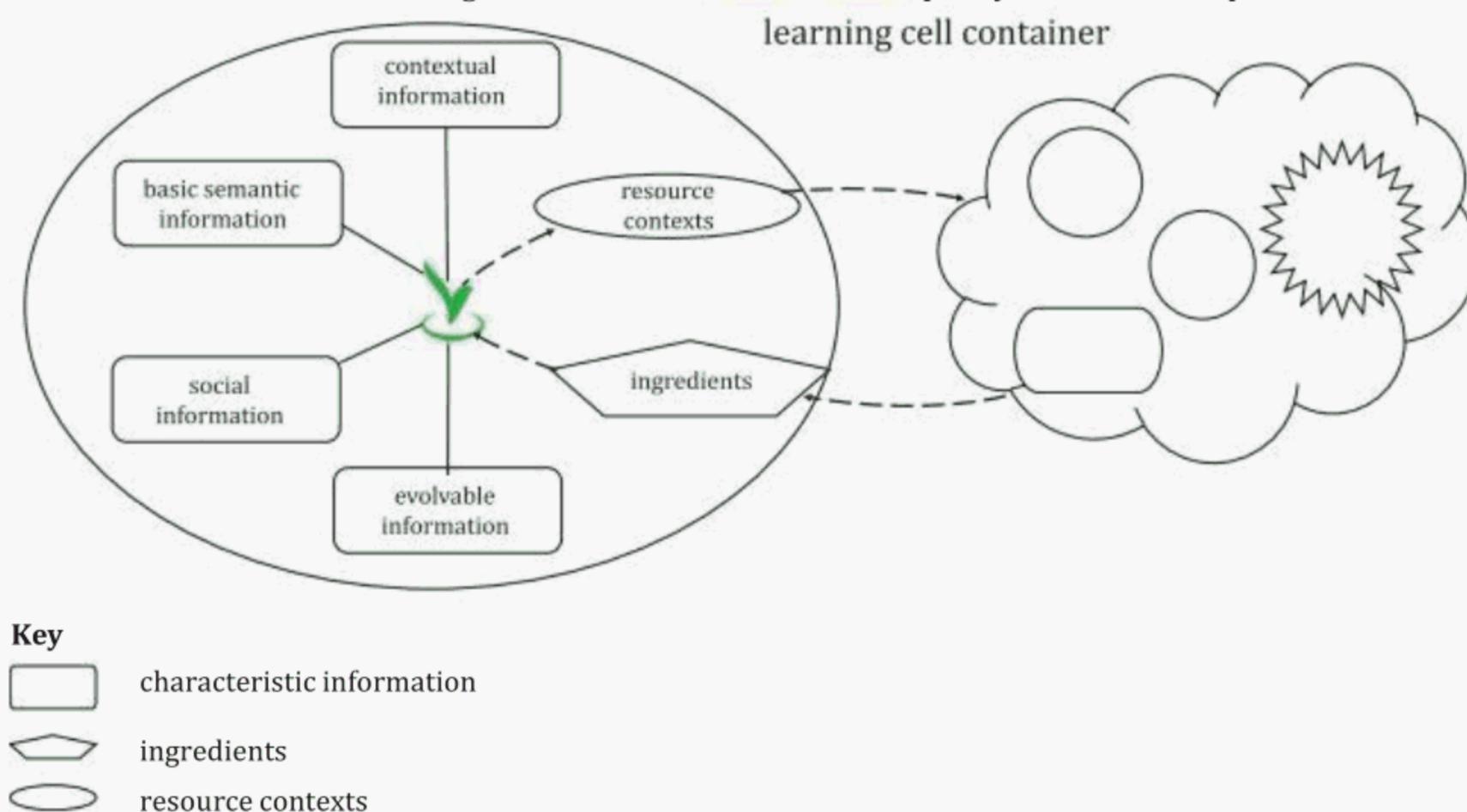


Figure 7 — Content organization of the learning cell

6.3.2 Basic semantic information

This document supports semantic description for basic metadata existing in previous learning resource standards, such as title, description, life cycle and so on. This framework defines all of these properties using triples, like $\langle \text{Class}, \text{relation}, \text{Class} \rangle$, $\langle \text{Class}, \text{hasProperty}, \text{Property} \rangle$, $\langle \text{Property}, \text{hasValue}, \text{PropertyValue} \rangle$. With numerous triples, resources can connect to each other based on the relations defined. When one resource is changed, the related resources can successively be updated according to the relations in the triples. The basic semantic information will facilitate the representation, categorized management, browsing, searching, sharing and exchange of learning resources, and enhance completeness of the description.

In detail, basic semantic information in the learning cell framework mainly includes the following data elements: basic information of resources (general), copyright information of resources (right), pre-defined relation information (relation), annotation information (annotation, conforming to the web annotation data model and the ISO/IEC 19788 series), historical edition information (lifecycle), learning material organization information (organization, extend the classification and education in LOM), learning content information (learning content), learning objective information (learning objective), evaluation scheme information (evaluation), practice/test information (practice), learning activity information (learning activity), version description information (content version), sensor and so on (see [Figure 8](#)). Most of these data elements are used to describe the content of the resources, while sensor is a data element which realizes the perception of information through tags or QR codes.

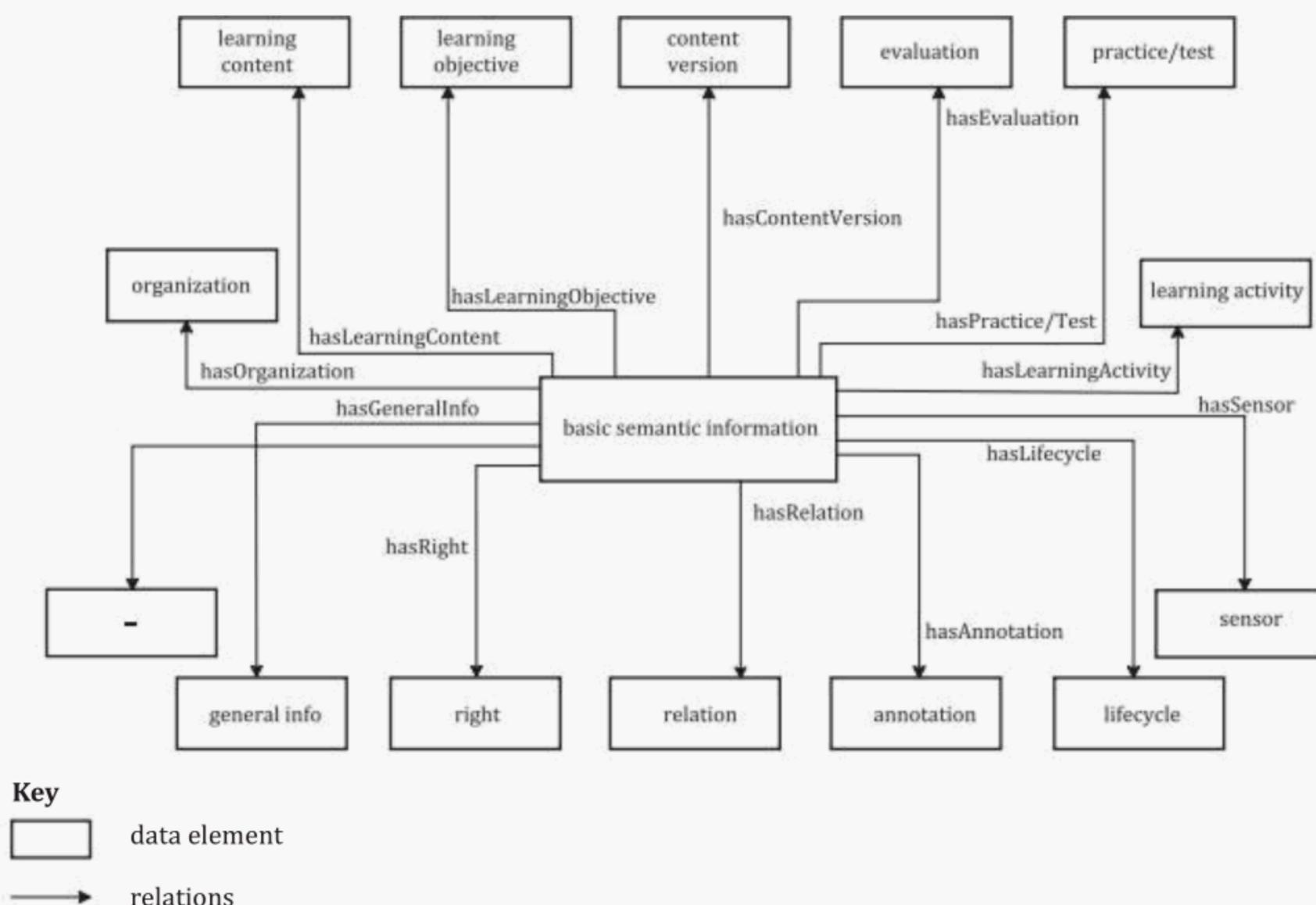


Figure 8 — Basic semantic information

The data elements, information and their citations are shown in [Table 1](#). These elements are basic elements in composing the learning cell. Their citation sources and obligation status are described. The information can be extended if needed.

Table 1 — Cited elements

Data elements	Citation source	Obligation status
Annotation	19788-5:2012::RC0001 Annotation	optional
Classification	19788-5:2012::DES1000	mandatory
Content version	19788-8:2015::DES0500	optional
Contributor	19788-2:2011::DES0600	mandatory
Coverage	19788-2:2011::DES1400	optional
Creator	19788-2::DES0200	mandatory
Data	Dublin Core	mandatory
Evaluation	Adjusted from Educational of LOM	optional
Format	19788-2:2011::DES0900	mandatory
GeneralInfo	Adjusted from LOM(General)	mandatory
Learning activity	19788-5:2012::RC0005 Learning activity	optional
Learning content	New	optional
Learning objective	Adjusted from Educational of LOM	optional
LifeCycle	LOM	optional
Organization	Dublin Core(Publisher),LOM	optional

Table 1 (continued)

Data elements	Citation source	Obligation status
Practice/test	Adjusted from Educational of LOM	optional
Relation	Adjusted from 19788-5::DES2700 Pedagogical Relation	optional
Rights	19788-2:2011::DES1500	mandatory
Sensor	New	mandatory
Source	Dublin Core	mandatory
Subject and keywords	19788-2::DES0300	optional
Other information

For each of these data elements, the learning cell can be represented in detail with some descriptive data properties, such as identifier, name, description, language (used to describe what language the element support) and other information. Apart from the proposed data properties, two new properties are needed: ‘RecordPermission’ and ‘AccessibleToOthers’, to describe if the learner would like their data to be recorded and open access to others. The detailed description is like the following:

DES-FORMAT:

- Identifier: from 19788-1;
- Name: from 19788-2:2011::DES0100 Title;
- Definition;
- Language;
- RecordPermission;
- AccessibleToOthers;
- OtherInformation.

Figure 8 shows the elements of the learning cell, which are described in detail in Figure 9. Each element is drawn as a rectangle or circle, and each relation is drawn as an arrow. The arrows and the objects at the arrows’ start and end constitute the triples which describe the learning resources.

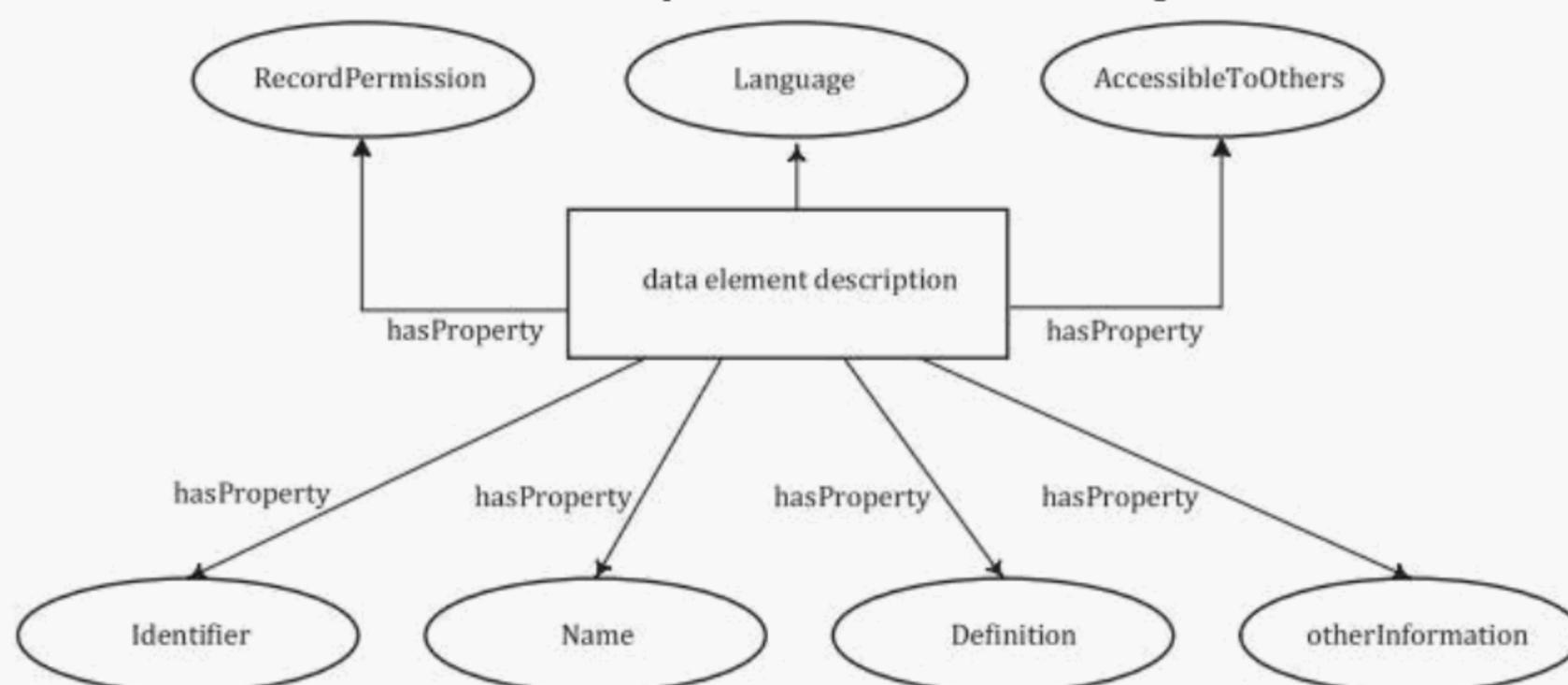


Figure 9 — Description of each element

6.3.3 Contextual information

Contextual information is one of the core characteristics of ubiquitous learning and it represents factors that indicate if a specific resource can be used in one context. This is quite important for the effectiveness and adaptability of learning. The context-based adaptation considers different types of contexts, such as devices, output format, content, and so on. On one hand, the output service is required to be in accordance with the devices and the outer conditions to make sure the format of the resource adapts to the learners. On the other hand, the content shall be adapted to learners with different abilities or characteristics to realize content adaptation (see Figure 10). As shown in Figure 10, learners can start learning under different contexts with different devices. Under this condition, the learning resources provided to the learners can be different and adaptive to the devices and contexts. Also, as noted in Figure 10, Learner1 and Learner2 are different users with varied abilities who need to get specific content adapted to their learning abilities and requirements. This can help make learning more efficient. To realize these efficiencies, a method shall be proposed to define and describe the contexts of learning resources, as well as a contextualized process.

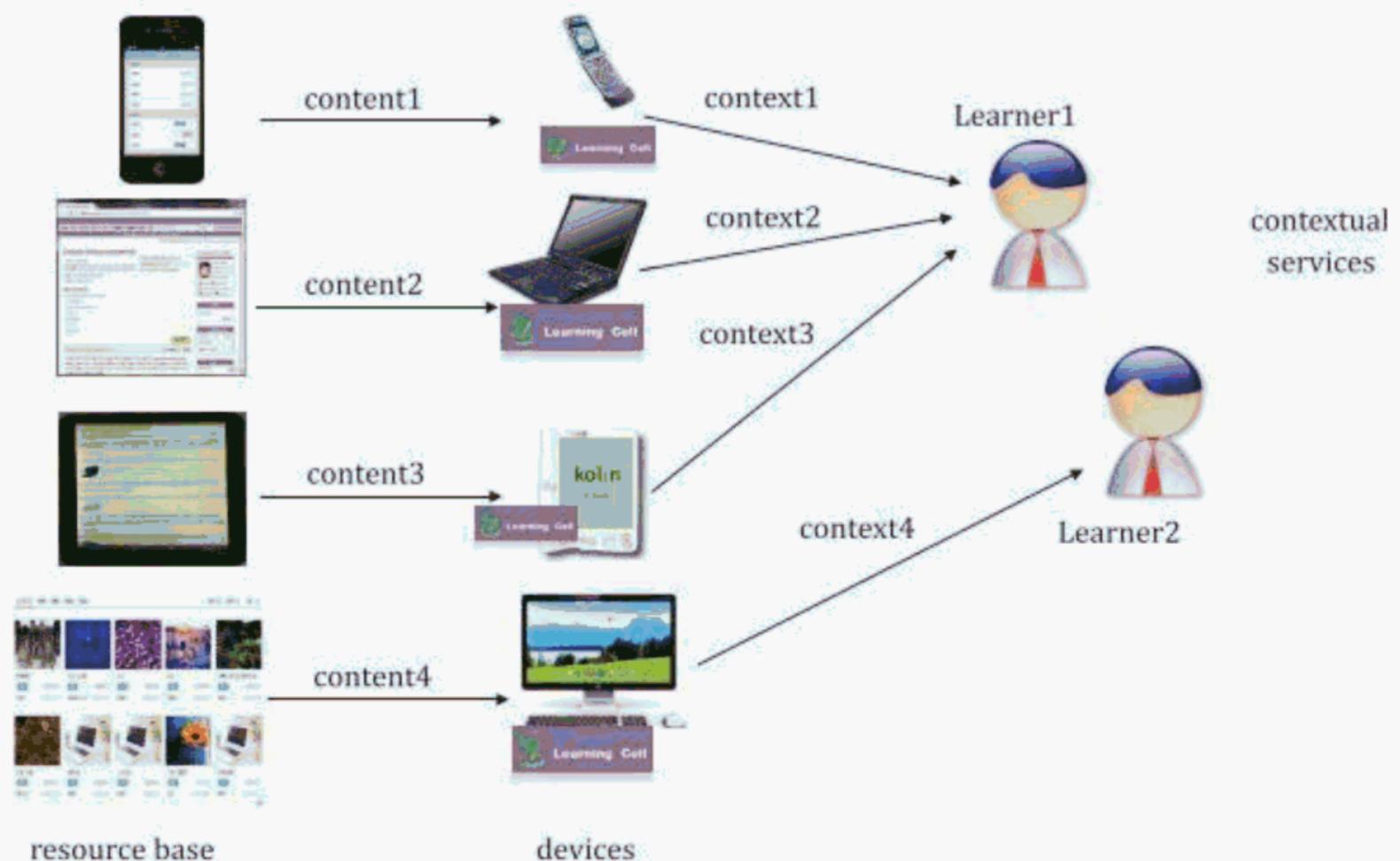


Figure 10 — The demand for contextualized resources

To satisfy varied learning demands, categories of contexts, and the detailed properties under them, will be defined. Also, resources in the learning cell container are tagged with provided context properties. Only in this way, the ubiquitous learning system can recommend resources accurately. For example, when a learner is learning Knowledge A at Location L, the ubiquitous learning system should provide resources that are adaptable for Knowledge A and Location L. If the resource was not tagged before, the ubiquitous learning system would not be able to decide whether this resource is appropriate for the specific learner or not.

To ensure this, the contextual service framework is specified, which is used to describe the function of contextual services for learners (see Figure 11). In this service framework, the details of contextual information are defined: equipment context, time-space context, physical state context, instructional state context and learning state context.

In the contextual service framework, there are several factors: learners, sensor, context-aware, adaptive resources, adaptive resource instances, and resource and rule database. Learner1, Learner2, Learner3, ... represent different kinds of learners. The sensor represents the medium that can sense learners' requirements and convey the appropriate information. The context-aware module can match

each learner’s requirement with the resources in a database based on specific relations. The adaptive resources module defines two kinds of adaption: format and content. The adaptive resource instances module identifies the final resource shown to different users. The database is a place that stores all the resource ingredients and rules. When learners’ requirements are identified, the demands can be transferred to the ubiquitous learning server through sensors. After that, the server will conduct context matching (format adaption and content adaption) with the defined context relations. Finally, adaptive resource instances will be pushed to different learners.

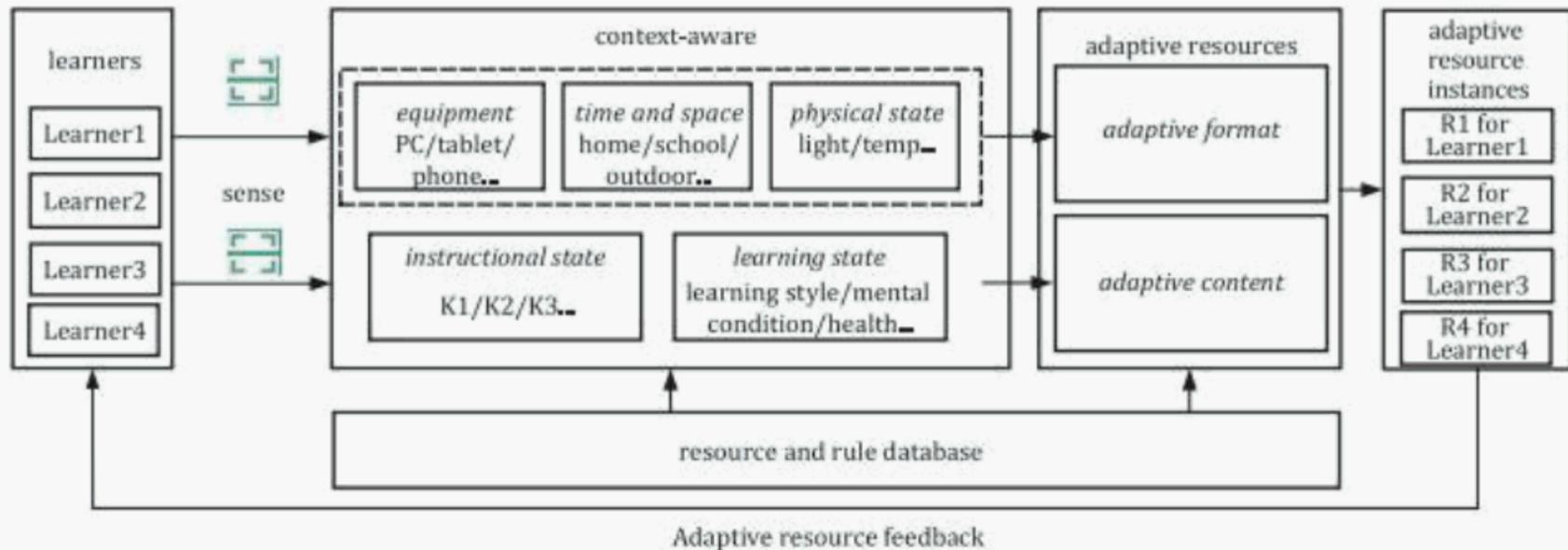


Figure 11 — Contextual service framework

In the framework, five kinds of contextual information are defined. The equipment context describes basic parameters of the equipment suited to this resource, such as the type of equipment (PC, laptop, smartphone, tablets, PDA etc.), dimension, definition, memory, etc. The time-space context describes the optimal time and space for a resource to work well, for example, when learning about the firefly, the best time to learn it would be a summer night, and the best place is outdoors. The physical state context means the best physical conditions for a resource to function well, such as light, temperature, humidity and other natural conditions. The instructional state context means teaching characteristics supported by learning resources, such as instructional objective, related knowledge structure and other rules. The learning state context means a learner’s current state or preference. With these types of contextual information, the learning cell conducts reasoning based on an ontology and rules and then exports adaptive learning resource instances. [Figure 12](#) shows the information used in this process.

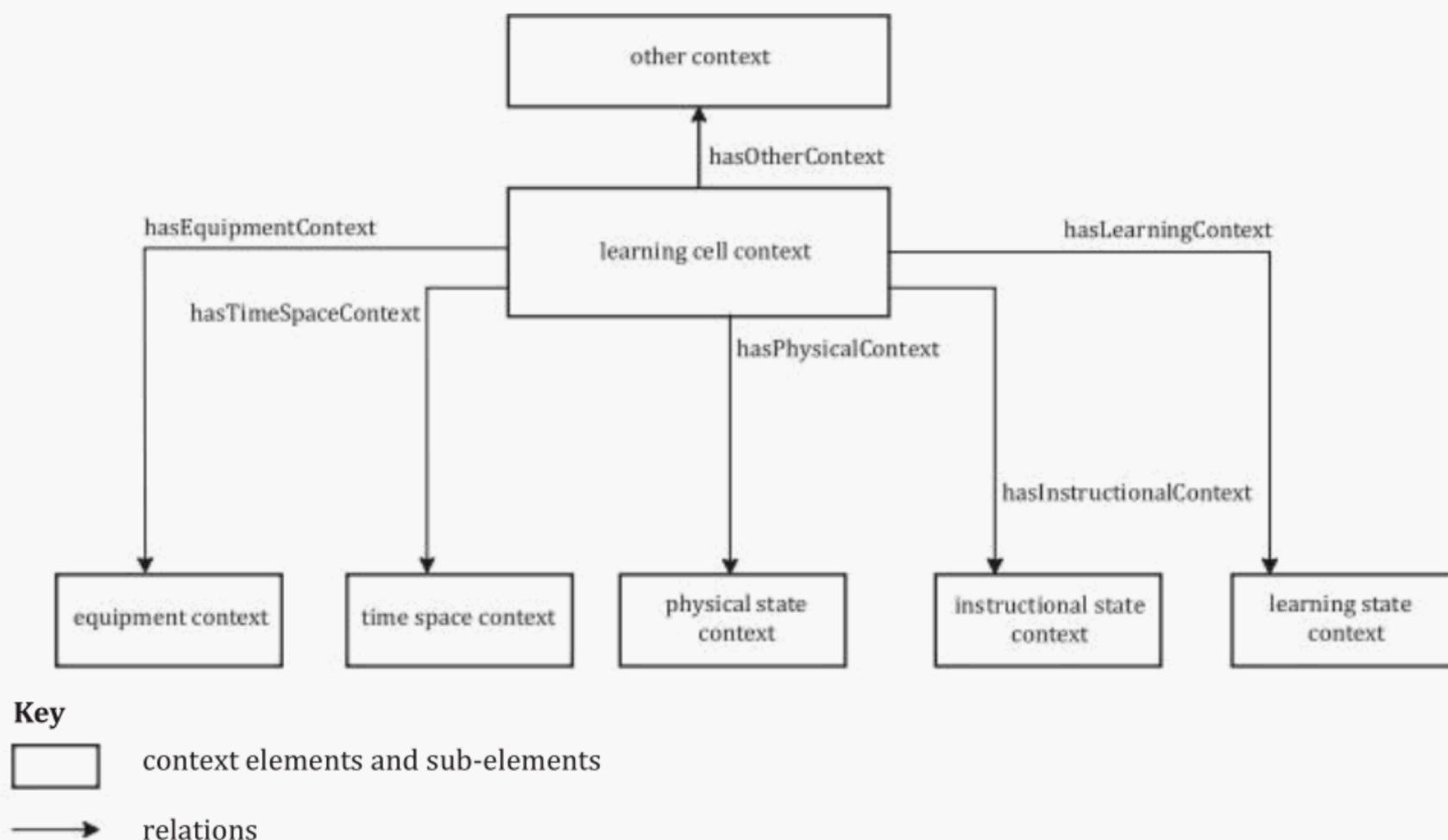


Figure 12 — Contextual information

Table 2 shows the details of the contextual information. All the elements shall be described based on the DES-FORMAT (not defined in this document).

Table 2 — Details of the contextual information

Data elements	Sub-elements	Obligation status
Equipment context	device	mandatory
	size	mandatory
	operation system	mandatory
	CPU	mandatory
	storage	mandatory
TimeSpace context	location	mandatory
	time	mandatory
Physical state context	temperature	optional
	heart rate	optional
	blood pressure	optional
Instructional state context	strategy	mandatory
	subject	mandatory
	objective	mandatory
	difficulty	mandatory
Learning state context	knowledge level	mandatory
	cognitive style	mandatory
	learning style	mandatory

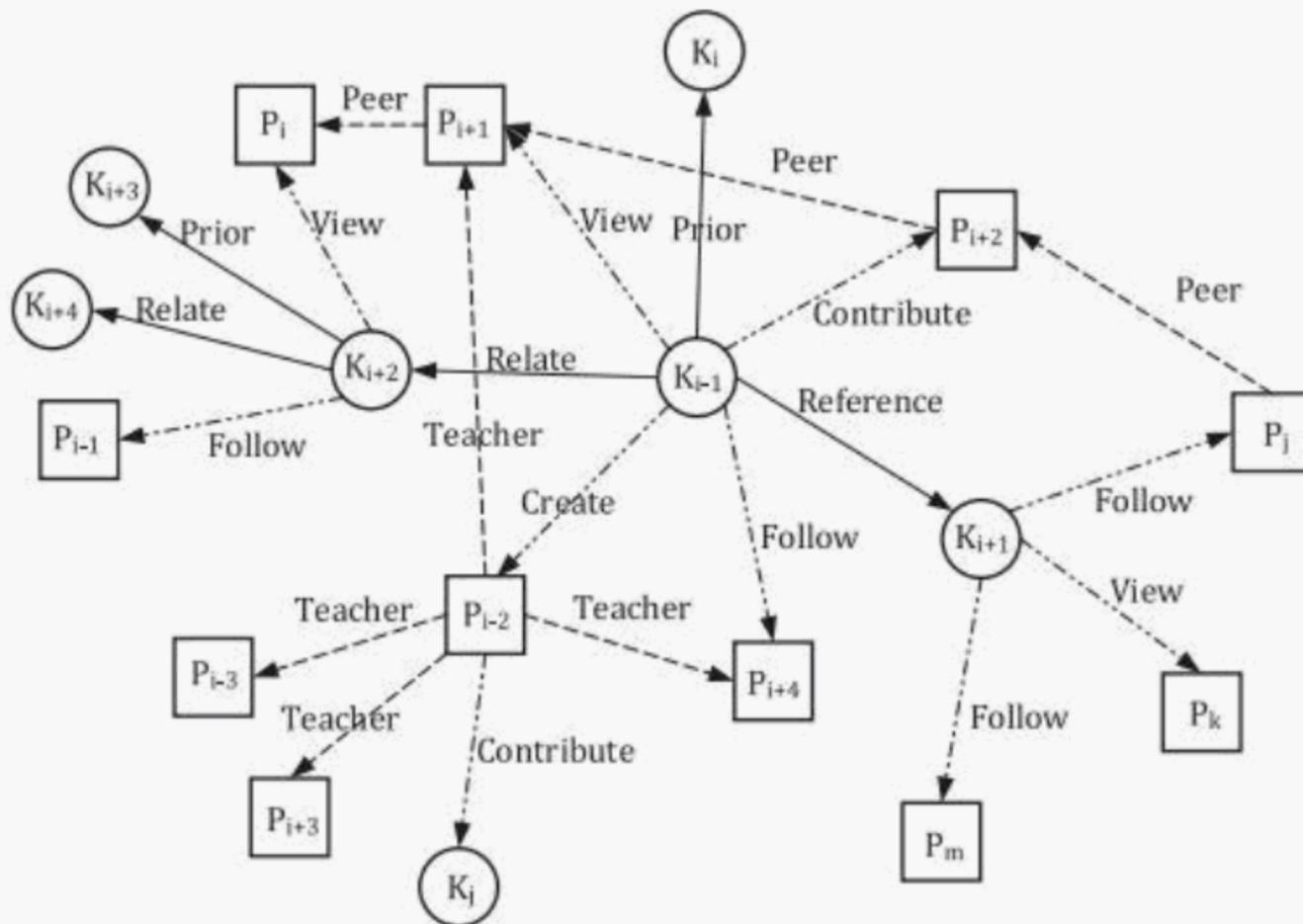


Figure 14 — Social knowledge network framework

As can be seen in the social knowledge network, person and knowledge are the two most important elements and they can be seen as different kinds of resource class. There are three kinds of relationships for these two classes: person-person relationship, person-knowledge relationship, and knowledge-knowledge relationship. All the relationships are generated based on learners' interactions in different learning activities (see Figure 15). In this figure, knowledge class is represented with rectangle, person class is represented with ellipse, and relationships between each class are represented by lines.

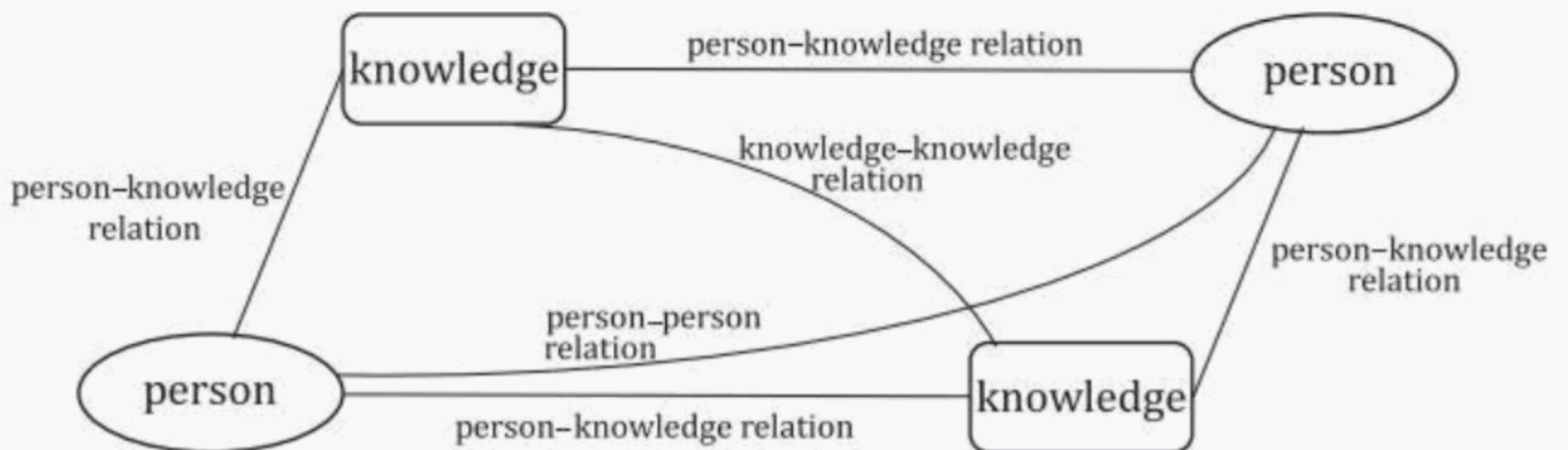


Figure 15 — Semantic relation representation in social knowledge network framework

For person-person relationship representation, this document adopts the friend-of-a-friend (FOAF) specification and extends it from the learning aspect. Five roles are defined (teacher, learner, parent, manager and learning supporter), as well as the relations among these roles (Figure 16). The relationships for different roles can decide to what degree a person influences another. These relations are mainly represented via ontology, and the format is: {person, relation, person}.

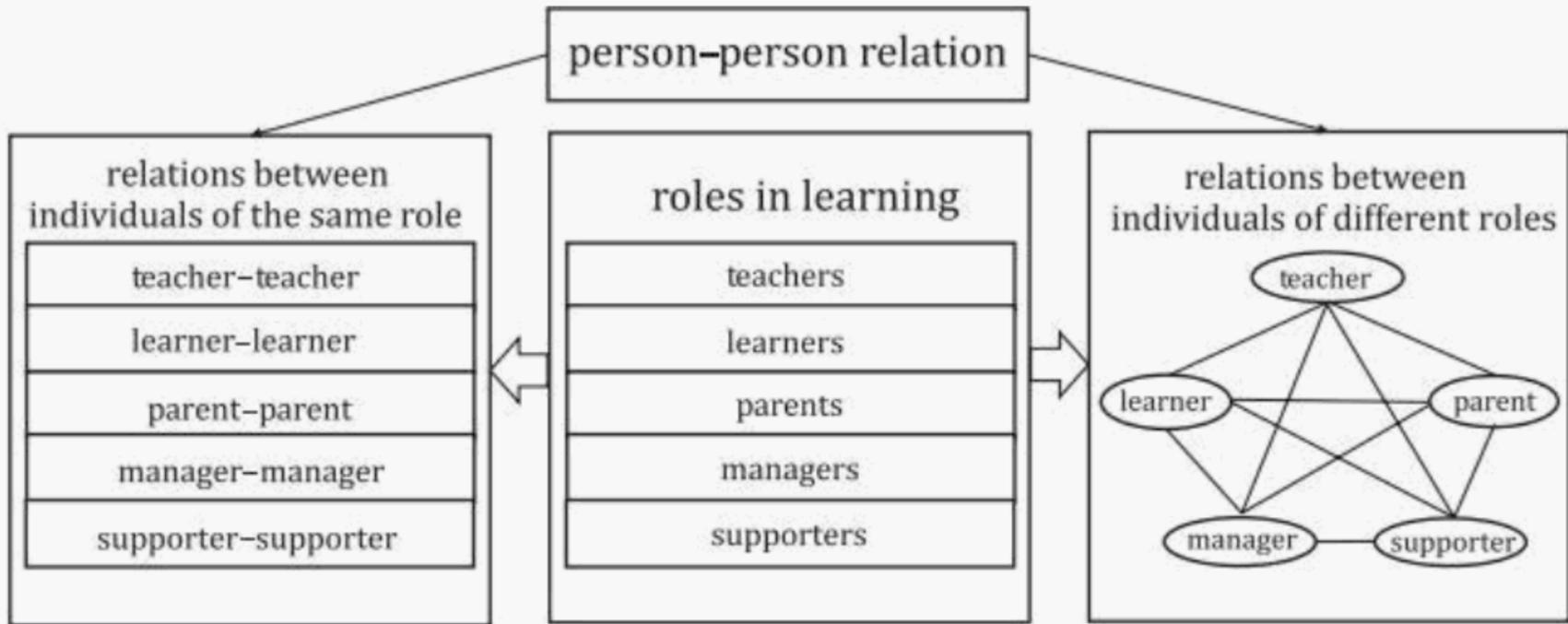


Figure 16 — Person-person relation representation

Knowledge-knowledge relation is described by semantic technology and mainly includes two types: logical relations and teaching relations. These relations are mainly used to describe how two instances of knowledge elements are related, such as knowledge instance A can be similar to knowledge instance B. These relations will be helpful during the knowledge reasoning and recommendation. Logical relations are used to represent the logical relations among different knowledge areas, such as knowledge instance A contains knowledge instance B or knowledge instance A is prerequisite knowledge for knowledge instance C. Logical relations include sequential relation, subordinate relation, relevance, equivalence, similarity and reference. Teaching relations are descriptions of knowledge from the teaching aspect, such as if knowledge K is a definition or theory. The teaching relations include definition, theory, principle, example, counter-example, evidence, etc. All these relations are shown in [Figure 17](#). The format of the description is: {knowledge, relation, knowledge}.

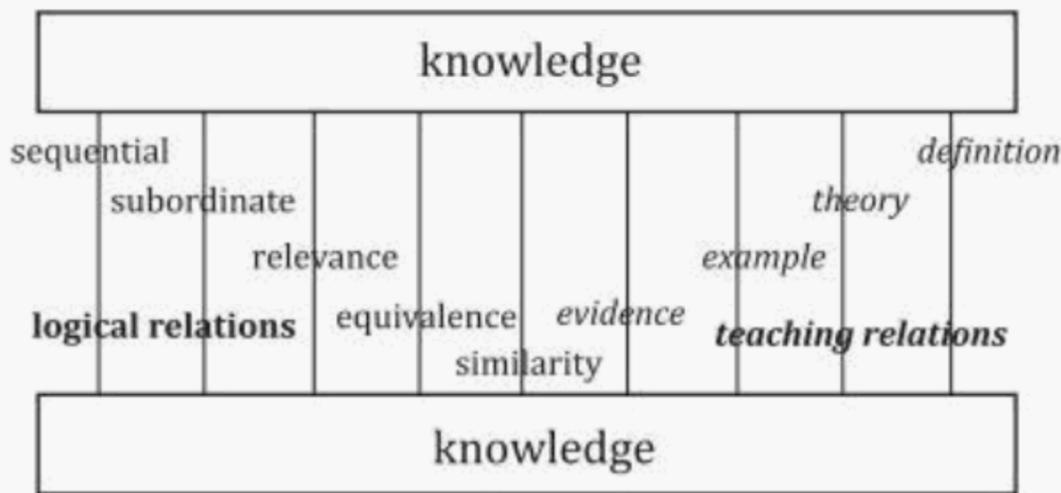


Figure 17 — Knowledge-knowledge relation

Person-knowledge relations are mainly used to represent the interactions between them, as illustrated in [Figure 18](#), including create, edit, comment, score, collect, view, share, vote and upload. These relations are represented by ontology. The format of the description is: {knowledge, relation, person}.

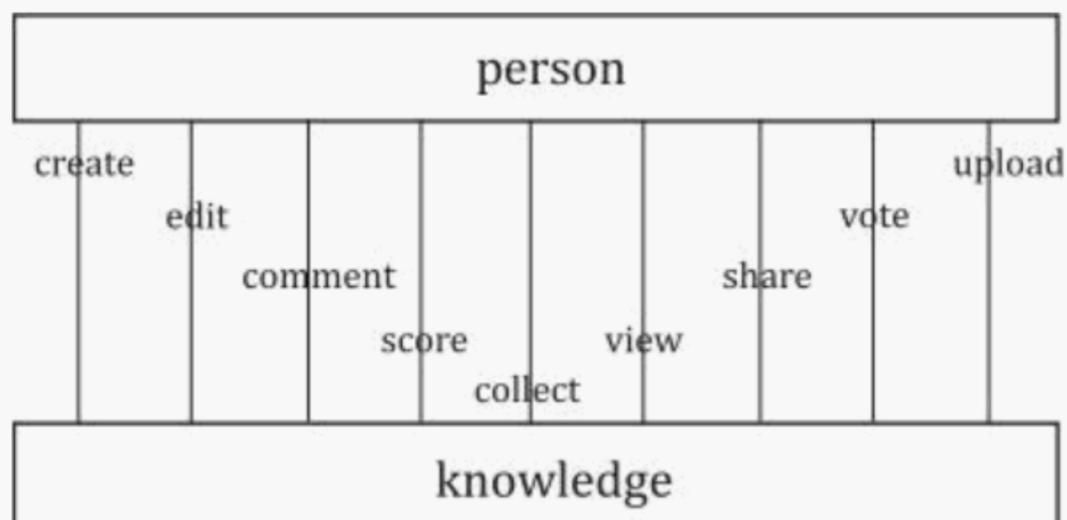


Figure 18 — Person–knowledge relation

Table 3 shows the details for social information. All the elements shall be described based on the DES-FORMAT (not defined in this document).

Table 3 — Details for social information

Data elements	Sub-elements	Obligation status
person–person relation	peer	mandatory
	colleague	optional
	learner–parent	mandatory
	facilitator	optional
	tutor	mandatory
	help seeker	mandatory
	...	
knowledge–knowledge relation	sequence	mandatory
	subordinate	mandatory
	relevance	mandatory
	equivalence	mandatory
	similarity	mandatory
	evidence	optional
	example	optional
	theory	optional
	definition	optional
	...	
person–knowledge relation	create	mandatory
	edit	mandatory
	comment	mandatory
	score	mandatory
	collect	mandatory
	view	mandatory
	share	mandatory
	vote	mandatory
	upload	mandatory
	...	

6.3.5 Evolvable information

Evolvable information represents the changes and development of the learning resources. There are two types of evolution: content evolution and associate evolution.

Content evolution describes the evolutionary process driven by learners. When learners start learning, they can comment, edit, mark or annotate the content, which then becomes a contribution to the content. As a result, the content will gradually evolve into another version with higher quality (Figure 19).

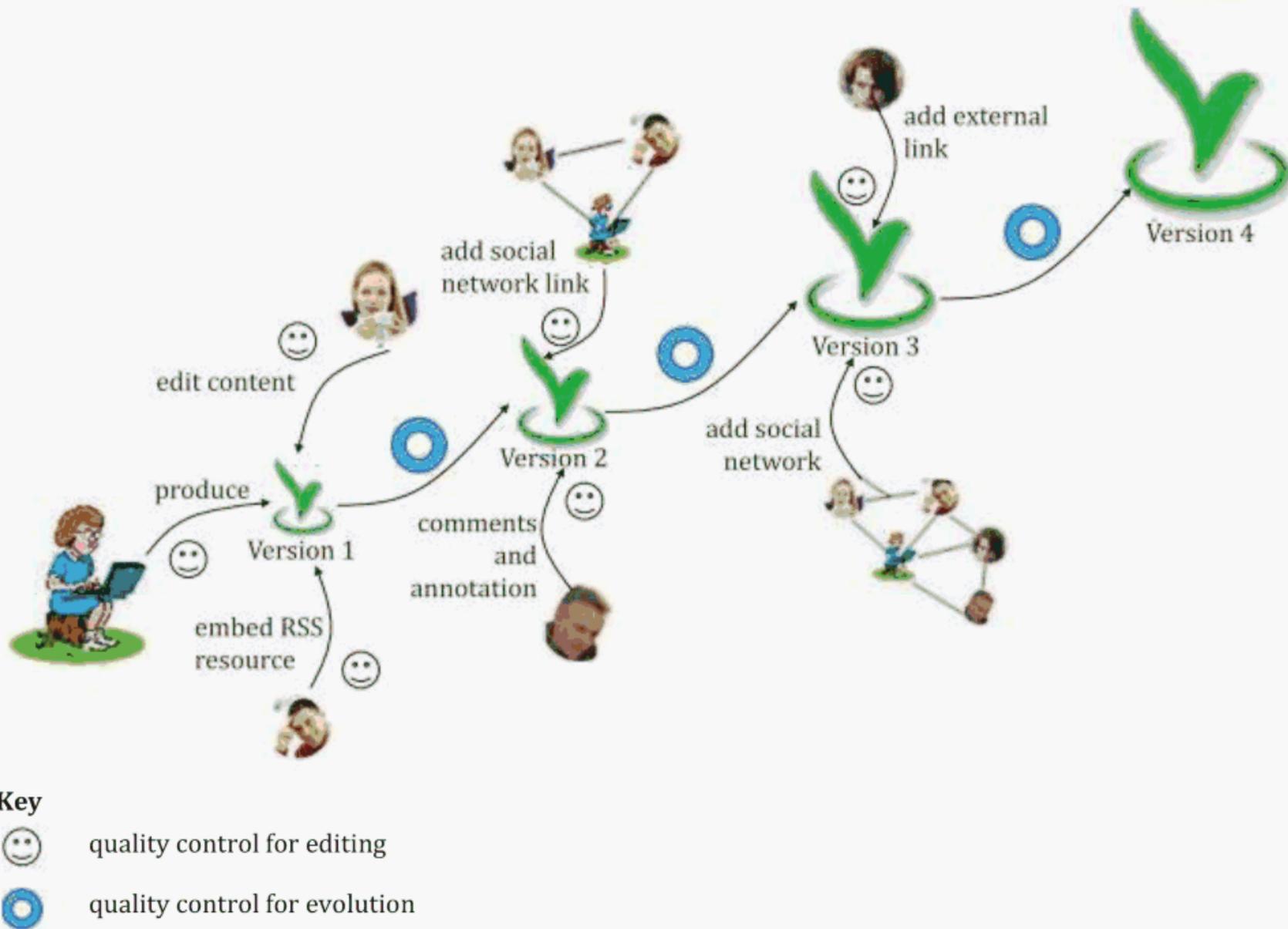


Figure 19 — Content evolution of learning resource

To ensure the process and the quality of the content, the learning cell framework combines a manual audit and machine audit to filter low-quality content. After these processes, the new version of the resource can experience another evolution cycle, and finally, form high-quality resources which will meet the learning needs of different users (Figure 20). Content evolution mainly describes the evolution elements through editions. Commentary, mark-up, annotation operations of resources (learning cell) and the reserved versions after each operation are also measurements of evolution. Based on different versions, the learning resource (learning cell) realizes evolution and improvement.

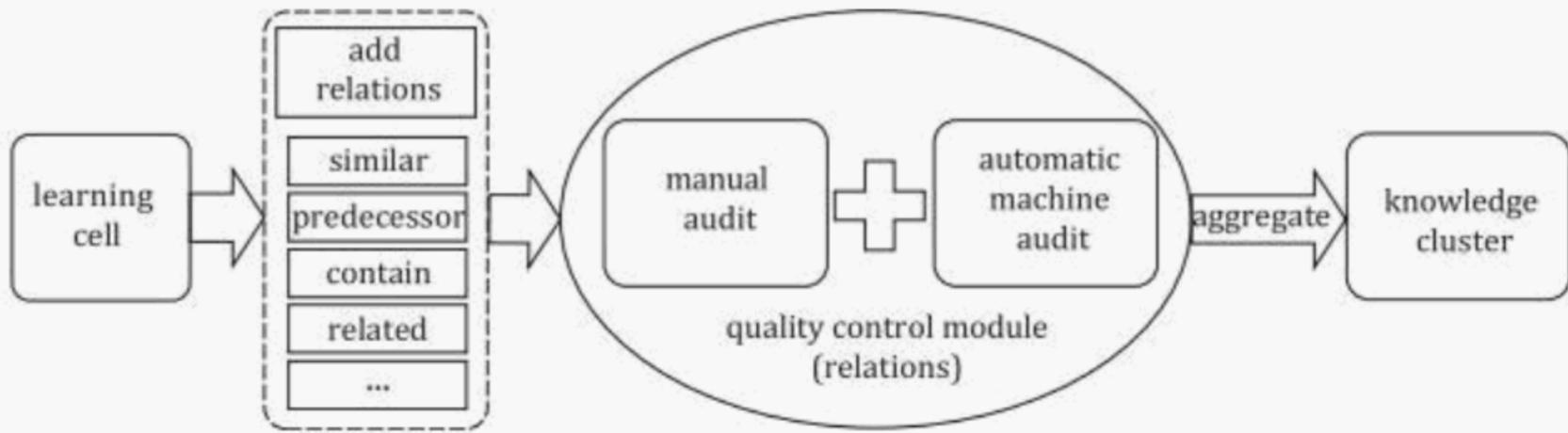
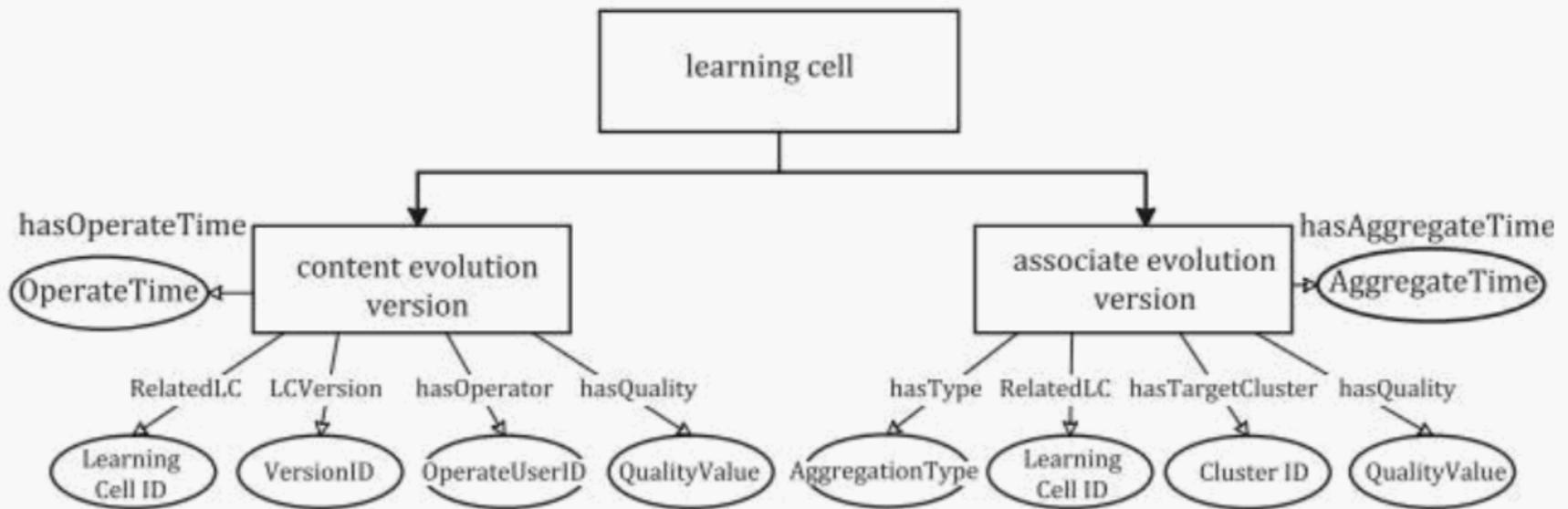


Figure 22 — Associate evolution process of learning resource

Figure 23 provides an overview of the elements or properties needed to represent learning cell evolution. The evolution description schema shows the main components, sub-elements and properties which are used to realize the evolution process. For content evolution, it is mainly based on learning cell versions contributed from different learners. Each learning cell has different versions (content evolution version). And the version is a sub-class for learning cell and it has several properties. In representing a version, learning cell ID, version ID, OperateUserID, OperateTime and QualityValue are involved to ensure the relations with learning cells and contributors can be found. With these elements, it is possible to decide who has contributed to the current evolution and to what level the quality is. For another type of evolution (associate evolution), it is also a sub-class for learning cell. The schema uses the aggregation history to represent the associate evolution. The elements mainly include AggregationType, learning cell ID, cluster ID, AggregateTime and QualityValue.



- Key**
- elements and sub-elements
 - properties
 - category relation
 - property relation

Figure 23 — Evolution description schema

Table 4 shows the detail of the evolvable information. All the elements shall be described based on the DES-FORMAT (not defined in this document).

Table 4 — Details for evolvable information

Data elements	Sub-elements	Obligation status
Content evolution	Learning Cell ID	mandatory
	Version ID	mandatory
	OperateUserID	mandatory
	OperateTime	mandatory
	QualityValue	mandatory
Associate evolution	AggregateType	mandatory
	Learning Cell ID	mandatory
	Cluster ID	mandatory
	AggregateTime	mandatory
	QualityValue	mandatory

6.4 Context-aware learning services

6.4.1 Context-aware services for learners

6.4.1.1 Context-aware process

The context-aware learning services mainly sense learners' learning contexts and requirements, and accordingly aggregate adaptive learning resources for them. During the process, learners interact with the learning systems and the context-aware services embedded in the learning systems (6.5 describes how the learning cell service can be embedded into learning systems) will detect the learners' information with sensors. During this process, video capturing, audio recognition, and related intelligent technologies are used. Also, communication technologies like 5G are used to ensure the data transfer. Then with the acquired information, the service will decide what to be provided to the learners. Finally, the recommended ingredients will be extracted and re-organized based on the element description information in the content organization. The process of the service is shown in Figure 24. With the services embedded in the learning cell system, different learners can receive adaptive learning cells. The learning cells are aggregated based on the aggregation model and content organization information. The ingredients in the learning cell come from the learning cell container which collects and classifies resources from different systems. After aggregating all the ingredients in the learning cell container, the aggregation model will be the structure which decides the elements and targets in the aggregated learning cell. Then the learning cell can be provided to learners after being organized under the information of the content organization. The dashed lines in the figure represent the resource aggregation process based on topic K. The solid lines in the figure represent the context-aware and resource generation process.

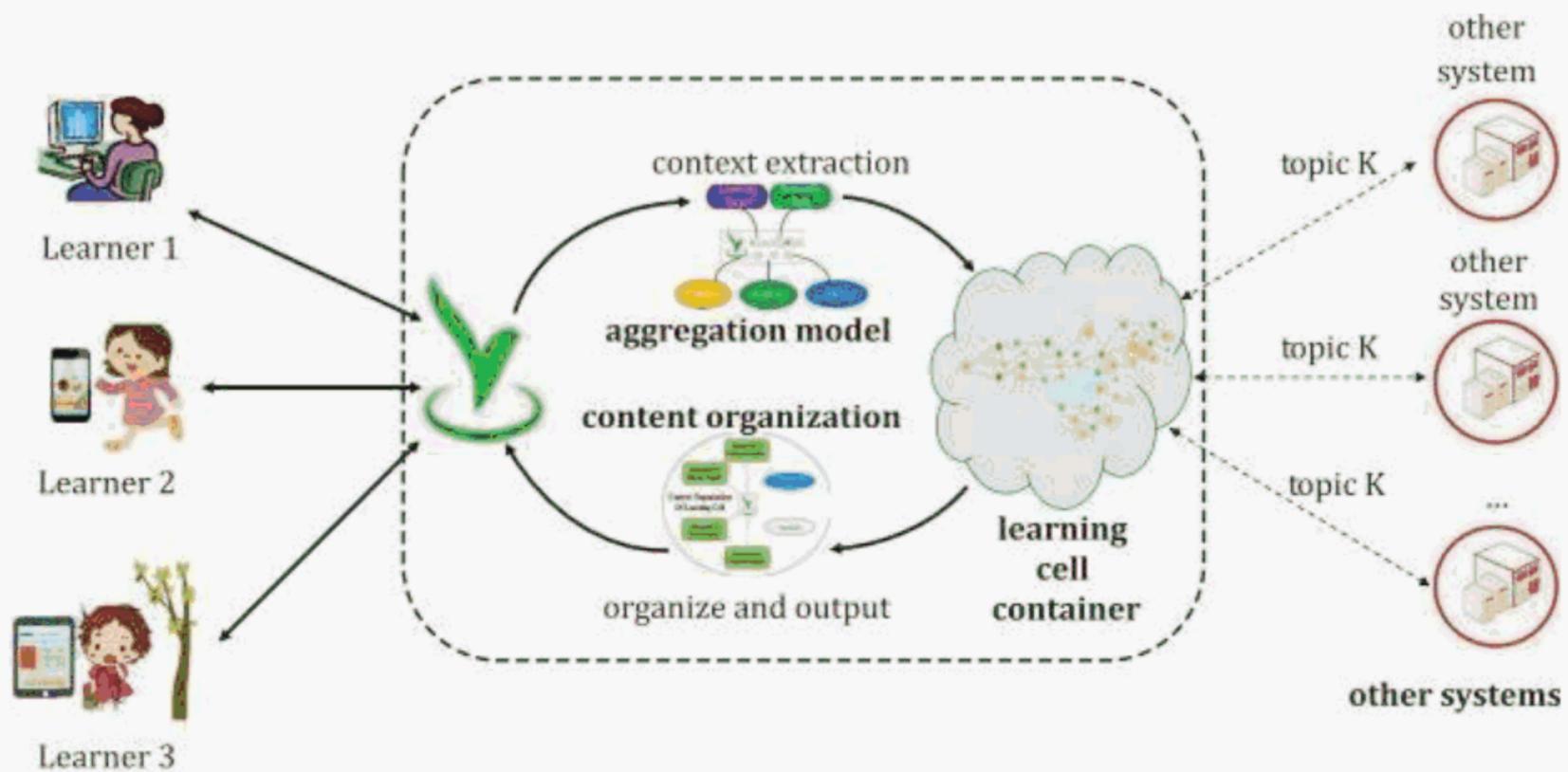


Figure 24 — Process of the context-aware learning services

6.4.1.2 Structure of learning cell container which supports the services

In ubiquitous learning, the learning cells through which learners access resources are composed of resources from different learning systems. The learning cell container provides a space and classification management, which makes these disordered resources well-organized. After the processing, the resources can effectively support the generation of learning cells. [Figure 25](#) shows the structure of the learning cell container. The local server of the learning cell aggregates a large amount of learning resources from different learning systems with multiple formats. The source of the resources includes local resources in the local server and resource links from other learning systems. These resources can be aggregated in the learning cell container with a specific topic. After integration in the learning cell container, the resources would be re-organized and classified according to unified organization requirements defined by the learning cell container. The learning cell container collects all the resources from different learning systems. It will first acquire the metadata of the input resource and transform it to a unified format for which the learning cell can use, such as {resourceName, resourceDescription, ResourceUri, ResourceType, Tags...}. After that, the learning cell container will re-classify the acquired resource into different subsets. The learning cell container defines 10 basic subsets: ontology, activity, learning objective, strategy, tool, record, group, generative information, multimedia content and evaluation. It also supports extended classifications. With these classifications, when the new resources are aggregated based on specific topic, the learning cell container can assign them in order. The well-organized resource structure will make it easy for learning cell aggregation.

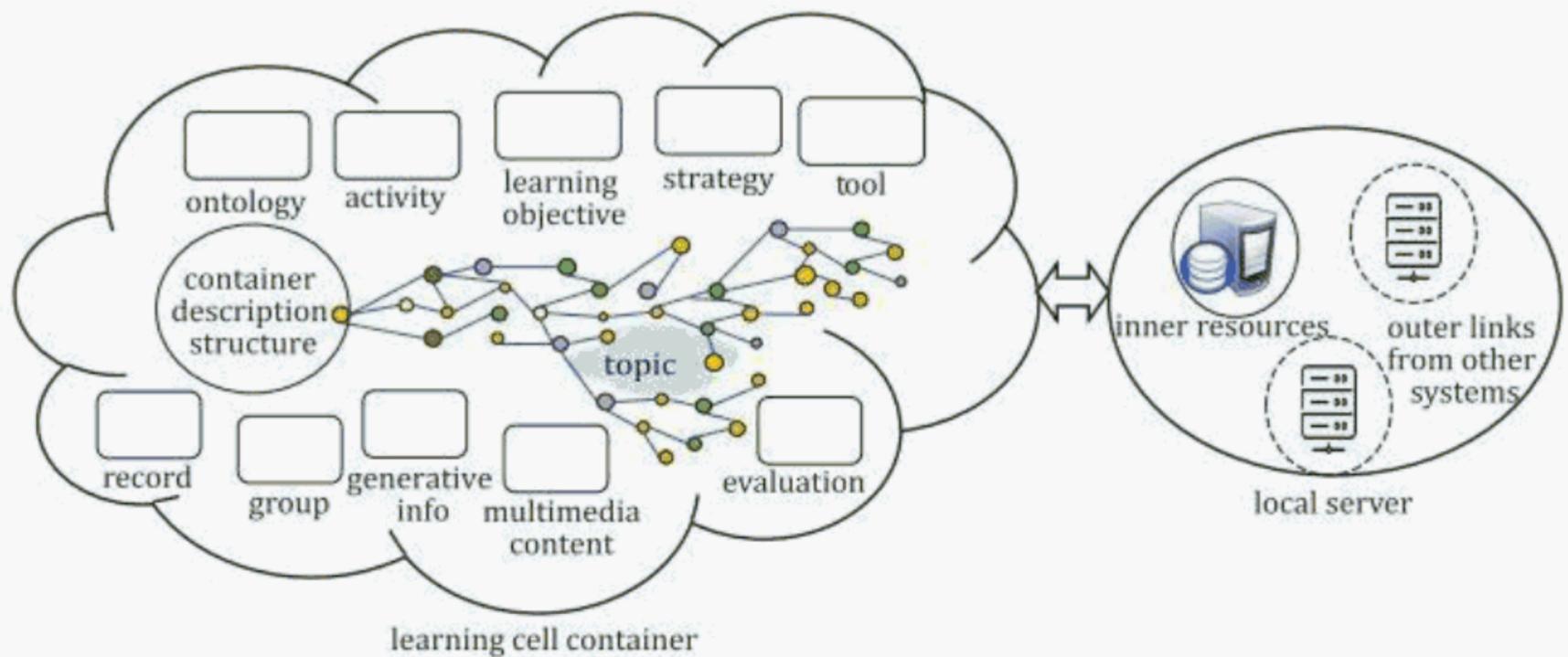


Figure 25 — Learning cell container structure

6.4.2 Data interaction under the service

This subclause introduces the data interactions under the learning cell service which is used to collect data for analysis in service computing. Data interaction under the service is divided into system interaction and user interaction. Wherein, system interaction records all processes conducted by the educational systems rather than learners' clicking or interactions, mainly includes context-aware and the storage of perception information, automatic aggregation of contents, and construction of social network based on the collected information. The process to collect system interaction is shown in [Figure 26](#). When the user studies using equipment in specific context, the context information sensing and collecting function are triggered. The learning cell can sense learners' physical information and pass it to the educational cloud computing centre. During this process, the physical information can be transformed to the context information by logical layer. With the context information, learners' context, and requirement model can be established which will support the context-aware learning services. After that, the learning cell can output the recommendation service. The user's feedback to the recommendation service is further recorded by the learning cell which will strengthen the efficiency and adaption of the automatic service. This document does not introduce how to compute the efficiency or adaption of the system.

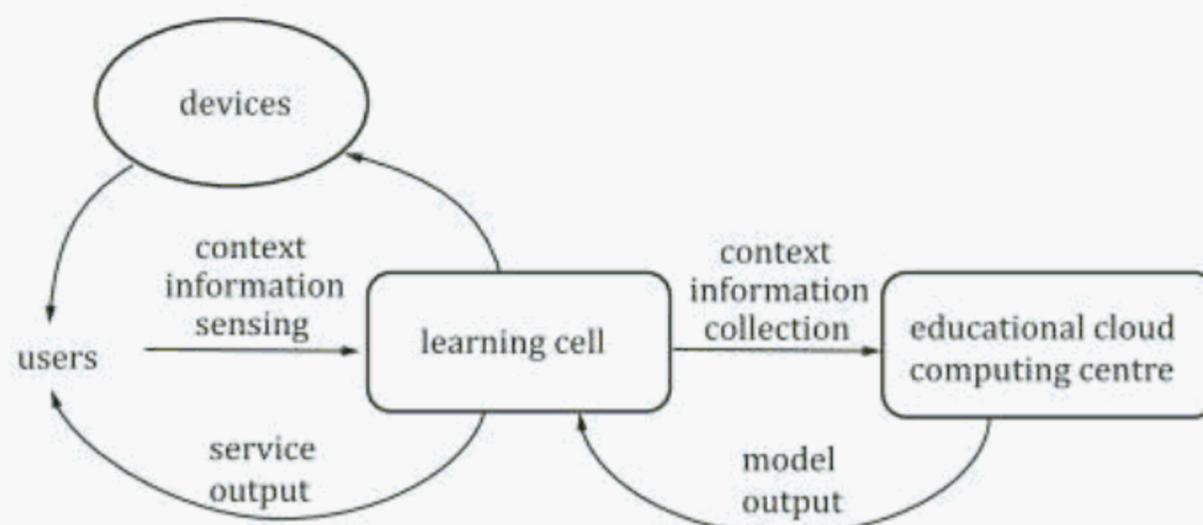


Figure 26 — System interaction

User interaction in this process mainly records learners' operating behaviours. These behaviours are automatically recorded and will be used to decide learners' interactive preferences or provide learners with feedbacks in further learning. The behaviours mainly include: creating, editing, collaborating, annotating, commenting, scoring, viewing, modifying the basic information, voting, collecting,

recommending to the knowledge group, establishing link, uploading resources, downloading resources, sharing and recommending, referring to tools, modifying the classification, designing learning activities, participating in learning activities, designing evaluation scheme, collaborator’s review, editing and reviewing the contents. During this process, learner interacts with the learning cell to meet the learning objectives. At the same time, the user’s operation information will be collected and stored in the database. The storage format references the experience API known as xAPI (Figure 27):

{userId, behaviourType, startTime, endTime}

In this record, userId represents the learner’s identifier; behaviourType represents what kind of interactions the learner is conducting; startTime represents when the behaviour begins; endTime represents the time when the behaviour ends.

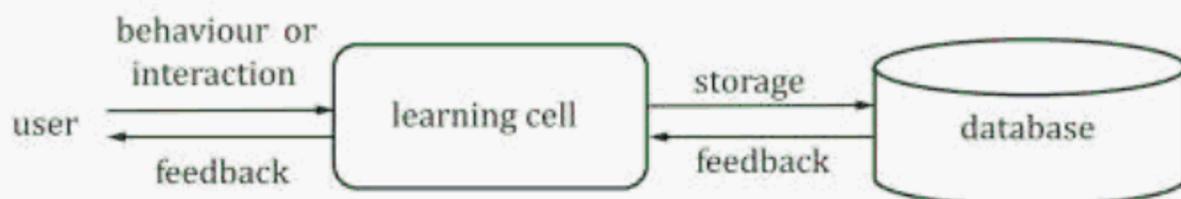


Figure 27 — User interaction

6.5 Learning cell service provider

In the learning cell framework, the learning cell service provider interface makes the learning cell services open to different learning systems. Services provided by different learning systems can be integrated into the learning cell server. This means the learning systems can be the learning cell service provider as well as the resource management systems. This helps to realize the distribution of services in different learning systems. It is essential in supporting learners’ personalized demands at anytime and anywhere under any ubiquitous learning environment. In this document, the web service interface for learning systems references the rules of web service and realizes dynamic, real-time, distributed services. The structure is shown in Figure 28. In this figure, the dashed lines represent the service register process while the solid lines represent the service output process, and the dashed icons represent the learning cell service embedded in different systems.

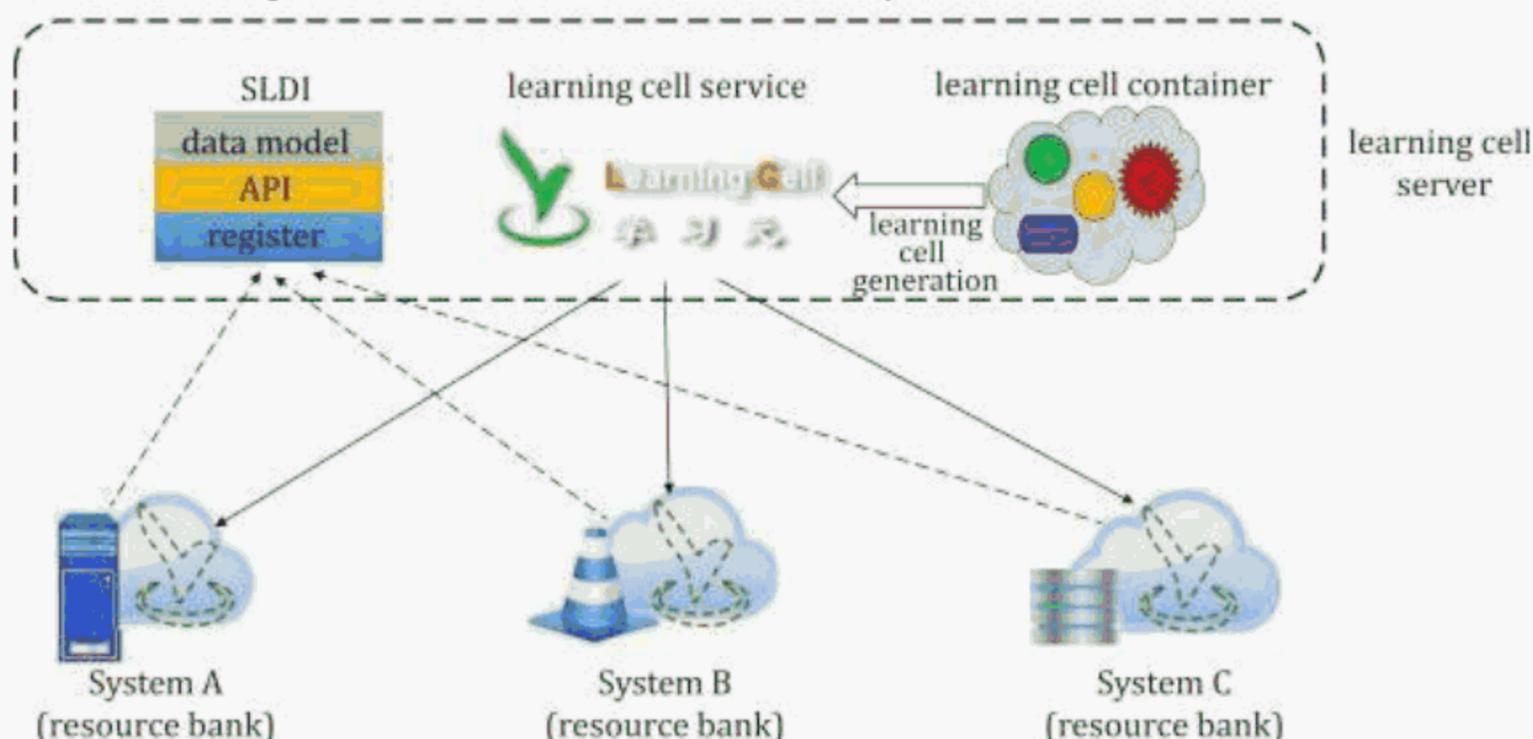


Figure 28 — Learning cell service provider

There are two ends in the structure: learning cell server and the learning systems. The roles of the two ends can change according to the main body of the learning cell service provider. The learning cell server defines three core elements: learning cell service, SLDI (sharable learning cell description interface), and the learning cell container. The “SLDI” is a protocol defined in the learning cell which

revises the UDDI protocol. All the services defined should be based on the SLDI protocol. This document introduces the function process for SLDI. The SLDI defines the process of how the service defined in the learning systems is uploaded to the learning cell server. This will help provide open access to services and resources in different learning systems. It also defines the information (data model) and interface (API) that the learning systems shall provide in using this service. In the communication of learning systems and learning cell server, XML and SOAP are used to support online data transfer. The learning cell service defines the detailed function for learning cell aggregation and manages extended services registered by the learning systems. The learning cell container is the space where the ingredients for services are stored.

With these elements, the learning cell server can provide services to different systems. If the learning systems want to use learning cell services to support learners' learning, they first send register information to the learning cell server according to the rules in the SLDI. Then the learning cell service can be embedded into the current system. Also, if learning systems want their services to be used by other learning systems, they shall define and register their service through SLDI and open access in learning cell server. Then the current learning system becomes a service base (server). After the information of the other learning systems is registered, the new learning cell service can be embedded into other learning systems (that is the service embedding). The learning systems citing the services act as the space to contain the learning cell service and the real computing or aggregation process is conducted in learning cell server or other servers.

During this process, the roles of the learning systems are information collectors and service containers. They do not need to develop data analysis and resource aggregation functions themselves. A register operation will integrate the learning cell service with the outer systems. As to the learning cell server, the structure and function of the learning cell container is described in 6.4. The learning cell service is modularized from the learning cell framework and will be an open service for other systems to link. The service realizes the sharing of resources to support learners and services across different learning systems.

Annex A (informative)

Use case 1: Learning cell knowledge community in China

This use case is an application of the learning cell framework. It is a ubiquitous learning platform and its resources are under the standard of the ubiquitous learning resource organization and description framework. All the resources have basic semantic properties such as general info, rights and so on. All the resources are described from three dimensions: context description, social description and evolvable description. Learners can get learning resources according to their context and relate with the resources according to their operations. Moreover, with the operations, the resource will evolve gradually. All of the information collected by the platform will be transferred to other platforms with the data transfer API.

To implement the learning cell framework, a trial platform was developed based on the framework. The platform includes six modules: learning cell, knowledge cluster, knowledge cloud, resource centre, community and personal space. Each module can establish relations with other modules via two approaches: operation of user (learner) and semantic relations.

Users can create the learning cell after which they can go back to carry out collaborating, collection, editing and other operations on the learning cell, whereby logical relations between the user and learning cell are established. Each user has his/her own independent personal space for the storage of personal learning information and records of all of the learning operations of the user, such as creation, collaborating, collection and editing of the learning cell; creation, collaborating and collection of knowledge clusters; join community, etc. Meanwhile, users can join a learning community, which plays a key role in users' forming highly functional social relations and users' operations on the learning cell or knowledge cluster can also directly or indirectly help establish relation between user and resource.

With the increase of users' operation, more and more connections and relations between relevant users and resources take shape in the system. These relations include not only content and semantics relations, but also situational semantic and generative semantic relations. Based on these relations, the system can aggregate similar content into knowledge clusters. At a higher level, learning cell and knowledge clusters can be aggregated again into knowledge clouds according to their similarity. Newly formed learning cells, knowledge clusters, communities and knowledge clouds will again be recommended to learners according to learners' context. The procedure is shown in [Figure A.1](#). During all of the processes, all elements in the platform can be aggregated from a basic learning cell to collections, such as a knowledge cluster, community and knowledge cloud. It is the central part and what implements the contextual, social, and evolvable features of learning resources.

Description	Target group	Technologies
As above	Students, teachers and adult learners in the workplace.	Mobile device (mobile phone, tablet, three-dimension glasses) or laptops, wireless network which provide access to learning cell community.

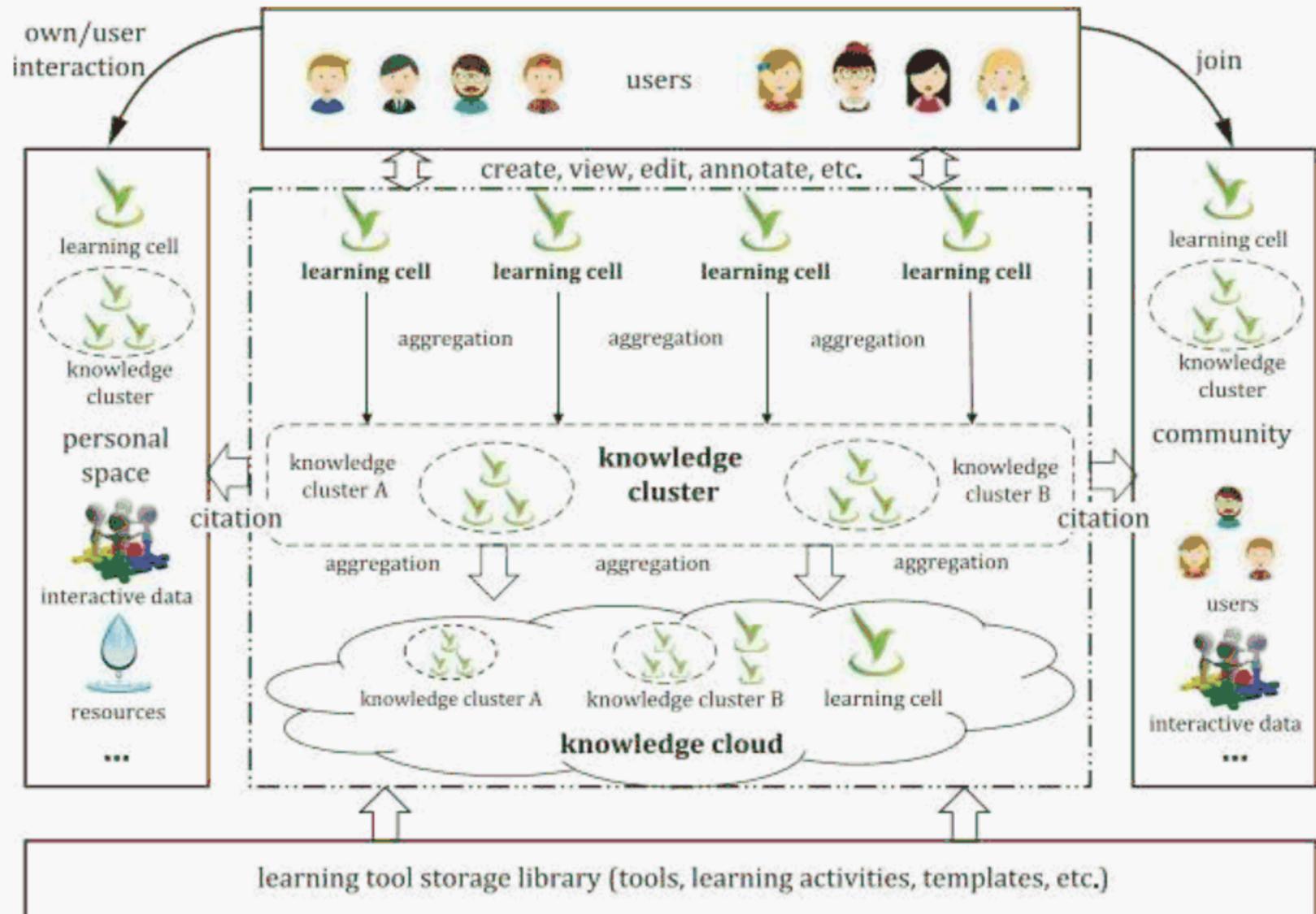


Figure A.1 — Relationships of different modules and their aggregation pattern in trial platform of learning cell

Annex B (informative)

Use case 2: China Mobile's "AND Education"

China Mobile's "AND Education" is an application of the learning cell framework. It is also a platform which supports ubiquitous learning and mobile learning. In this platform, there are large amounts of learning resources, and they are organized with the ubiquitous learning resource organization and description framework. For example, the resource is annotated semantically with the general info property, right property, learning content property and other basic properties. The resources are also tagged with contextualized tags, social tags, and tags which reflect the evolvable information. In a real learning environment, the platform first senses the needs of learners as in [Figure 11](#) and then provides the learners with context-related resources. During the learning process, the learners can connect with the related resources and people who form the network shown in [Figure 13](#). All of the information will be maintained for further evolution. All of the information will be transferred among different ubiquitous or mobile learning platforms under "AND Education".

In order to solve the educational problems and achieve high-quality education, China Mobile has made great efforts to build "AND Education" guided by the study of meta-theory. Since 2015, the platform has been based on China Mobile's resources, and has entered the K12 education, early childhood education, and three links platforms, and expanded to universities, vocational education and other fields.

- The "And Baby" series is designed for government education departments, schools and parents to create different series of products and applications and to meet individual needs in terms of resource management, baby monitoring and park management.
- The "AND Campus" series achieves balanced education, a closed learning process and improved learning efficiency by sharing high-quality resources, collecting learning data and developing fun applications. It helps all students in K12 to access better learning, whether learning at school or learning online.
- China Mobile has created three types of applications in vocational education: teacher training, party school training, vocational training, paying close attention to the core needs of various occupations for education, meeting the requirements for further development of different occupational groups, and creating a lifelong learning system.

Description	Target group	Technologies
<p>This scenario is used by young children, K12 students, teachers, adult learners, schools and government education departments. All types of users can log in to their personal accounts and independently select the required learning resources and learning applications through various application platforms. The platform records personal search traces, analyses user images, and retrieves matching learning resources for personalized recommendations.</p> <p>The “AND Education” cloud platform is paved with various versions of textbooks across the country to absorb local high-quality resources to meet the learning needs of users in different regions; covering the whole business scenarios of teaching, learning, evaluation, training and testing; reducing the teaching burden of teachers and improving user learning efficiency.</p> <p>The information management platform provides a one-stop convenient service for the education management department to improve management efficiency and work level. All kinds of application products meet the user's usage habits, providing a good experience and helping users improve their learning efficiency and learning quality.</p>	<p>Young children, K12 students, teachers, adult learners, schools and government education departments.</p>	<p>Access to "AND education" through mobile devices (mobile phones, tablets, laptops or China Mobile autonomous smart terminals), wireless networks.</p>

Annex C (informative)

Use case 3: “GoC” online programming education in China

This is an application based on the learning cell framework. It is used for kids’ programming education in mobile environment. The services are based on what has been provided by the ubiquitous learning resources organization and description framework. It can sense the learners’ needs and then compute the services which can make the learners get the best performance. The resources are tagged with four kinds of semantic metadata defined in ubiquitous learning resource organization and description framework: basic semantic property, contextualized property, social property and evolvable property. With these properties, the resources can be well organized and used. And with the learners’ operations, the relations and logs will be stored according to the rules in 6.4.2-based on the agreement of the learners. With these data, the platform can provide adaptive services to the learners. And if the learner goes to another mobile learning platform to learn, the data can be transferred according to the rules defined in 6.5.

Description	Target group	Technologies
<p>This application provides an online programming education platform for K-12 learners and instructors. It includes four parts: GoC courses, C++ courses, my team and my homework. The platform involves a large number of tests, which are semantically annotated with specific knowledge points. It recorded the learners’ online behaviour according to the principle of the learning cell framework, such as the view, discussion, collect and participating activities.</p> <p>When the learners use the platform to learn programming and do the practice, they can get access to other learners, experts and groups, thus a KNS is formed with the behaviours and relations. And through the iterative learning, there will be a larger social network and knowledge network for programming, which can be called programming KNS. With this KNS, the practice as well as the knowledge relations will evolve to a higher level.</p>	<p>Young children, K12 students, teachers, adult learners, schools and government education departments.</p>	<p>Mobile technologies; ubiquitous network.</p>

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