TECHNICAL REPORT

ISO/IEC TR 18121

First edition
2015-12-15

Information technology — Learning, education and training — Virtual experiment framework

Technologies de l'information — Apprentissage, éducation et formation — Cadre d'expérience virtuel

Reference number
ISO/IEC TR 18121:2015(E)

ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

Contents

Page

Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/IEC JTC 1 *Information technology*, Subcommittee SC 36, *Information technology for learning, education and training*.

Introduction

New and emerging technologies are allowing learners to test and develop new knowledge for the creation of virtual experiments. By employing a collection of different technologies, virtual experiments are widely used within K-12 and higher education institutions (e.g. scientific laboratory experiments, technical training in medicine and biomedicine) and also within corporate training (e.g. flight simulators, manufacturing process control). Virtual experiments allow access to a wide range of different experiments, decrease the timeframe to complete experiments, eliminate hazardous situations, and reduce the costs of materials.

To facilitate the development of virtual experiment technology and specification integration, this Technical Report defines a virtual experiment framework that indicates how various standards and specifications can be combined to support the design, implementation, analysis and evaluation of virtual experiment systems. This Technical Report denotes the components and categories of related standards and specifications that can be used to support virtual experiment systems and learners. It illustrates how the components and categories can be structured to support implementations to improve reusability, reduce costs, and broaden applicability. It defines the framework of related virtual experiment standards and determines the mutual relations between different standards for designing, analysing and comparing different virtual experiment systems in order to promote the design and application of the virtual experimental components and systems. The framework of virtual experiment standards also helps to illustrate the categories of related virtual experiment systems and their relations in order to guide the development of other standard-setting work and normatively describe virtual experiment system.

Virtual experiments are typically accessed from an IT system, such as a learning management system (LMS), which provides the environment for learning. In addition to tools specifically tailored for learning, IT systems (such as LMSs) can also provide access to external tools. In a common scenario, an identity federation mechanism will automatically log into the external service but it is up to the learner whether to provide data inputs to the external tool. At the end of the activity, a score is returned to the IT system (e.g. LMS). This type of approach can be used to support activities, such as those involved in the scientific experimental approach, where there are requirements to repeat an experiment with a variety of parameters in order to assess their individual role in a process. There is a need to bridge the switch from the IT system (e.g. LMS) to an external virtual experiment tool, providing data inputs and recording outputs for further analysis. This Technical Report can be used to support these types of activities. In addition, this Technical Report provides specific considerations for the development of ITLET supportive technology and specification integration.

Information technology — Learning, education and training — Virtual experiment framework

1 Scope

This Technical Report defines the framework for IT standards and specifications on virtual experiments supporting IT-enhanced learning, education and training. It is based on implementations of standards and specifications that are used to support virtual experiment, development, evaluation and management that rely on ITLET.

This Technical Report

— provides a framework that can be used for virtual experiment systems that rely on ITLET,

— determines the categories of different virtual experiment standards and specifications and their relationships to facilitate their integration,

— promotes the appropriate design and application of virtual experiment components so that IT systems that are being used are reusable, low cost, and more broadly applicable,

— indicates considerations to be taken into account when developing ITLET systems that are being developed or used to support virtual experiment systems,

— provides sample architecture of a virtual experiment system framework that can be used to support further development of virtual experiments,

— illustrates various roles that different actors can have at various points within the virtual experiment system,

— demonstrates how standards and specifications that support virtual experiments can be combined to form the basis for future work and implementations.

The following aspects are not addressed in this Technical Report:

— specifications of the implementation details of virtual experiment systems;

— accessibility;

— privacy;

— security.

2 Conformance

It is noted that it is possible for a virtual experimental instruction system to support more than one standard or specification by utilizing different combinations that include base standards, specifications, etc. The standards or specifications coordinate with circumstances or the virtual experiment instruction system that is configured separately to support specific standard or specification combinations.

This Technical Report provides the framework and objective to assist in the development of virtual experiments for information technology supporting learning, education, and training. This Technical Report also provides a proposed architecture of a system framework that is used to support the further development of virtual experiments. This Technical Report provides specific considerations for the development of ITLET supportive technology and for the integration of IT standards and specifications.

3 Terms and definitions

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

3.1
component cartridge
assembly of all the junior units based on specific rules to form a bigger component cell

3.2
remote access laboratory
laboratory in the physical world which can be accessed remotely

Note 1 to entry: Access to simulated equipment and virtual laboratories are excluded.

Note 2 to entry: A remote access laboratory enables learners to perform experiments at their own pace, time and location and allows teaching staff and learners to access laboratory facilities beyond their institutions.

3.3
virtual experiment
experiment based on multimedia, simulation and *virtual reality* (3.6), etc. which can assist or replace the operating segments of traditional, face-to-face experiments

3.4
virtual experiment component
smallest unit in a *virtual experiment* (3.3) which is composed of controllable and operable virtual experiment objects that may be reused

3.5
virtual laboratory
open networked instructional system based on web and *virtual reality* (3.6) technologies, which consists of virtual benches

3.6
virtual reality
artificial environment presented in the computer

4 Symbols and abbreviated terms

CP	Content Packaging
CC	Common Cartridge
LOM	Learning Object Metadata
LIS	Learning Information System
LMS	Learning Management System
MLR	Metadata for Learning Resources
QTI	Question and Test Interoperability
SCORM	Sharable Course Object Reference Model
SOA	Service-Oriented Architecture
XML	Extensible Markup Language

5 Framework

5.1 General

The framework for IT standards and specifications on virtual experiments supports IT-enhanced learning, education and training. For assistance with the development of profiles, the related standards and specifications for virtual experiment instruction is shown in Figure 1.

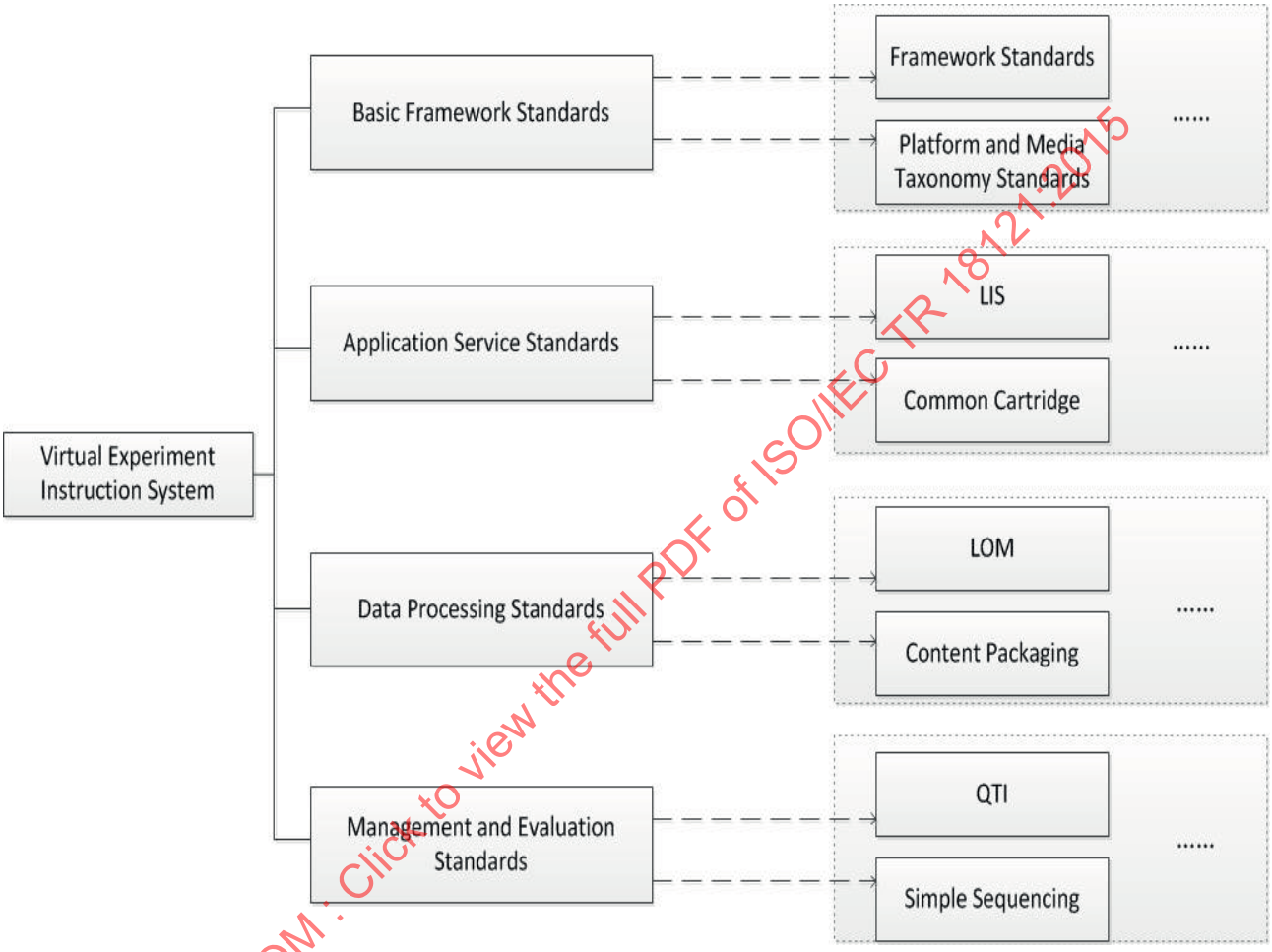

Figure 1 — Related standards of a virtual experiment instruction system

The virtual experiment standard system establishes the whole virtual experiment standards framework system and identifies the various links to standards of the virtual experiment instruction. The virtual experiment standards system also defines the relationship of standards and specifications and combines them with each other properly.

5.1.1 Overview of virtual experiment framework

The virtual experiment framework standard consists of the following four major parts.

— Basic framework standards and specifications

  Basic framework standards focus on various compatible specifications of the virtual experiment platform and tools. They are the basis of the whole virtual experiment standard system.

— Application service standards and specifications

Application service standards focus on the normative description of service interface provided by virtual experiment teaching systems which can help to improve the management of services.

— Data processing standards and specifications

Data processing standards are the hard core of the whole virtual experiment standard system, providing data elements of virtual experiment component metadata and a conceptual data mode, which are used to define an instance of metadata structure.

— Management and evaluation standards and specifications

Management and evaluation standards concentrate on how to control and manage the virtual experiment procedures in a standardized way for the purpose of helping learner complete the experiment in the experimental processes.

5.1.2 Core feature of virtual experiment framework

The virtual experiment framework mainly illustrates the categories of related virtual experiment standards and describes the relations among the standards in order to promote the virtual experiment resources-sharing and interoperability of virtual experiment systems.

5.1.3 Basic specifications

The virtual experiment framework is established on some related specification such as CP, CC, SCORM, etc. All the specifications are described in detail in their own documents.

5.1.4 Relationship

The examples below provide the standard structure of a typical virtual experiment instruction system which normatively describes the standardized environment of the virtual experiment instruction system.

As shown in Figure 1, this virtual experiment instruction system conforms to some related virtual experiment standards which are divided into four categories: basic framework standards, application service standards, data processing standards, and management and evaluation standards. The specific explanations of virtual experiment instruction system are provided below.

— Basic framework standards and specifications

The virtual experiment instruction system may conform to the virtual experiment terminology specification to regulate the definition of key terms and the explanation of symbols which are used in the system. The system unify the terms in the development process and help users to translate and use the standard correctly; meanwhile, it may also be beneficial to manage the virtual experiments system. Basic framework standards are in reference to framework standards (ISO/IEC/TR 24725-1:2011), platform and media taxonomy standards (ISO/IEC/TR 24725-3:2010), which help to manage the platform effectively and efficiently.

— Application service standards and specifications

In the process of virtual experiment instruction, the system has interoperability between different platforms. LIS is the definition of how to realize the exchange of information related to learning domains. Interoperability is best defined through the use of a domain profile. Common Cartridge is another successful example to establish a standardized way to package course so as to export and import content quickly and easily in learning management system. To some extent, the application service standards of virtual experiment are established on the basis of these two standards. However, it has its unique characters according to actual needs. Personal information and operation procedure, such as saving, resetting, configuring, are all recorded in the application service programs which can provide personalized service. Simultaneously, real-time feedback is offered to encourage correct operation or revise errors timely in the course of the experiment.

— Data processing standards and specifications

While using the virtual experiment instruction system, the data processing is a core part. The example of virtual experiment instruction system conforms to component description specification and component packaging specification. The function of component description specification is similar to LOM and includes exclusive environmental elements of virtual experiment beyond LOM; additionally, it helps to describe and classify the components of virtual experiments of the system normatively to promote the interchange and sharing of virtual experiment resources. The content packaging specification can be a method to assist packaging the components of multi-domain modelling standardized and define detailed interface to facilitate the retrieval and management for learners and instructors in the future.

— Management and evaluation standards and specifications

The virtual experiment instruction system also conforms to the procedure of management specification and the evaluation of test specification, which helps to standardize the procedure controlling and management of virtual experiment on the purpose of helping learners complete the experiment in learning process, tracking the learners' behaviour and providing accurate feedback. QTI specification and Simple Sequencing Specification can offer the references to deal with procedure, evaluation, and feedback.

5.2 Basic framework standards

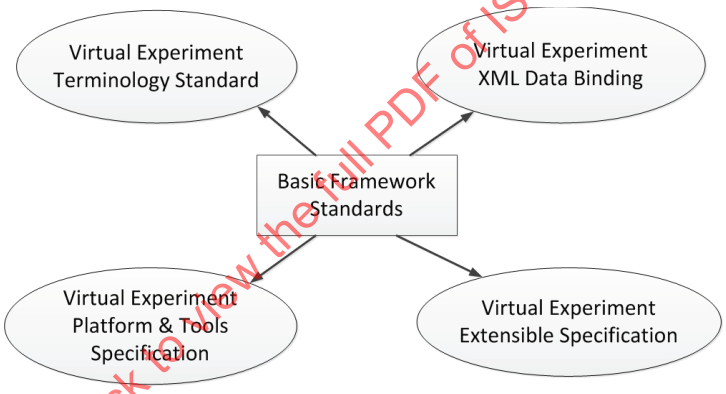

Figure 2 — Basic framework standards

Basic framework standards include virtual experiment terminology standard, virtual experiment Extensible Markup Language (XML) data binding, virtual experiment platform and tools specification and virtual experiment extensible specification as shown in Figure 2.

Virtual experiment platform and tool specification focuses on various compatible specifications of the virtual experiment platform and tools. Virtual experiment extensible specification studies the extensible rules and implementation method aiming at the development process of virtual resources and experiments. Virtual experiment terminology standard provides the definition of key terms and the explanation of symbols which are used in virtual experiment standard system to unify the terms in the development process and help users translate and use the standard correctly. Virtual experiment XML data binding uses the common rules of the data format of XML binding for the processing of data streams and the integration of the system.

5.3 Application service standards

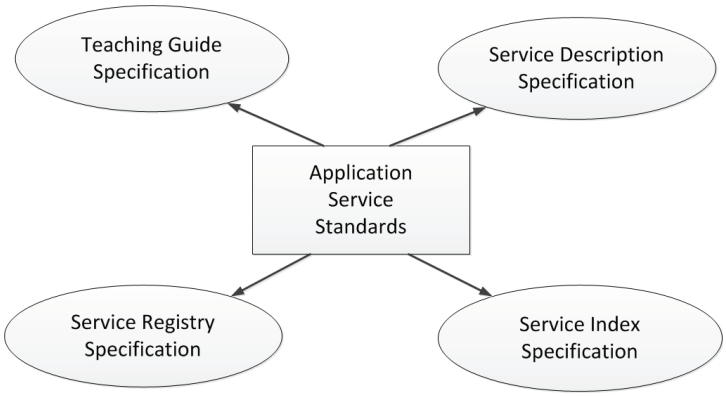

Figure 3 — Application service standards

Application service standards/specification include teaching guide specification, service description specification, service registry specification and service index specification as shown in Figure 3.

The teaching guide specification formulates guiding model for virtual experiment evaluation and defines the rules, data formats, and interface of virtual experiment platform. Service description specification focuses on the normative description of services provided in virtual experiment teaching systems for the management of services. The service registry specification deals with the registration of virtual experiment component and interface specification. Besides, it defines rules in the implementation of web services for Service-Oriented Architecture (SOA) integration. The service index specification provides advices and guidelines on the retrieval of the virtual experiment service which conform to virtual experiment standards.

Application service standards and specifications, such as the common cartridge (CC) specification can be used to package content with more interactive application type functionality (e.g. discussion board, tests, web links, etc.). The CC specification allows the content and application functionality to be bundled into a common structured format that can be shared across different systems.

5.4 Data processing standards

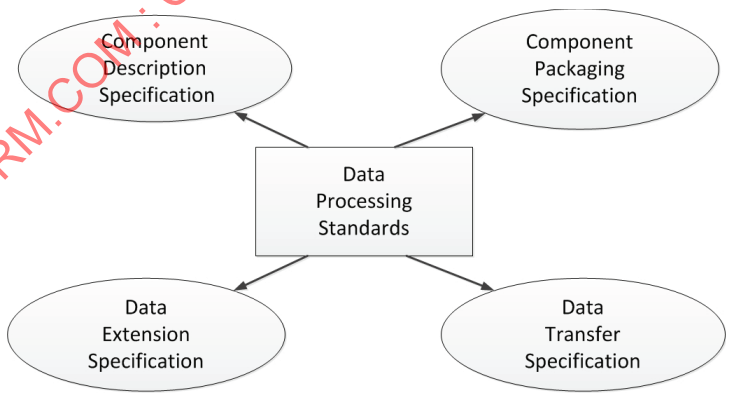

Figure 4 — Data processing standards

Data processing standards include the following sub-categories: component description specification, component packing specification, data extension specification, and data transfer specification, as shown in Figure 4.

Component description specification studies how to describe the multi-domain modelling components in order to retrieve and manage the components in the future. Component packaging specification

specifies how to package the multi-domain modelling components and defines communication interface between components. Thus, it can provide a standardized way to package resources and make different virtual experiment systems sharable. Data extension specification and data transfer specification are involved in the transfer of resources and components among different systems and they build a bridge between different virtual experiment systems.

Some examples of different standards and specifications that may be used within the data processing category are provided below. A data processing standard or specification, such as Learning Object Metadata specification (LOM) can be used to describe resources (sometimes referred to as assets) that are being used in the virtual experiment system. The Content packaging (CP) standard (ISO/IEC 12785) can be used to exchange virtual experiment content between different virtual experiment systems without converting the material into new formats. ISO/IEC 12785 allows the original resources to be packaged into a standard structure so that they can be imported, exported, aggregated and disaggregated as needed.

5.5 Management and evaluation standards

Management and evaluation standards include procedure management specification, evaluation specification and test model specification as shown in Figure 5. Procedure management specification studies how to control and manage the virtual experiment procedure scientifically for the purpose of helping a learner complete the experiment within the process. Evaluation specification studies how to evaluate and test learners' behaviour in a standardized way in virtual experiments, and provides accurate feedback.

Test model specification provides assistance in choosing the correct test approaches and constructing proper test models which help to build a systematic, comprehensive and effective test in the defined standard. In addition, test model specification provides proper index for effective system performance and rational guidelines for selecting the appropriate methods to test, such as black box testing, white box testing, automated testing, regression testing, integration testing, etc.

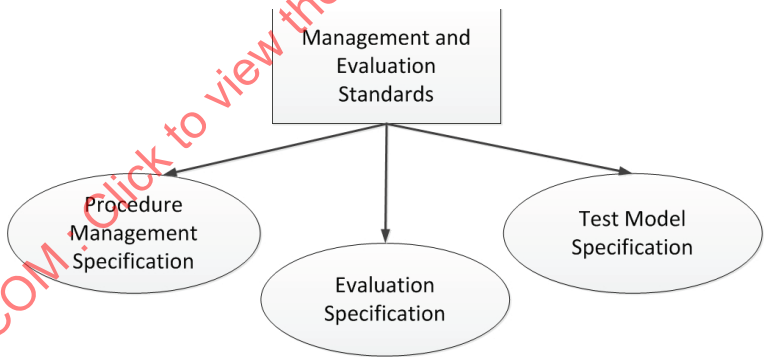

Figure 5 — Management and evaluation standards

Similar to Simple Sequence Specification which defines a method for representing the intended behaviour, management and evaluation standards describe behaviour model to sequence and evaluate discrete experimental activities in a consistent way.

5.6 Relationship among specifications

Virtual experiment development, evaluation and management specifications and test standards are technical standards which meet the demands of virtual experiment instruction. They solve the problem of resource sharing and system interoperability in the field of virtual experiment research and provide the conforming framework and interface for the virtual experiment resource and system.

Basic framework standards are the foundation of the whole virtual experiment standard system. As peripheral standards, basic framework standards are the precondition and requisition of the

development of other standards. All the sub-standards should be developed referring to basic framework standards.

Application service standards are standards related to service management in the virtual experiment standard system. They are the general process specifications which should be complied with in the practical use and service provision of the virtual experiment application system and they help to lower the threshold for standard use.

Data processing standards are the hard core of the whole virtual experiment standard system, providing data elements of virtual experimental component metadata and a conceptual data model which is used to define the instance of metadata structure.

Management and evaluation standards are frequently used during the development of virtual experiment system which includes many functions, such as evaluating and testing the standardized effect and the standardization degree of experimental components and procedures. As to data processing standards, management and evaluation standards also test the standardization degree of component description and component cartridge specification.

5.7 Considerations for virtual experiment systems

When developing or using a virtual experiment system, it is important to fully understand the underlying specifications and standards that are being used. More detailed information regarding the component standards and specifications can be obtained from the following documents.

a) Specification text

The specification or standard text describes the relevant specification or standard and includes information such as purpose, scope, terms and definitions, elements and interrelation, metadata definition, data exchange format, etc.

b) Practice guideline

Practice guidelines usually include detailed explanation on the key points about the standards or specifications and provide practical examples of how to apply the standard or specification.

c) Test specification

The test specification describes the procedures and methods on how to test and validate the standardized products developed by designers and others.

d) XML binding

The XML binding defines the methods that are used to bind the information model.

As specification or standard text is described in language that may not be easily read by ordinary users, it is necessary to refer to other documentation such as the practical guidance. As there can be many interpretations of key points, it can be helpful to refer to related application examples as well.

Annex A
(informative)

Major parts of virtual experiment framework

A.1 General

To facilitate the development of virtual experiment technology and specification integration, the virtual experiment framework standard defines the framework of related virtual experiment standards and specifications. Besides, it determines the relationship between different categories of virtual experiment standards and specifications for integration. However, it establishes a solid foundation for the development of other related standard-setting work without specific implementation details of virtual experiment system.

There were five use cases contributed from four countries including Canada (1), China (2), Kenya (1), and Korea (1). The use cases were reviewed with several other application examples of virtual experiment systems. The common components of the virtual experiment systems were abstracted. Four main categories of standards and specifications were identified including basic framework, application service, data processing, management and evaluation. These categories of standards and specifications include published standards and specifications from ISO/IEC and other related organizations.

The virtual experiment data model is based on ISO/IEC 19788. For example, the virtual experiment environment data model can include the virtual experiment topic, time, and purpose at overall level. The main categories of the virtual experiment framework are used to group together standards and specifications that are used to support virtual experiment system.

Figure A.1 demonstrates sample architecture for a virtual experiment framework. It includes the various categories of standards and specifications to support virtual experiment implementation.

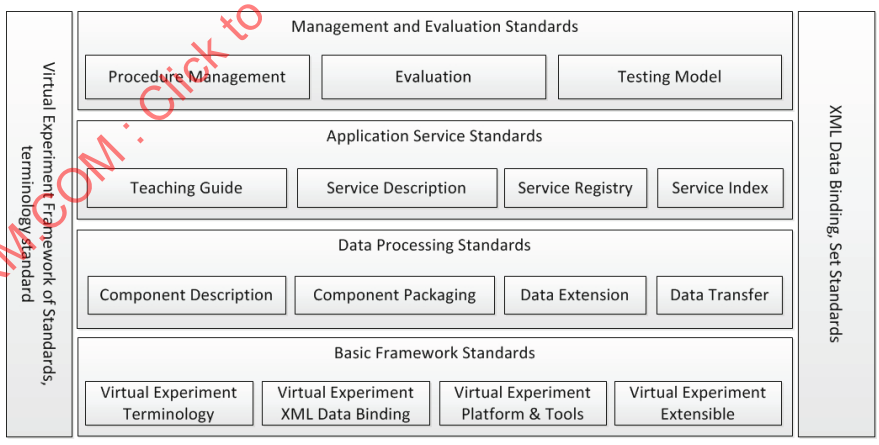

Figure A.1 — Framework structure

For an overview of the virtual experiment framework, please review 5.1, which provide some examples of different standards and specifications in each category. 5.2, 5.3, 5.4, and 5.5 include information about four main categories of the virtual experiment framework. 5.6 indicate some of the relationships between the standards and specifications. 5.7 include some considerations for virtual experiments. Finally, Annex B includes some application examples of virtual experiments.

Annex B
(informative)

Application examples of the virtual experiment framework

B.1 General

With the development of 3D and platform technologies for virtual experiments, many universities and research institutions in some countries have constructed the open network teaching system of virtual experiment, established the virtual experiment platform and managing system of open labs. Compared with other experimental teaching modes, virtual experiments possess incomparable superiority. Advanced virtual experiment courses have many advantages in enhancing the coherence and relevance of various disciplines of knowledge, exploiting the potentiality of learners' comprehensive quality, helping learners' transition from school to the workplace and strengthening learners' preparation for graduate education.

Virtual experiments can effectively resolve difficulties in expenditure, space, equipment and materials. Meanwhile, carrying out virtual experiment teaching can overcome the limitations of traditional experiments on time, space, and funding whenever and wherever possible, both teachers and learners access into a virtual laboratory to operate instruments, perform experiments, which help to improve the efficiency and quality of experiment teaching.

B.2 Application examples

B.2.1 Virtual experiments in China

B.2.1.1 General

In order to manifest the specification of framework clearly, we split the Virtual Experiment Education Platform into Multi-Subject examples. The four main parts of the framework architecture play their respective roles in the system separately. Specific examples are demonstrated as below.

Once a learner logs into the system, the platform of virtual experiment will be shown as Figure B.1.

Figure B.1 — Platform of electronic circuit virtual experiment

Learners can drag or click the icon which represent different components from the left side, and assemble these spare parts on the right side to accomplish the virtual experiment.

B.2.2 Virtual experiment platform and tool related components

The whole experimental process will be shown in Figure B.2. By clicking the button "Experiment start", learners will enter the experiment environment in Figure B.3.

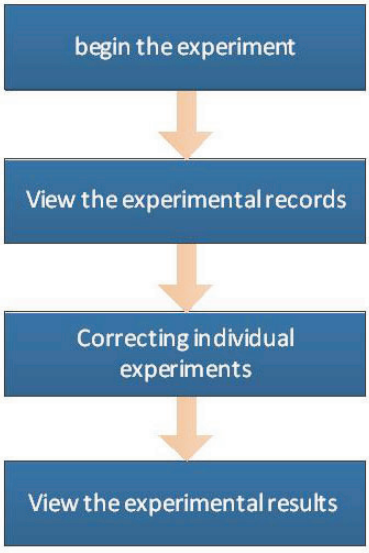

Figure B.2 — Environment navigation

Each experiment procedure contains four stages: start experiment, inspect experiment records, check experiment records, display experiment grades.

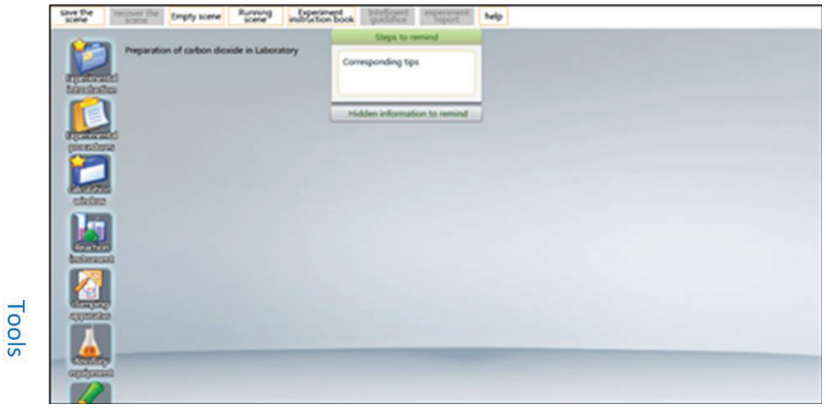

Figure B.3 — Virtual experiment platform and tool-related components

The virtual experiment platform provides access to the environmental tools. These are indicated in Figure B.3 with navigational icon on the left. It offers a service for the learner to conduct experiments freely, observe the experiment phenomenon and take down experiment process data.

B.2.3 Data processing components

Data processing components include component description and data transfer as shown in Figure B.4 and Figure B.5.

Figure B.4 — Virtual experiment component description

The component description specification provides the mechanisms to describe the multi-domain modelling components in a standardized way to index and manage components successfully.

Figure B.5 — Data exchange format specification

This part aims to define the structure of standardized data binding which is applicable to exchange data between different systems.

B.2.4 Test specification module

The test specification module provides for testing learners' behaviour by presenting accurate feedback in accordance with standardization experiment procedure, as illustrated in Figure B.6.

Figure B.6 — Test platform

Learners provide their experiment scene data and get feedback from the platform.

B.2.5 Virtual experiments in biology

As shown in Figure B.7, biology majors of the University of Illinois at Urbana-Champaign began to use education system of remote network laboratory (iLabs) constructed by Massachusetts Institute of Technology (MIT) since 2011. Learners are exposed to the advanced biological technology. For example, learners can simulate disease diagnosis of real experimental study in medical field by using web-based software. The specific virtual experiment includes the diagnosis of the disease (sicklemia, Cystic fibrosis, Huntington Disease, hemophilia), DNA fingerprint atlas experiment, DNA restriction enzyme digestion experiment. Learners can clone an animal or do the experiment of transgenic crops in the modern methods and obtain the experiment result by operating, data input and analysis.

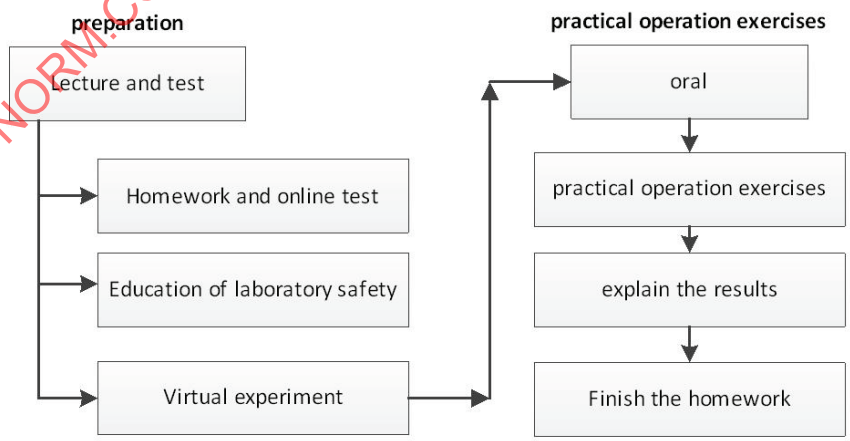

Figure B.7 — Instruction system of virtual experiment in biology