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D4.2.2. Methodology and Process for Creating FIRE Courseware - Update

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1. Executive Summary

The methodology outlined in D4.2.1 *Methodology and Process for Creating FIRE Courseware* has acted as a very successful guide to help Open Call (OC) partners with course and proposal design, FIRE testbed selection and development. This deliverable contains updates and refinements to D4.2.1 supporting the final FORGE methodology and process view. These updates are recorded based on experience and lessons learned from carrying out tasks in WP2 and WP5 and after issues raised during the execution of prototype and external OC lab courses.

Updates in this deliverable are built on experience of integrating and deploying courseware, widgets and adapters on FIRE testbed infrastructure. These updates have considerations and recommendations based on experiment size, testbed reservation practicalities, open course formats (i.e., for eBooks and ePub), following Learning Tools Interoperability (LTI) standards and gathering Learning analytics information. It also provides an overview of adjustments to courseware and technology evaluation and adaptation mechanisms. These considerations and recommendations will provide valuable input for future course designers and developers using the FORGE methodology.

The remainder of this deliverable is structured as follows. First, the FORGE methodology in relation to Inquiry-Based Learning research is analysed and literature in online labs published since the last deliverable is reviewed. Second, updates to the methodology and process outlined in D4.2.1 based on lessons learned during course design, execution and post hoc analysis are presented. Third, we outline how the FORGE methodology can be applied to non-ICT areas. Finally, we conclude the deliverable.

2. Introduction

This document updates the existing methodology described in D4.2.1 to support teaching module designers and developers creating new courses that utilise Future Internet Research and Experimentation (FIRE) facilities. The updated methodology is based on a combination of design experiences from the execution of prototype and external lab courses coming from the Open Call and lessons learned during course implementation. Its main objective is to update the existing steps defined in D4.2.1 based on these experiences. The updated methodology is supported by technologies offered by FORGE such as FORGEBox, FORGEStore, widgets and FIRE adapters, which facilitate technology sharing, reuse and rapid course development.

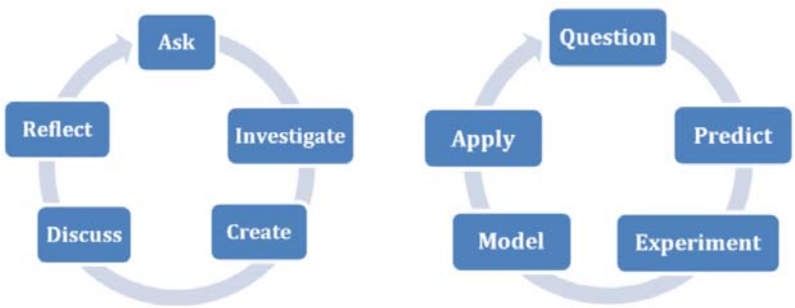
3. State of the Art

3.1 Learning Design: The FORGE methodology in relation to Inquiry-Based Learning

One of the main goals of FORGE is to enable educators and learners to access and actively use FIRE facilities in order to conduct scientific experiments. We thus follow a constructivist approach to education where learning takes place by students creating artefacts rather than assuming the passive role of a listener or reader. Our approach is based on a wide range of studies that have shown that with the right scaffolding competent learners benefit greatly from constructivist or learning-by-doing approaches [Jong06][Hakkarainen03][Kasl02].

FORGE fosters Inquiry-Based Learning (IBL) by turning learners into active scientific investigators, equipped with world-class experimentation facilities. IBL supports the meaningful contextualization of scientific concepts by relating them to personal experiences. It leads to structured knowledge about a domain and to more skills and competences about how to carry out efficient and communicable research. However, the shift from passive to inquiry-based learning is challenging for both learners and educators. Information and Communication Technologies (ICT) have the potential to contribute positively towards this end [Blumenfeld91]. FORGE is addressing this gap by offering world-class experimentation facilities to learners and educators, as well as the tools and processes that enable them to integrate these experimentation facilities into their learning and teaching practices.

The literature of Inquiry-based Science Education presents several approaches, which can be considered as templates or models for IBL. Based on John Dewey's philosophy that IBL begins with the curiosity of learners, several authors [White98][Bruce02] suggest a 5-step cycle of inquiry, as shown in Figure 1.



(a) (b)
(b)

Figure 1: Five-step models by (a) [Bruce02] and (b) [White98]

These steps comprise a continuous cycle for asking questions and making predictions; investigating solutions through experiments; creating new knowledge and models; applying/discussing discoveries and experiences; and reflecting on newfound knowledge and/or starting new questions.

A slightly different approach proposed by [Llewellyn04] is a 6-step inquiry cycle (Figure 2): generating a question; brainstorming; stating a hypothesis; choosing a course of action and carrying out the investigation; gathering data for appropriate conclusions; and communicating the findings.

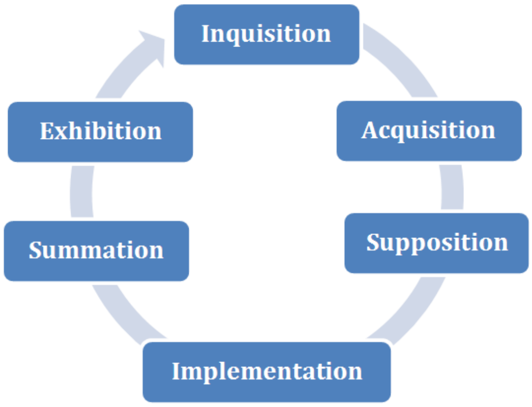


Figure 2: Six-step model by [Llewellyn04]

There is also a significant number of approaches originating from a variety of learning contexts, such as collaborative or individual inquiry; real or simulated environment; curriculum guided or not. [Murdoch07] proposes 7 steps of inquiry for implementation in groups and integration of investigation to the curriculum (Figure 3).

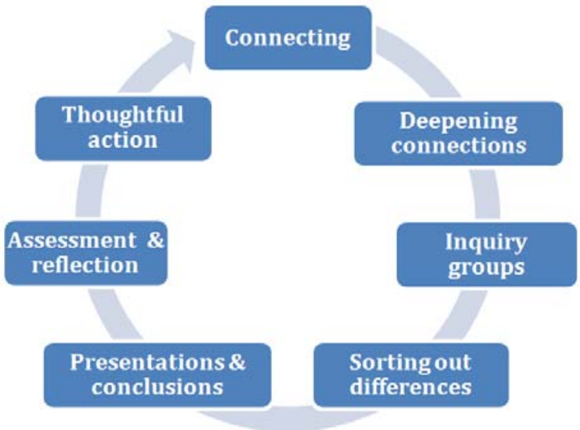


Figure 3: Seven-step inquiry cycle by [Murdoch07]

[Mulholland12] highlight the inquiry cycle based on an 8-phase model, comprised by initial topic selection, communication of findings and reflection upon the method of inquiry (Figure 4).

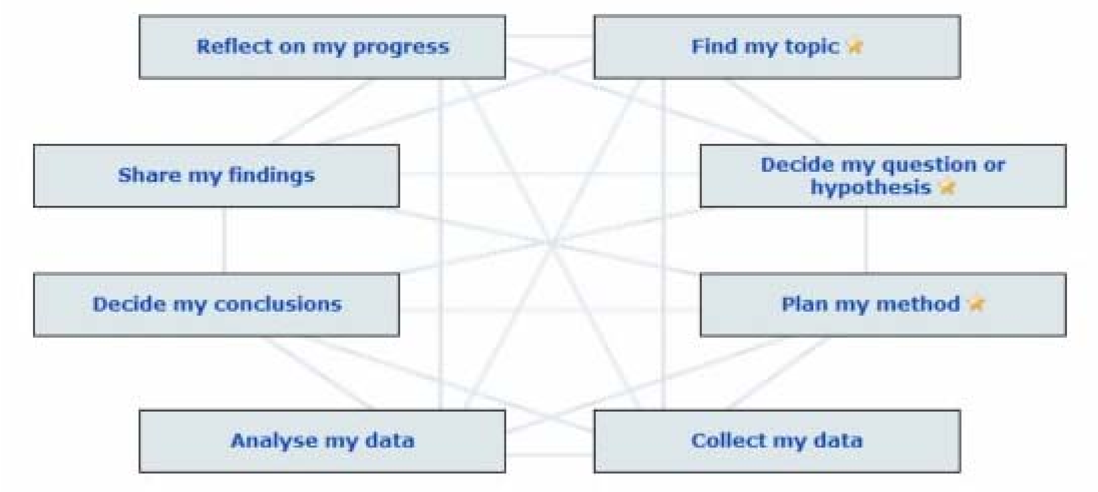


Figure 4: Eight-phase inquiry model by [Mulholland12]

The IBL model developed in the context of the weSPOT[1] project moves on from the simplistic cyclical models as it aims to model the complete scientific inquiry process (Figure 5). The weSPOT model is based on the steps required for good research, such as data collection, data analysis, hypothesis forming, communication and dissemination of findings etc. It also shares some of the phases that [Mulholland12] describe in their model, such as create a question or a hypothesis, collect data, analyse data etc., but it is more elaborate regarding the sub-phases, providing a detailed description of tasks that teachers and students should consider when performing an inquiry [Protopsaltis14].

[1] http://wespot.net

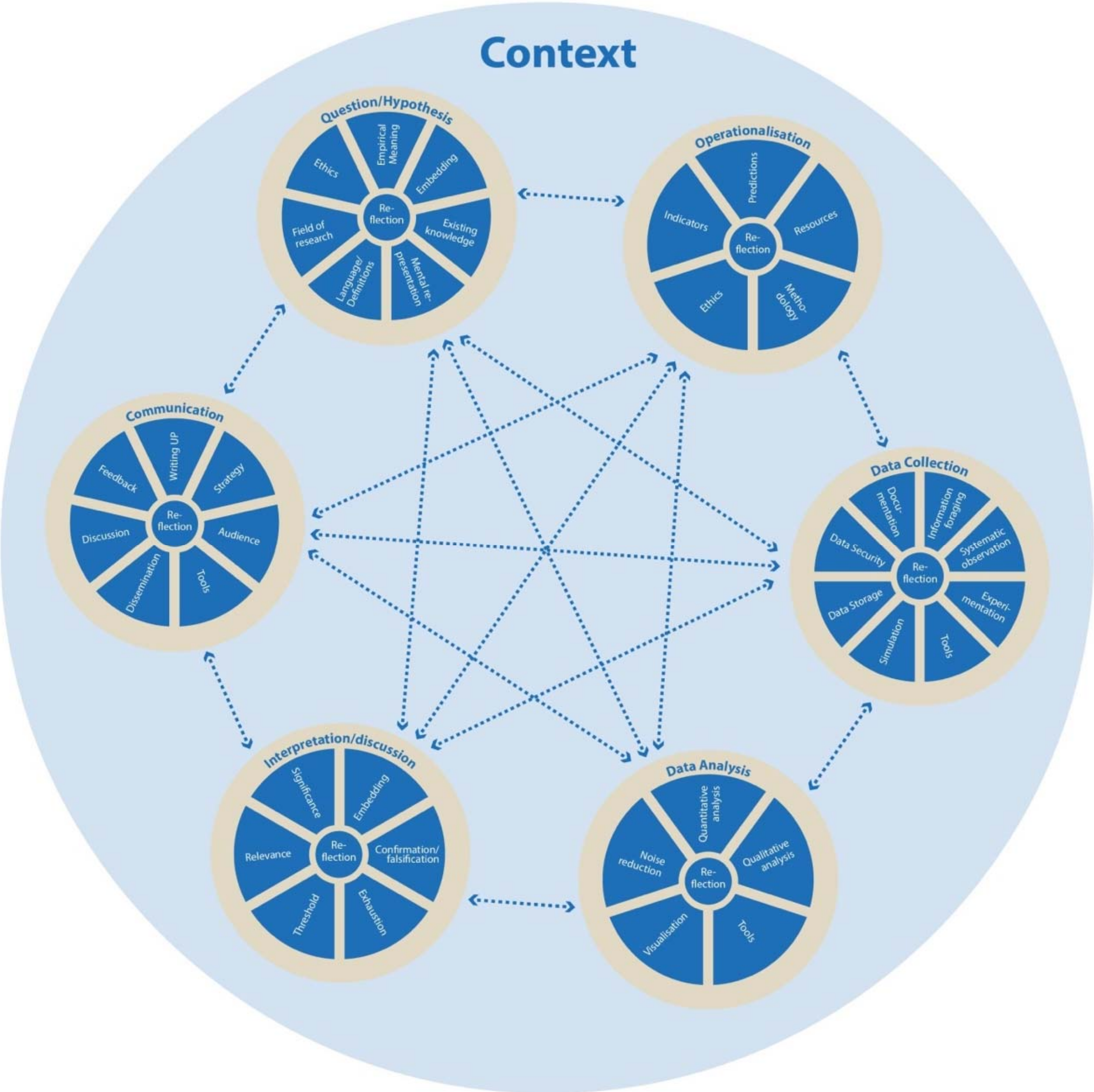


Figure 5: The weSPOT IBL model [Protopsaltis14]

The FORGE methodology does not propose yet another IBL model, but instead it complements the existing IBL models with processes and tools that build on top of core IBL phases, such as data collection, data analysis, interpretation of findings, as well as reflection. The methodology for the creation, deployment and evaluation of FORGE courseware enriches the aforementioned IBL phases, by enabling learners to collect and analyse data via the FORGE widgets, interpret their findings with the help of the FORGE courseware and reflect upon their learning progress via Learning Analytics. Therefore, the FORGE methodology can be used in conjunction with existing IBL approaches in order to provide ICT support to learners and educators that are in need of experimentation facilities and courseware in different phases of their learning and teaching.

3.2 Online Labs

There has been some minor updates to the literature related to remote labs for teaching telecommunications courses. These include: eComLab [Gampe14] and the Smart Device paradigm [López15]. This is in addition to the literature recently published by the FORGE team in the areas of virtualizing testbeds [Marquez-Barja15] and methodologies for remote experimentation [Mikroyannidis16].

eComLab is a dedicated VNC-based remote desktop software that supports remote lab configuration and experimentation using Emona DATEx and NI ELVIS boards [Gampe14]. Remote access to equipment is supported by a gateway server that creates virtual machines, which have direct access to the board hardware supporting direct experiment control. A user can access these machines using a regular web browser with support for Flash and Java plugins. Students can experiment with hardware units and control parameters such as: large carrier amplitude modulation (AM) and demodulation, binary phase-shift keying (BPSK), PCM encoding and decoding, amplitude-shift keying (ASK), frequency-shift keying (FSK), and so forth. Like the Bose and Pawar [Bose12] remote lab for wireless signaling surveyed in D4.2.1, the eComLab can only be accessed by one student at a time.

The Smart Device specification [López15], initiated by the Go-Lab[2] EU FP7 project, advocates all devices (clients or servers) use common interfaces such as metadata, logging, data collection, configuration, and so forth, to simplify communication between remote labs, external services and applications. This is supported by: open protocols; WebSockets, which uses asynchronous bidirectional communication between client and server; and Swagger, a JSON-based description language for RESTful web services that easily integrates with WebSockets. Smart Device metadata is exposed on the Internet enabling applications, services and other devices to interact with the remote lab. Telecommunications courses, such as the oscilloscope lab available on Go-Lab-Project.eu, utilise the Smart Device specification to support design, integration and usability.

[2] http://www.go-lab-project.eu/

4. Methodology

The methodology described in D4.2.1 leads the course designer from defining the course up to implementing and deploying it, supporting them with considerations for educational and technological requirements. This deliverable provides an update to the steps described in the D4.2.1 methodology based on the experiences and lessons learned from the execution of prototype labs, IBL considerations and helping OC partners design and implement lab courses.

The methodology is split between two major processes (see Figure 6):

- **FORGE Course Preparation**, is a set of activities general enough to be performed without any FORGE tool, which helps identify the requirements of developing and deploying a lab course. The designer must identify and/or define several *context components* that will affect the course development and deployment since the most suitable FIRE facility and FORGE tools will be adopted based on this criteria.
- **FORGE Supported Activities** is a set of elements that are oriented towards the development or reusing of FORGE material within a course. At this point, the course requirements have been specified and an appropriate FIRE facility has been identified, so the course designer needs to determine what technology components (i.e., widgets and adapters) that interface with the experiment and facility will be used.

Figure 6 presents the methodology as given in D4.2.1, which is slightly updated with the activity of "*Prepare Support Material*" within the FORGE course preparation process. Preparation activities include the preparation and development of Course Support Web Pages, Widgets/FIRE Adapters that enable the course/testbed setup (see D4.1.2 Section 3.3 Teacher Companion Lab courses Widgets/FIRE Adapters). The following sections outline the updates and refinements to the 4.2.1 methodology and process.

4.1 Specifying Requirements

The educational objectives or learning outcomes a student should acquire after completion of a course according to the European Qualification Framework (EQF) include:

- knowledge,
- skill
- and competence.

When developing a course to meet these learning outcomes, a course designer must identify several *context components* including:

- date of course execution,
- number of students participating,
- geolocation and Internet connectivity availability,
- supported devices,
- language used,
- financial restrictions (if applicable)
- and learning management system (LMS) utilised.

These objectives and components form the basis of the selection of **FORGE Course Preparation** process in the methodology (see Figure 6). The definitions of the educational objectives and context components have been comprehensively defined already in D4.2.1 requiring no further update here.

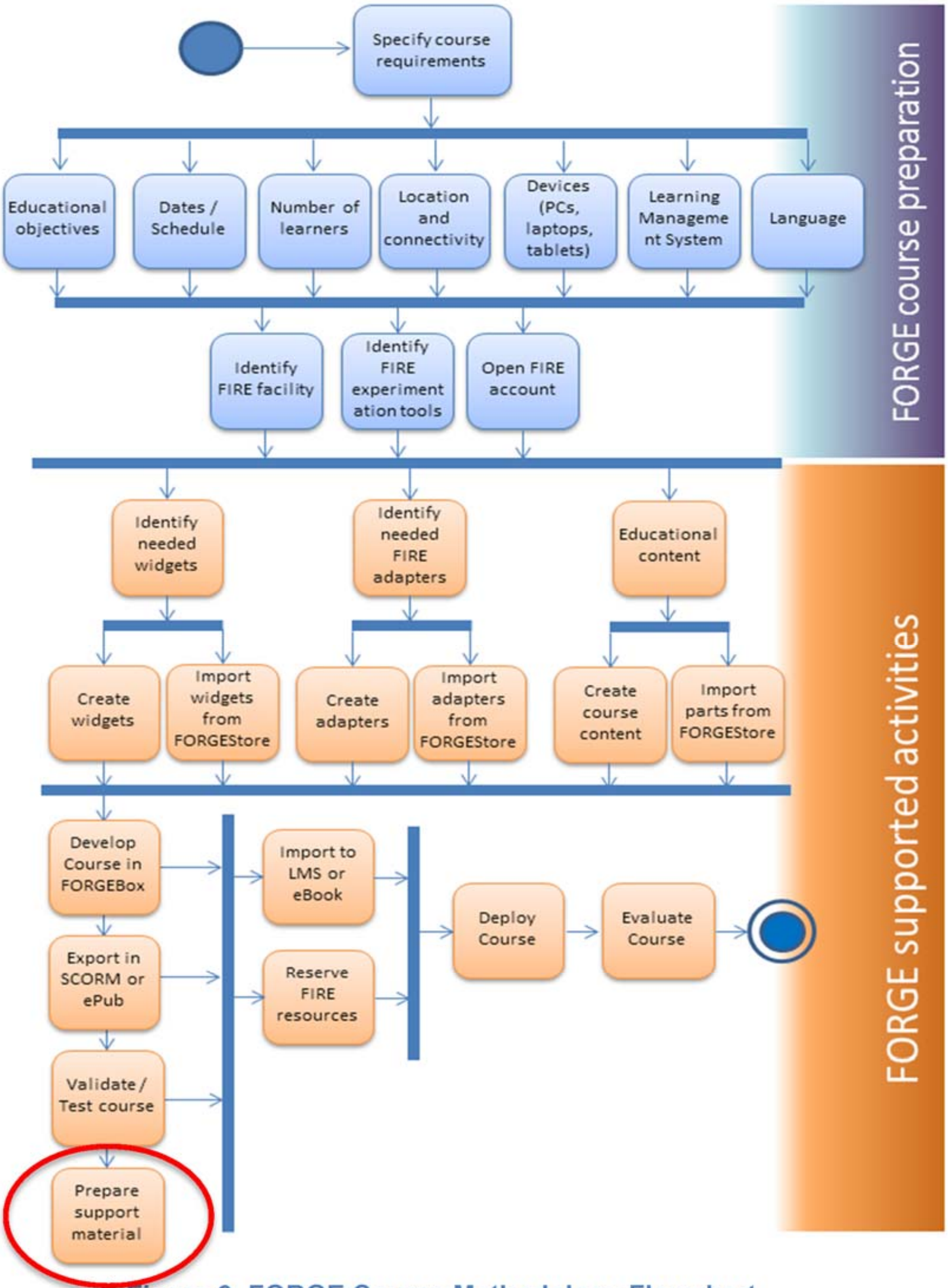


Figure 6: FORGE Course Methodology Flowchart

4.2 Identifying FIRE facilities

The description of the methodology and process outlined in D4.2.1 is still valid for the identification of the appropriate FIRE facility. However, the following testbeds in Table 1 have new or updated information compared to the testbeds listed in D4.2.1.

Table 1: New or Updated Testbeds Compared to D4.2.1

Facility	Location	Focus	Nodes	Prominent features
w-iLab.t	Belgium	wireless	120	IEEE 802.11,802.15.1,802.15.4 interfaces cognitive radio platforms spectrum scanning engines 20 mobile robots
IRIS	Ireland	wireless	16	SDR testbed with 16 USRP N210s Private computational cloud Support for OpenBTS, Amarisoft, GNURadio, SRSLTE
NITOS	Greece	wireless	>100	Outdoors: Wi-Fi, WiMAX, LTE technologies Indoors: 40 Icarus nodes and 10 USRPs Openflow Enabled

All Fed4FIRE testbeds offer a possible integration path with FORGE tools. However, using FORGE partner facilities has led to faster course development and allowed the full reuse of existing widgets, adapters and FORGE partner knowledge and experience. We also noticed that most OC partners selected a FORGE enabled testbed if it fit their requirements, as specified in D4.2.1. By selecting these testbeds it was easier to verify the more detailed requirements and reuse existing course material, which demonstrated the capabilities of these facilities. It is worth mentioning that NITOS has recently joined the FORGE enabled testbeds, through the "ENVISAGE" OC project by the University of Thessaly, Greece (more details about this project will be presented in D6.8 "*Opening the FORGE platform and engaging the community*" [M36]).

4.3 FORGE Widgets and Adapters

4.3.1 Methodology: FORGE Course Preparation (Update)

Following the *FORGE Course Preparation* process in the methodology (see Figure 1), course designers are able to identify the FIRE facility that best suits their course requirements. During this step the course designers (including FORGE consortium partners and partners from OC) can select relevant FIRE facilities based on:

A. Facility features
B. Reservation practicalities

As discussed above, most OC partners preferred to use facilities from FORGE partners such as iMinds, PlanetLab and Trinity College Dublin (TCD). However, there were cases where new testbeds were brought into the project, according to the specific needs of the OC projects. The IoTStreams course used their own IEEE 802.15.4 (Zigbee) platform which interacts with iMinds' Virtual Wall. Additionally, the ENVISAGE course, proposed using their own FIRE facility, the NITOS testbed. The GÉANT course did not reuse any widget or FIRE adapter. However, it did offer and create (with iMinds support) a service to include GÉANT testbeds in FIRE.

4.3.2 Methodology: FORGE Supported Activities (Update)

Following the *FORGE Supported Activities* process of the methodology (see Figure 6) described in D4.2.1 and specific course designer requirements, the course designers are able to identify any existing FORGE widgets and FIRE adapters that they can use to support their needs, after selecting the appropriate FIRE facility. If no widgets or FIRE adapters are available for a FIRE facility then one needs to be created (and be shared within FORGE).

Through the Open Call the FORGE ecosystem was enriched with new widgets and FIRE adapters. Namely, the ENVISAGE team created a widget and FIRE adapter to support their course and access to the NITOS testbed facility and the IoTStreams team created a widget and a FIRE adapter to enable learner access to the IoTSTREAMS platform, backend services and sensor management middleware. Table 2 summarizes identified widgets and FIRE adapters created or used by OC partners.

Table 2: Widgets and Adapters Created and Used by FORGE Open Call Partners

Proposed course	FIRE facilities used/offered	Widgets used/created	FIRE Adapters used/created
IoTStreams (University of Ioannina, Greece)	• iMinds Virtual Wall • Own IoT testbed (IEEE 802.15.4 (Zigbee) platform)	the Node-RED widget	iMinds Virtual Wall reservation Adapter for the IoT Streams
ENVISAGE (University of Thessaly, GR)	• NITOS	WiFi and LTE	ENVISAGE adapter based also on iMinds work
PRO-LEARNING (Universitat Politècnica de València, ES)	• iMinds Virtual Wall • iMinds w-iLab.t	Reuse of WiFi and expanded LTE widgets, 1 new widget for reservation of resources	Full reuse of all iMinds adapters
FORGELAN (Universidade de Brasília, BR) (UnB)	• iMinds Virtual Wall • iMinds w-iLab.t • TCD IRIS testbed	Reuse of Wifi widgets, 1 new widget for provisioning of resources in WLAN course, Reuse of TCD control widget and expanded graphing widget	Reuse of WiFi adapters Reworked TCD adapters for GNU radio
METRO (INRIA, FR)	• PlanetLab	The PlanetLab Widget	
WN_SP (Tecnologico Nacional de Mexico, MX)	• iMinds w-iLab.t	Reuse of iMinds Wifi Widgets	
GTS-UCP (GÉANT Association (NL), Friedrich-Alexander University of Erlangen-Nuremberg (D))	• GÉANT Testbeds Service (GTS)	GTS as a widget (new widget)	

Following the experience of executing the prototype courses, considerations for IBL and the implementation and deployment of the OC courses, two issues were identified as critical in the process of creating FORGE courses and need to be checked by each course designer according to the FORGE methodology: the *size of the experiments* and *reservation practicalities.* To properly address these requirements affects the development (or improvement) of widgets and FIRE adapters, as well as how to prepare and setup a testbed prior to deploying a course. For example the requirement to have an open course and given that the resources are limited drives the developer to choose a queuing mechanism. An extensive implementation example is given in the FIRE adapters provided by iMinds for WiFi and LTE courses in D2.1 and D2.2. Table 3 summarizes these two issues per the experience of OC course partners identified in section 4.3.1 (more details about the improvement of existing or development of new widgets/adapters within the OC will be presented in D6.8 "*Opening the FORGE platform and engaging the community*" [M36]).

Table 3: Experiments and Reservation Practicalities for Open Call Partners

OC Course	Size of Experiments	Reservation Practicalities.
IoTStreams	iMinds Virtual Wall is capable for high demand. However, there is a problem regarding the offered IoT resources. IoTStreams will adopt a queue mechanism in this case.	iMinds Virtual Wall seems adequate to facilitate resource reservation.
ENVISAGE	Target for now is Un. of Thessaly students. The NITOS FIRE testbed seems capable to handle the experiments	NITOS is fully compliant with FED4FIRE mechanisms
PRO-LEARNING	The LTE experiments require a small amount of very limited resources, shifting the resource issue fully to a reservation issue. WLAN uses only 3 nodes from a homogeneous pool of 60.	The w-iLab.t has an enforced reservation system, coupled with FORGE adapters leading to guaranteed experiment availability.
FORGELAN	The course targets UnB, with 7 simultaneous setups being sufficient, using 21 nodes from a homogeneous pool of 60.	The w-iLab.t has an enforced reservation system, coupled with the FORGE adapters leading to guaranteed experiment availability.
METRO	This course is a MOOC and therefore it has high demands on resources.	Planetlab has sufficient resources to cover this activity. Although a queue mechanism was also implemented in this case
WN_SP	The course targets 14 simultaneous setups being sufficient	The w-iLab.t has an enforced reservation system, coupled with the FORGE adapters leading to guaranteed experiment availability.

4.3.3 Summary

In summary, course designers are not limited to using testbeds only defined in the 4.2.1 methodology. Similarly, course developers are not restricted to using existing widgets and adapters and can easily update existing or define and build new ones if required. Finally, the size of the experiments and reservation practicalities are important factors to consider when choosing testbed infrastructure for courses.

4.4 Educational Content and Integration of Widgets and Adapters

Based on experience and lessons learned from integrating courseware, widgets, adapters and testbeds to provide an interactive course for students, we include several considerations useful to support future course design and development. These include:

- If the course is targeted to be used by eBooks and ePub formats then it is best that the course be offered as open as possible, without any account restrictions on widgets/FIRE adapter usage.
- If the content is targeted to be open then special care should be focused on resource reservation due to possible high demand.
- Open access has the drawback that it is not possible to collect Learning Analytics for specific users and therefore record their actions. However anonymous actions can be tracked and reported.
- Course components should be as reusable as possible. In FORGEBox and in FORGE Moodle we propose building as many reusable contents as possible.
- Any newly developed widgets should follow the LTI and Learning Analytics recommended in the reference architecture of D4.1.2

In summary, for open formats there should be limited restrictions for enforcing user account creation, which will have an impact on learning analytics. Additionally, testbed resource reservation should be considered during high demand, course components should be reusable and new widgets should incorporate LTI standards and gather learning analytics information.

4.5 Deployment

At the deployment phase there are different strategies to follow besides the one mentioned in D4.2.1. These include:

- Course installation on FORGEBox.eu. This has the benefit of using LTI and Learning Analytics. The drawback is that you need to use a separate LMS system.
- FORGE has a Moodle installation that can consume LTI courses and offer FORGEBox Learning Analytics. The drawback is that this is a shared installation and also the sustainability of the course is not guaranteed
- If it is possible create support pages and Widgets/Adapters that target instructors and facilitate course deployment and FIRE testbed setup. This is why the activity of “preparing support material” was added to the “FORGE Supported Activities” process of the methodology in Figure 1. This process includes the preparation and development of Course Support Web Pages, Widgets/FIRE Adapters that enable the course/testbed setup (see D4.1.2 Section 3.3 Teacher Companion Lab courses Widgets/FIRE Adapters).
- It is recommended to adopt the Sharable Content Object Reference Model (SCORM) or use FORGEBox to export SCORM functionality directly and share the course through FORGEStore

In summary, considerations for choosing a platform are needed if Learning Analytics is required. Course support material should be created to enable teacher/student interaction with widgets and adapters. Adoption of the SCORM reference model should be a priority when designing and implementing courses.

4.6 Courseware and Technology Evaluation and Adaptation

4.6.1 Courseware and Technology Evaluation

The evaluation of the courseware and technology is performed using the following structured methods, which are outlined in D4.2.1:

A. Interviews and questionnaires (Qualitative Instruments)
B. Learning Analytics (Quantitative Instruments)

Feedback information can also been collected from teachers in an informal manner via email, skype and direct interview after course execution. These qualitative methods have recorded teacher views such as issues experienced during course execution and recommendations or suggested courseware or technology improvements. Quantitative instruments have also been utilised by several of the courses offered by institutions such as iMinds, UoP, UPMC and TCD to gather learning analytic information based on student interactions with remote lab courseware. Quantitative analytics offer a methodology to improve teaching mechanisms, support student learning and success [Ferguson12]. This information is being collected by FORGE partners using a variety of mechanisms including monitoring log files and using the Learning Record Store (LRS) framework such as the Learning Locker system. Additionally, information gathering is supported by several methods to record user activity including using: a Central Authentication Service (CAS) to authenticate known users and standardised FORGEBox verb query parameters (based on actions performed) such as *actoremail* or *actorname*. Anonymous tracking of users is supported using unique server side identifiers.

4.6.2 Adaptation

The information collected and analysed using these mechanisms helps FORGE course designers and developers identify and address some of the educational and technological challenges experienced by both students as individuals and as groups. For example, based on feedback received from students and teachers, Trinity College Dublin's OFDM course was re-implemented to be more scalable, real-time, responsive, reusable and sustainable for end-users. A comprehensive overview and analysis of survey information gathered from existing courses is available in *D5.3: Evaluation of the Execution of Prototype and External Lab Courses*. Finally, several of the FORGE partners have also used learning analytics to support student assessment, which was achieved by giving students a certain amount of time (e.g., 30 minutes) to complete a remote lab experiment and answer course assessment questions. The results led to the improvement of several components of the courses.

4.6.3 Summary

In summary, it is strongly recommended that course designers include mechanisms to gather courseware and technology evaluation information using qualitative and quantitative mechanisms. This information can support important course adaptation and evolution.

5. Extending the FIRE Course to non-ICT Disciplines

Many disciplines rely on performing laboratory experiments, which support the development of critical thinking and problem solving skills in students, to reinforce the theory material taught in classrooms in areas such as biology, chemistry, physics and so forth. There is limited availability of a generic methodology, open framework and reusable software that can be applied and used in non-ICT courses. The FORGE methodology and process for creating courseware can be followed, substituting courseware and FIRE testbeds for non-ICT course content and remote experimentation equipment. Additionally, FORGE tools such as FORGEBox, FORGEStore, widgets, FIRE adapters and facilities can be utilised or modified to support access and authorisation, learning analytics gathering, data generation and visualisation, and so forth. These tools can facilitate the rapid generation of technologies and courseware that access remote experimentation equipment and support the development of interactive artifacts for online courses and labs.

In summary, the FORGE methodology and process for creating courses can be followed by non-ICT courses.

6. Conclusions

In this deliverable we have refined and updated the methodology and process for creating FIRE courseware presented in D4.2.1 based on new artifacts and issues raised after both the execution of prototype and OC lab courses. This includes new and updated information about available FIRE testbed infrastructure, experience of integrating and deploying course material, widgets and adapters and considerations for open course formats, testbed reservation practicalities, awareness of LTI standards, and technology evaluation and adaptation mechanisms. These considerations and updates will provide valuable input for future course designers and implementers using the FORGE methodology. Finally, the FORGE methodology and process can continue to support future course evolution and development ensuring the methodologies sustainability into the future.

7. Annexes

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7.2 Acronyms

ASK	Amplitude-Shift Keying
BPSK	Binary Phase-Shift Keying
CAS	Central Authentication Service
EQF	European Qualification Framework
FIRE	Future Internet Research and Experimentation
FSK	Frequency-Shift Keying
IBL	Inquiry-Based Learning
ICT	Information and Communication Technologies
IEEE	Institute of Electrical and Electronics Engineers
LD	Learning Design
LMS	Learning Management System
LRS	Learning Record Store
LTE	Long-Term Evolution
LTI	Learning Tools Interoperability
MOOC	Massive Open Online Courses
OC	Open Call
OFDM	Orthogonal Frequency Division Multiplexing
SCORM	Sharable Content Object Reference Model
SDR	Software Defined Radio
TCD	Trinity College Dublin
UnB	Universidade de Brasília
UPMC	University Pierre and Marie CURIE
USRP	Universal Software Radio Peripheral
WLAN	Wireless Local Area Network
WP	Work Package