

Towards Outcome Based Learning: An Engineering Education Case

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Abstract— Following the European initiatives like European Qualification Framework (EQF), Europass [4] and European Learner Mobility [3], the aim of this paper is to introduce specifications, services and applications that enable the management and use of learning outcome information. We present pilot implementation and validation of the adoption of standards and specifications related to outcome based learning. Prototypes are developed as widgets and modules of Learning Management Systems (LMS) like Moodle, to produce and import data about intended learning outcomes of learning opportunities and achieved learning outcomes of learners. We demonstrate an outcome based Engineering Education use case.

Keywords—learning outcome; knowledge; skill; competence; engineering education; standards; pilots; recommendations

I. INTRODUCTION

The advancement of learner mobility and employability certainly remains a high priority action item worldwide. Several HE institutions and international and national bodies are now confronted with the challenge to accomplish the initiated shift to a competitive and knowledge-based economy in order to ensure growth and employment in the long term, taking into account job market demand for new skills and competences [2][3][14]. The achievement of this ambitious goal has been linked to a fundamental transformation of learning, education, and training, from an input-based to an outcome-based paradigm.

As stated in [17], "learning based uniquely on input will not respond adequately to future challenges for individuals, society or the economy. The trend is to rely, increasingly, on the identification of learning outcomes. This trend is recognised as critical in many different contexts across education and training systems". Formal learning and training opportunities (e.g. HE and VET programmes [18]) cannot, of course, satisfy all the requirements of lifelong learners, therefore non-formal and informal learning opportunities become of crucial importance.

Learning outcome development might typically start in the initial education context, which includes traditional school settings, however dynamic changes in the society and economy demand more and more lifelong learning and development of knowledge, skills and competences in the work context,

encompassing both informal learning activities (i.e. intentional, but not accredited) as well as non-formal ones (i.e. as a side effect of other activities).

ICOPER project is a Best Practice Network [6] co-funded by the eContent^{plus} programme of the European Community with the mission to collect and develop further best practices for the design, development and delivery of interoperable content which supports outcome driven higher education.

In this paper, we introduce specifications and standards developed/adopted by ICOPER in Section III. As proof of concept for adoption of specifications, pilots around outcome based education design, delivery, tracking of learners achieved learning outcomes in engineering education are illustrated in Section IV. Results of pilots evaluation are given in Section V. Discussions and recommendations are provided in Section VI, while conclusion and future directions are presented in Section VII.

II. BACKGROUND AND RELATED WORK

A. Outcome Based Education

The importance of capturing data about life-long learners' knowledge, skills and competences has been stated by several national/international initiatives, standardisation bodies and researchers. A learner's knowledge is about what the learner knows, or is presumed to know. Knowledge or belief does not automatically turn into behaviour, but needs to be applied to be of practical use. Skills, in contrast, are about patterns of behaviour in the learner's actions. In practice, all skills are supported by knowledge. Competences are more complex; they involve the application of knowledge and skill, but they are also about the kinds of situations (context) in which the knowledge and skill are applied. These kinds of situation are patterns that are instantiated in the world just at those times and places where the competence is applicable. The European Qualification Framework (EQF) [2] was proposed as an instrument to make learning outcomes more transparent and comparable across Europe. This is an important step towards outcome based learning and mobility. Employers seek people matching particular qualifications and graduates seek jobs matching their qualifications. This market is currently managed primarily using paper certificates and heterogeneous university

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management systems that describe the intended learning outcomes (knowledge, skill and competence) of learning opportunities and track the achievements, and related evidence records, of learners after successful completion of learning opportunities. On the other hand, required learning outcomes and qualifications of a specific job are represented in corporate information systems.

The following is an example that illustrates an outcome based engineering education scenario. John is a teacher at Faculty of Mechanical Engineering. Next year he will start teaching on the basics of engineering at undergraduate level. During the course (learning opportunity) preparation, he first defines which learning outcomes the students will obtain after they successfully finish his course. The outcomes are selected from a pool of study program's learning outcomes. Based on the list of selected outcomes, he identifies appropriate learning designs [1], and teaching and assessment methods, creates new or re-uses existing educational resources on the topic, and integrates everything in a course. Learning designs, e.g. basics on reverse engineering, and educational resources to be re-used are found in an educational network that connects a number of educational repositories. Finally, information about the course is uploaded as a learning opportunity to the university's Moodle system.

Peter is a student at the same faculty. As for every university student, his obtained and required learning outcomes are stored in his personal achieved learning outcome profile. During the enrolment process a university's service helps Peter to match his already obtained and expected learning outcomes to the learning outcomes of courses and select the optimal course list. One of the courses is also John's course on the basics of engineering. The on-line course is entirely implemented within the Moodle system. Once Peter has successfully completed the course, the data collected about personal achieved learning outcomes are generated by the learning system. Based on the assessment results, the faculty issues Peter a certificate that proves the obtained learning outcomes, and registers Peter's achievement in the form of an achievement record. The achievement states attainment of all learning outcomes Peter obtained in a certain context in the course, and can be verified on the basis of a certificate. The achievement is stored in Peter's profile. To allow others, e.g. prospective employers, to have access to his obtained outcomes, Peter decides to export information about the achievements from the profile to several social platforms, such as Facebook.

B. Outcome related Standards and Specifications

The important role of personal competence profiles in human resource management and education was emphasized by [14], who demonstrates how a gap in learner skills can be identified in competence-based ontology-driven e-learning systems. Van Assche [17] and Sampson [15] extend the IEEE Learning Object Metadata [7] records with some attributes that capture generic characteristics of an intended competence, like title, type, description, proficiency level and context.

Emphasizing the importance of aligning organisational level core competences with individual level job competence,

in competence management systems, [10] develop an integrative model of competence that incorporates a typology of competence-in-stock, competence-in-use, and competence-in-making.

Regarding competence standards and specifications, IEEE LTSC Reusable Competency Definitions [8] is a world-wide standard that defines a data model for describing, referencing and sharing competence definitions, primarily in the context of online and distributed learning. IEEE RCD specification has a rather narrow scope, focusing on representing the key characteristics of a learning outcomes, it offers technical and semantic interoperability and (to some extent) extensibility.

HR-XML [5] is a specification that includes the possibility of formalization and ranking of competences, supported by HR-XML Consortium. The specification is, among other things, used to capture information about evidence used to substantiate a competence, their ratings and weights and reusable data typed for referencing competences. Competence data elements of this schema are designed in order to be used in process-oriented environments and can be used to rate, measure, match and assess competence against one that is demanded, required (e.g., as a prerequisite, skill required to take training).

As far as e-portfolio data is concerned, Leap2A [9] sets up the framework for the e-portfolio data interoperability. The purpose of the Leap2A specification is to represent e-portfolio information collected by the individual (learner) and not the information stored by the others (institutions/teachers) about this individual.

More analysis of competences and learning outcomes related specifications is provided in [13].

III. ICOPER STANDARDS AND SPECIFICATIONS

As defined in ICOPER Reference Model (IRM), a shareable educational resource is an addressable object in a repository that is relevant in the context of learning and teaching. It is described via metadata and identifiable through an identifier. The three types of IRM educational resources that are covered in this paper are the following:

- (1) A Learning Outcome refers to statements of what a learner knows, understands and is able to do on completion of a Learning Opportunity. Learning Outcome Definitions (LOD) data model [12], is used to describe, store and reference the characteristics of learning outcomes.
- (2) A Learning Opportunity refers to a contextualized, complete, self-contained unit of education or training that implements a specific Learning Design in a particular physical or virtual location. Examples of Learning Opportunities are web-based learning modules, face-to-face learning opportunities, instantiations of study programs, etc. MLO-AD [11] is used in ICOPER to describe metadata about published Learning Opportunities.
- (3) A Personal Achievement Profile is a collection of Learner's Achievements. The ICOPER PALO [12]

model is used to describe, store and exchange learners personal achieved learning outcome data between systems.

In this paper, the focus is on the design and development of software prototypes, services and modules that integrate learning outcomes and learning opportunities specifications. In the coming sub-sections, we briefly present LOD, MLO and PALO specifications. Pilot implementation of those specifications is presented in Section IV. Learning Designs, which are reusable representation of a concrete learning opportunity and are instructional models that arranges teaching methods, assessment methods, learning content and learning tools towards learning outcome attainment, are discussed in [1].

1) Learning Outcome Definitions (LOD)

The Learning Outcome Definitions (LOD) data model defines a conceptual base schema for describing and sharing learning outcome definitions in the context of online and technology enhanced learning. The data model provides a way to capture the key characteristics (identifier, title, description and type) of a learning outcome, independently of its use in any particular context or target group (persons). This model should enable the storage, findability and exchange of learning outcomes across learning systems that deal with learning outcomes data. LOD extends IEEE RCD with one metadata element (learning outcome.type) and its associated values to capture whether a learning outcome refers to knowledge, skill or competence. The aim is to help distinguishing knowledge, skills and competence following the definitions of the European Qualification Framework (EQF) [2].

The technical XML binding schema (xsd) of LOD is available at www.icoper.org/schema/lodv1.0.

2) Metadata for Learning Opportunities (MLO)

CEN Metadata for Learning Opportunity [11] is a European specification that covers a wide range of information about learning opportunities including intended objectives (learning outcomes); to some extent.

The conceptual model of MLO is depicted in Fig. 1. The key concepts are defined as follows:

- *Learning Opportunity Provider*: An agent (person or organization) that provides learning opportunities.
- *Learning Opportunity Specification*: An abstract description of a learning opportunity, consisting of information that will be consistent across multiple instances of the learning opportunity.
- *Learning Opportunity Instance*: A single occurrence of a learning opportunity.

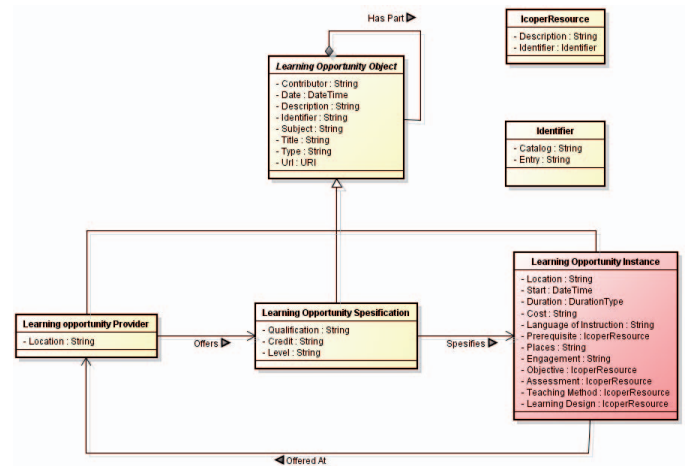


Fig. 1: ICOPER MLO Application profile data model.

As MLO records information about intended learning outcomes of an opportunity in free text format, this limits the interoperability and reuse of common learning outcome definitions across learning opportunities and curricula. Hence, some learning outcomes may be common between several learning opportunities of same program or across universities. Learning outcomes should be managed independently of learning opportunity metadata and be linked using a semantic web services; e.g., using a URI.

For this purpose, in ICOPER, we have extended the MLO Learning Opportunity Instance “objectives”, see Fig. 1, with a “learning outcome” sub-metadata metadata instance. In this way, the MLO objectives element can capture multiple learning outcomes for each learning opportunity instance that can be referenced using a URI. Hence, increase reusability of learning outcomes across learning opportunities.

The XML schema binding of MLO XML is available at <http://www.educanext.org/dotlrn/clubs/icoper/wp2/new-lors/MLO>.

3) Personal Achieved Learning Outcomes (PALO)

The Personal Achieved Learning Outcomes (PALO) data model is a simple schema proposed to capture information on knowledge, skills and competences achieved by a person (a learner), and the relations between those outcomes. Furthermore, information on the context where the learning outcomes are obtained or applied, evidence records (assessment), and levels (e.g. proficiency level) associated to the outcomes are also part of this schema.

One of the main challenges of communities and systems that deal with learning outcome information is the interoperability issue. Different communities and systems may use different data models to represent information on skills, knowledge or competence obtained by a person or that is required for a job or a task. The PALO specification is a step towards a common model supporting the exchange of such data, to enhance interoperability of personal learning outcome information between, for example, learning management systems, e-portfolios, social applications and recruitment systems.

The PALO data model, see Fig. 2, enables capturing the following information:

- Relations between achieved learning outcomes, regardless of the taxonomies or ontologies they belong to;
- Contextual information on where the achieved learning outcome is obtained or applied;
- Information about all types of evidence and assessment that prove the achievement of a learning outcome;
- Information about levels and ranking of an achieved learning outcome, like proficiency level.

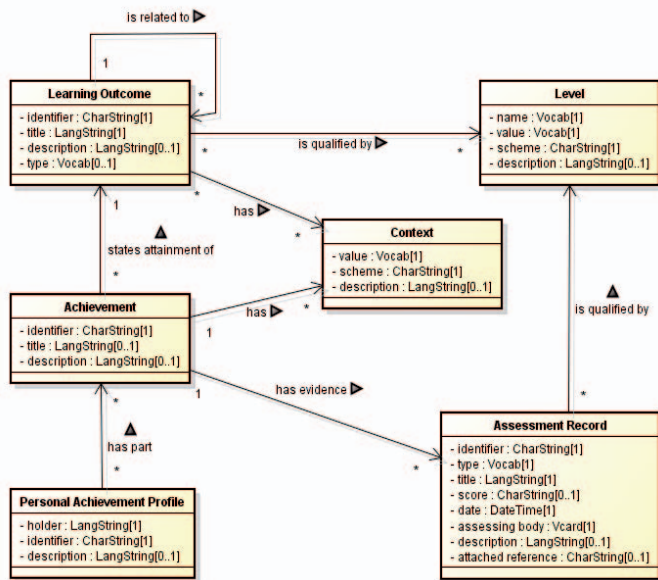


Fig. 2: The PALO data model.

The data collected in person's PALO profile can be used in different ways:

- They can be used in person specifications in the learning opportunity of recruitment.
- Individuals can claim to have attained them.
- Evidence can be assembled by or about individuals to support a claim to their attainment.
- They can be used by employers or professional bodies as the basis for review processes that tie in with career progression.
- This data can also be used for recommendation of relevant learning opportunities for the learner based on his achievements.
- This data can be used as part of a learner diploma supplement; European Learning Mobility (ELM) Diploma Supplement [3].

IV. PILOTS FOR ENGINEERING EDUCATION

Data about learning outcomes is attached to metadata records of learning opportunities and learning designs to enable

finding those educational resources based on their intended learning outcomes. Some selected prototypes developed in the ICOPER project, where learning outcomes are added to learning opportunities and learning designs, are introduced in this section.

A. Enriching Learning Opportunities with Learning Outcomes

The prototypical implementation in the eLearning .LRN platform Learn@WU aims at supporting WU Vienna in its effort to better align learning opportunity (course) delivery with what has been promised in the curriculum. Currently, one part of the general learning opportunity information relates to learning outcomes. However, editing support of this part of the learning opportunity information is very limited.

To overcome this drawback this prototype makes it possible for teachers to re-use learning outcomes from a curriculum-specific pool, described using the ICOPER Learning Outcome Definitions (LOD) schema, and to assign those learning outcomes to a learning opportunity, see Fig 3.

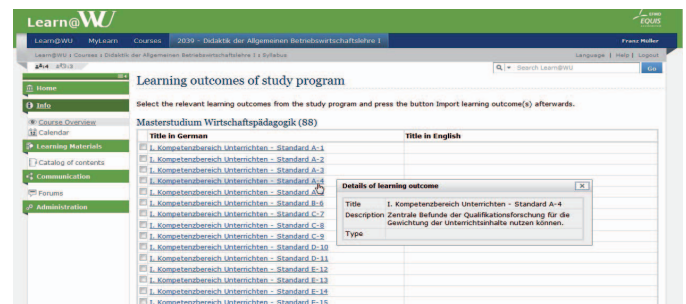
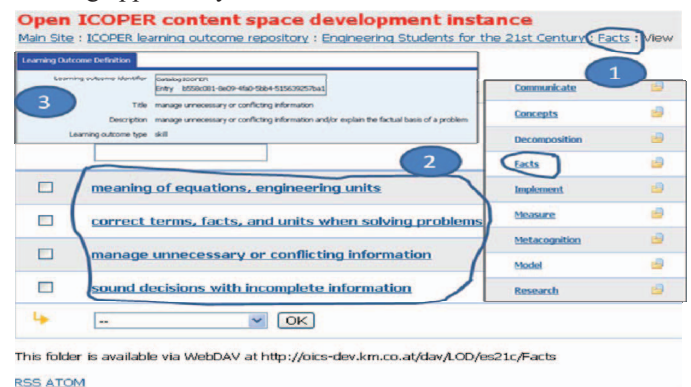


Fig 3: List of learning outcomes in a study program.

After assigning learning outcomes to a learning opportunity, the teacher has the possibility to change its title, description or type to make the learning outcome more suitable for his learning opportunity; nevertheless it is not recommended that teachers change definitions of learning outcomes to maintain a common practice and use of learning outcomes across learning opportunities, universities and workplace. In case teachers do not find relevant learning outcomes to their learning opportunities in the Open ICOPER Content Space (OICS) [16] learning outcome repository, in Fig. 4 they can create additional learning outcomes for each learning opportunity.



This folder is available via WebDAV at <http://oics-dev.km.co.at/dav/LOD/es21c/Facts>

BSS ATOM

Fig. 4: Mashed screenshots of OICS Learning Outcome Repository GUI.

Once the teacher has finished these tasks he can select the relevant learning outcomes and publish them to the learning opportunity description.

B. Outcome based finding of Learning Opportunities and Learning Designs

Search modules that enable searching and importing learning designs and learning opportunities based on their intended learning outcomes is implemented in several learning management systems. These modules use the metadata about learning outcomes represented in the LOD schema and that is linked to metadata of learning designs (described in IEEE LOM) and learning opportunities (MLO) during the design time.

For the purpose of this paper, we present the outcome based search module for Moodle. The purpose of this module is to enable teachers find relevant learning designs based on their intended learning outcomes; in addition to other attached metadata properties like title and description or subject. The search module lists learning designs that are relevant to a search query; like “reverse engineering”, see Fig. 5.

It is possible to filter the query by focusing the query matching to a specific portion of metadata for the given search string, like description of a learning outcome or title of learning design.



Fig. 5: Learning design outcome based search interface of Umea Moodle.

Once the user identified and selected his relevant learning design from the list, more detailed information about the learning design is provided to help the user to decide on the relevance of this learning design to him. Fig. 6 shows a screenshot of the details of a learning design after the user clicked on one of the items in the query results list. Data about learning outcomes, stored in the OICS repository, is represented in LOD schema at the technical binding of the

metadata instance and linked to LOM metadata record of the learning design using a URI. In this way, whenever metadata about a learning outcome is changed, these changes will affect, having up-to-date info, the metadata record of linked learning designs.

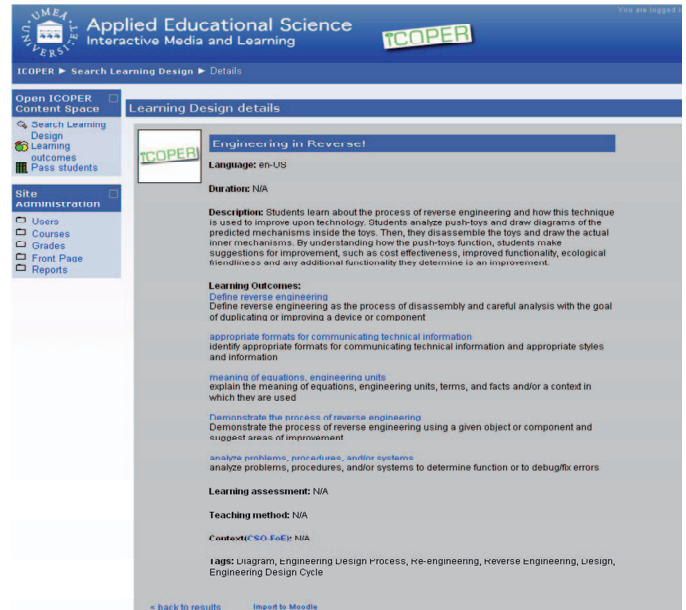


Fig. 6: Learning design detail display.

C. Tracking Personal Achieved Learning Outcomes

Tracking and management of learners’ achievements is a core focus of this section. Once the learning opportunity is successfully completed in the learning management systems and depending on the local policy (e.g. after explicit clearance is given by the teacher, the institution, and/or the student), the Personal Achieved Learning Outcomes (PALO) profile of the learner is updated in the OICS PALO repository.

This module, implemented as a Moodle block, takes care of the publication of the learners’ achievements. Once the learners completed a learning opportunity (explicit clearance is given by the teacher), the learners can update their PALO profile in the OICS PALO repository. After importing a learning design(s) to a learning opportunity, Moodle “knows” what outcomes are to be added to the PALO profiles of learners who pass the learning opportunity, see Fig. 7.



Fig. 7: Publish personal achievements in Moodle to OICS PALO repository.

These published achievements are also evidenced by an assessment record, which is an official record with a title, description, date, type and the university as the assessing body. The OICS- learner credentials needs to be provided to enable exporting the data to the relevant profile.

D. Recommendation of Learning Designs and Peers Based on Learning Outcomes

After the learning design is successfully imported into Moodle, several benefits of data collected in learners' PALO profiles can be exploited. The system can keep a PALO profile of intended learning outcomes of learning designs that are – or have been – taught by a particular teacher registered to Moodle. Based on such data, Moodle can recommend other teachers who have similar profiles of taught learning outcomes. This enables teachers to create practitioner communities around the learning outcomes they teach simply based on the intended learning outcomes linked to learning opportunities where they have a teacher role in Moodle; see (1) teacher recommendation widget in Fig. 8.

This OICS Teacher Recommendation Viewer widget follows the W3C Widget Specification and therefore the widget can be run in widget containers supporting this specification. We are using the Wookie Moodle plugin to include it in Moodle.

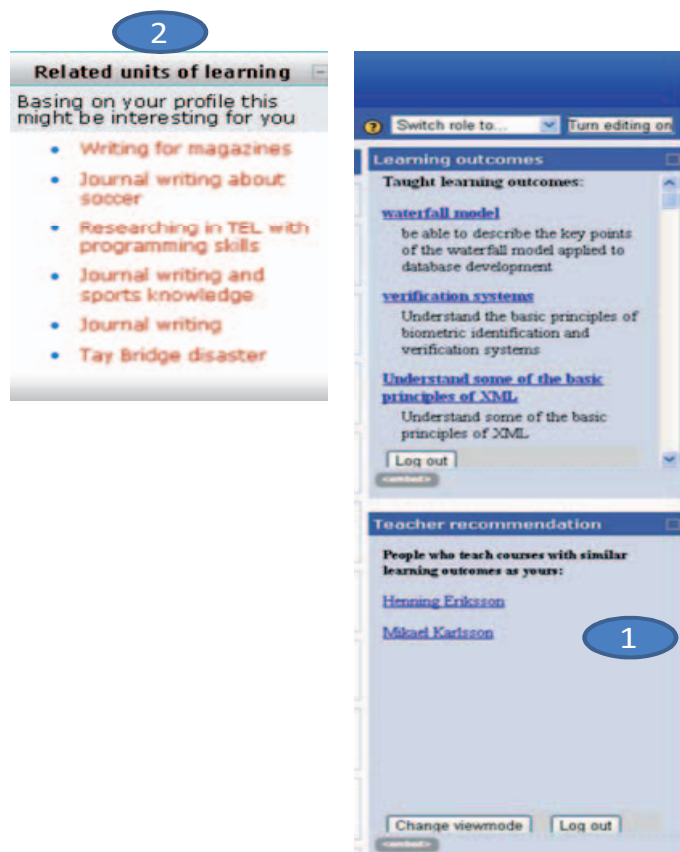


Fig. 8: Learning outcome and Teacher recommendation widgets.

The other type of recommendation approach is to recommend a learner other “similar” learners, e.g. who are currently working on achieving the same or similar outcomes; based on the intended outcomes of learning opportunities currently being attended, the and achieved learning outcomes already in the learner’s PALO profile. Additionally, Moodle can recommend learning designs which address the same learning outcomes as the ones attached to the learning design currently followed by the learner. In this way, learners can have access to additional resources during learning; see (2) in Fig. 8.

It is important to note that learners can only have access to their PALO profiles in OICS repositories via Moodle systems by providing their OICS credentials.

E. Sharing Learner Achieved Learning Outcomes

In order to increase the employability of learners, they would need to share and import their achieved learning outcome profiles into recruitment and social applications. This requires representing the data about these achievements and related evidence data in an interoperable and widely used format. For this purpose, an Atom XML binding of the PALO schema was defined. This binding is used to publish PALO profiles to third party applications like Facebook and iGoogle.

Facebook application that views PALO Atom feeds of learners’ outcomes is shown in Fig. 9.

The application retrieves user’s public PALO profile and displays it in an application in Facebook. More than one feed can be viewed and merged into this application; a user who is a learner and a teacher at same time may have two feeds, one for achieved learning outcomes and another one for taught outcomes.



Fig. 9: PALO data viewed in Facebook.

Thanks to use of the Atom syndication format of PALO, a PALO instance of a learner is viewed in an iGoogle application. In all applications, once users click on any of the view details of the learning outcomes, data will be retrieved from the OICS as shown in (3) Fig. 4.

V. EVALUATION

The prototype evaluation was carried out at different universities. The target user groups for the evaluation were programme managers, faculty members and learners. During the evaluation sessions, the testees were asked to carry out some predefined tasks using the prototypes and then they were invited to participate in an interview. All evaluation sessions were conducted from August to mid-September 2010. Following are the evaluation results.

A. *Enriching Learning Opportunities and Learning Designs with Learning Outcomes: Learn@WU Case*

Five (5) sessions were conducted for the Learn@WU evaluation with teachers of WU Vienna, Austria, and each lasted between 40 to 70 minutes.

The testees like the idea of supporting the work with learning outcomes with this software. On the one hand, it could help decide what should be achieved after one semester. On the other hand, it works as a quality assurance process for the following semesters and learning opportunities. The testees also express opinion that the prototype would help the teachers to see the learning outcomes of the program and therefore could get a feeling of what the students should be able to do after having completed the program.

Related to the importing of learning outcomes from the study programme functionality, the prototype would improve the current system as the learning outcomes could be imported from the program into the learning opportunity. Within a program it could be helpful for a teacher to see the learning outcomes of other learning opportunities. However, there are still drawbacks. In the current version, the teachers have to copy the program's learning outcomes from the website or another resource and paste them into their learning opportunities' descriptions. So, they would appreciate a functionality that allows importing learning outcomes from a repository. With such functionality, they would be more aware of the learning outcomes at the program's level and would also easily see how their learning opportunities contribute to the program. It could also be useful to have a personal pool for each teacher where he/she can save learning outcomes which are needed in several of his/her learning opportunities.

Related to the possibility of changing imported learning outcomes, as the learning outcomes of the program are described in a very broad way, it is helpful to change the title and description of each imported learning outcome to adapt it to the content of the learning opportunity. This would show the students how the learning opportunity contributes to the learning outcome of the program. A further way to show the contribution of the learning opportunity to the learning outcomes of the program would be the possibility to add further information to each imported learning outcome. However, this possibility would be a problem if no learning

opportunity contributed to a distinct learning outcome of the program. To overcome this problem, a third party should keep an overview of the relation between learning outcomes in a learning opportunity and learning outcomes in the program, perfectly with the help of a technical implementation. In addition, if the learning outcomes are changed very extensively, it may lead to a situation in which the programme manager may not know which learning opportunities address which learning outcomes of the programme. So, the program manager is the responsible person who decides whether the titles and descriptions of the imported learning outcomes should be changeable in the learning opportunity or not.

Concerning the creation of new learning outcomes in a learning opportunity, as the learning opportunity could address learning outcomes which are not defined in the curriculum, it is perceived as useful that the teacher could add new learning outcomes to the "pool" of the learning opportunity. In addition, it should be possible to sort the imported and added learning outcomes to determine a descending order concerning the importance. It is also useful that the prototype allows enough flexibility to define further learning outcomes.

For the implementation, there should be an alignment of the teaching with the announced learning outcomes in the learning opportunities. Therefore, the idea of learning outcomes must become manifest in the heads of the teachers. Otherwise, the problem could appear that the teachers just import or define some learning outcomes but don't address these in the learning opportunities. To minimise this problem, workshops and seminars should be offered, which address the outcome-oriented teaching and associated applications.

B. *Outcome based finding of Learning Opportunities and Learning Designs: Moodle Outcome Based Search Case*

Four (4) tests were carried out for the Moodle evaluation at Umeå University, Sweden. The testees believe that there would be lots of potentials in the prototype. Its features are believed to be innovative. The evaluation of the outcome based search feature shows that the testees, teachers, appreciate the possibility to find learning designs based on learning outcomes, but it also identifies lack of search options. It is suggested that it should be possible to search the OICS repository not only by free text search but also by selecting keywords (e.g. context and/or learning outcomes). Another suggested improvement is to implement instant search that shows results when typing. It would also be useful if the testee could find learning designs based on a set of categories and not having to solely rely on writing the right words in the search box. Interestingly, the testees indicate that the usefulness of the learning design search and import feature would heavily rely on the number of designs in the repository.

C. *Tracking Personal Achieved Learning Outcomes: UMU Learning Outcome Module*

The evaluation of the learning outcome view and export module identifies some problems, but they are related to the user interface and not to the core functionality of the module.

A certain level of knowledge about concepts used in the prototype is believed to be required. The concepts used, such as

learning design, are regarded as being highly relevant for the organisation. A successful implementation requires that teachers are aware of the concepts. Teacher training is suggested with support from best practice examples. The users also need a certain level of proficiency with ICT tools. Clear use cases showing usage and benefits could make the adoption process easier. If not properly introduced with good examples of usage and benefits, there is a risk (threat) that many teachers do not understand the purpose and therefore would not use the functionality. Another possible threat is that maybe neither teachers nor students understand how learning opportunities and its related learning outcomes can be used in the real context. If they understand, the prototype functionality will most likely be of benefit for the organisation. In addition, sharing, rating and recommending learning designs amongst colleagues may be an important factor for success.

The usefulness of the module is rated quite high, especially the learning outcome features from a student's perspective. However, one testee expresses opinion that it is a bit difficult to get a really good grip on how the tested functionality, tracking and export of achieved learning outcomes, could be used in real-life scenarios. A teacher should have the option to try the selected learning designs before using them with students. An increased exposure of learning outcomes for the student is a useful and important improvement. The possibility to expose learning outcomes for students in such a way as the prototype suggests would be highly relevant and useful. Such a possibility could help to improve both the structure of and the students' understanding of a learning opportunity and might also lead to an advantage in the competition from other universities. Teachers need to be able to edit imported learning designs to make them more appropriate for the given learning situation. Teachers need to preview the learning designs before the decision to import can be made.

D. Recommendation of Learning Designs and Peers based on Learning Outcomes

In four (4) evaluation sessions, at Umeå, the usefulness of the teacher recommendation widget and the view OICS learning outcomes widget is rated a bit lower compared to the learning outcome and outcome based search modules. The evaluation identifies some user interface related issues. Regarding the improvement to the core functionality of the teacher recommendation widget, see (1) in Fig. 8, it is suggested that it should be possible to trace the origin of a certain learning outcome to find the corresponding learning design and maybe even learning opportunities where the design is being used.

As far as learning design recommendation widget is concerned, see (2) in Fig. 8, two (2) evaluation tests were carried out at the Kaunas Technical University (KTU), Lithuania. Basically, the widget is seen to be quite easy to use and quite useful, especially the possibility of recommending the related learning designs. The prototype could recommend new relevant learning designs to include in the [testee's] learning opportunities. The testees consider that functionality innovative. Especially if the recommended content is useful and relevant, the teachers would use them in their teaching. However, the testees would like to get some specific

recommendations on some particular topics. It would also be great if the prototype could provide descriptions/explanation why it recommends that link or another link or content.

E. Sharing Learner Achieved Learning Outcomes

Ten (10) evaluation tests were carried out at AGH University, Poland, on the Personal Achieved Learning Outcome application. The application is considered innovative. One testee states that the concept is quite interesting as it nicely connects social software with education. In the same manner, there is a suggestion that the OICS should directly connect with social websites, so there is no need to create other tools. Also, the prototype should be integrated with more professional portals such as LinkedIn or GoldenLine in Poland. These websites are widely used by human resources offices. So, the employers can check what the students' achievements are. For some testees, from the end-user perspective, it looks simple, clear and nice. For some others, it is useful for people who work in education but for many people this will not be very useful because they don't work or learn in environments that support learning outcomes.

The most frequently discussed issue with the testees is the grouping of learning outcomes, i.e. the grouping should be allowed to collect similar types of learning outcomes. This functionality would be useful when users publish their different profiles on different social websites. Depending on the type of their e-portfolio they could share specific learning outcomes. The classification possibility would give them a flexibility of developing their portfolios.

The testees would like to find out the origin of some specific learning outcomes. This could help students gain knowledge about how such learning outcomes are achieved and what they would do to obtain it. One testee stated that if more learning opportunities were described with learning outcomes, the prototype would become very relevant. From the organisation's perspective, it may not be very useful because testees do not even work with learning outcomes. So, learning opportunity designers need to define and add the learning outcomes when designing learning opportunities.

The prototype is considered worth implementing. It could be helpful to develop standards at the universities for designing online learning opportunities in context of learning outcomes. It could be good that defining learning outcomes is one of the requirements while designing learning material. Privacy is an important issue that needs to be addressed. Further development is expected, including more options on how to manage and classify the outcomes.

VI. DISCUSSION AND RECOMMENDATIONS

Evaluation results show that different stakeholders in engineering education can benefit from the outcome based approach. Usage of the tools for the creation and management of learning outcome definitions and for the association of those outcomes to educational programs and courses results in more careful design and improve quality of the programs and courses in educational institutions. Teachers are able to design their courses around the intended learning outcomes more easily and enhance them with content, teaching methods and assessment

methods from other teachers. They are also able to find other teachers that teach courses with similar learning outcomes. Learners can find learning opportunities that best suit their intended learning outcomes. The Personal Achieved Learning Outcomes (PALO) profiles enable them to collect obtained learning outcomes over a long period of time and use them when continuing education, applying for a job, or getting national qualifications. Last but not least, relying parties, e.g. companies or recruitment agencies, are able to verify in the learners' profiles they have access to which learning outcomes certain individuals obtained in the past. This facilitates easier selection of prospective employees for certain positions or jobs.

Below, we formulate a few recommendations on how the stakeholders, in particular higher education institutions management, should implement outcome based education. The recommendations have been prepared on the basis of identifying good practices and user feedback during the evaluations described in the previous section and during other surveys, for example among the educational experts.

A. Formulation and Selection of Learning Outcomes

Teachers are free to formulate their own learning outcomes or choose them from a pool when creating a learning design or learning opportunity. Unfortunately, many teachers or learning facilitators still do not have any idea of how to formulate learning outcomes. Based on our experiences, the descriptions of learning outcomes often tend to be too generic to give meaningful or unambiguous information about knowledge, skills or competences a learner will obtain. A "too flexible" approach of defining learning outcomes of learning opportunities cannot lead to comparable learning opportunities/programs within or across universities either. Therefore, we recommend using learning outcomes that are common and agreed upon by a domain/subject interest group, national/international framework or university. Program managers should decide whether teachers are allowed to define new learning outcomes that do not belong to the common set of learning outcomes stored in the central repository of their university/program. Working in an international context, it is also important that descriptions of learning outcomes are provided in multiple languages.

B. Organization of Learning Outcomes and Learning Opportunities

A big picture of learning opportunities and their contribution to learning outcomes of a program is not provided in many universities. We recommend providing a matrix that shows the linkage between learning outcomes and learning opportunities of a program. This helps teachers and program managers understand which learning opportunities contribute to attainment of which learning outcome. Such matrix also enables program managers to identify gaps when a learning outcome is listed to be achieved by learners but not covered by any learning opportunity of the program. Also, at the learning opportunity level, such visualization of learning outcomes of learning opportunities helps a teacher understand which learning outcomes were addressed in the learning opportunity before and which learning outcomes will be addressed in the later learning opportunities. This approach helps making the

learning opportunity delivery more effective in the way that a learning outcome is not addressed multiple times.

Based on the feedback from testees it is important that the learning outcomes should also be organized in a way that allows browsing through the outcomes, not just searching in a large pool. The managers and teachers should be able to browse learning outcomes by program or learning opportunity they belong to.

C. Linking Learning Outcomes to Learning Designs, Learning Opportunities and Assessment

Educational institutions should support the teachers and learning facilitators by providing them with software tools for defining and linking learning outcomes with learning designs and learning opportunities. However, it should be noted that providing just a tool and access to a pool of learning outcomes is not enough. The institutions are also recommended to provide well defined procedure for linking learning outcomes to learning designs, opportunities and assessment that ensures the achievement of those learning outcomes after successful completion of learning activities.

As the same learning opportunity might be given to several groups of students by several teachers, we recommend that learning outcomes are first linked to learning designs of learning opportunities and then reused by teachers to make their own instantiation of those learning designs. A generic learning design can be implemented, whereas every teacher may add/adapt the learning outcomes and related assessment of his learning opportunity when appropriate.

D. Communicating Learning Outcomes of Learning Opportunities

Communicating learning outcomes to students who are the main target of the learning offerings is an important step towards transparent outcome based education. Learning outcomes should be made available for students in learning opportunity descriptions during the advertising phase of those offerings. This can help the students understand why they should follow the learning opportunity and what they would be able to know, understand and do after its completion. Students would also be able to provide valuable feedback on their achievements and quality of the learning opportunity afterwards. It would also help the teachers to find out to what quality level the learning outcomes were achieved. The students' feedback can in this way work as a tool for quality assurance.

E. Tools for Outcome based Learning

Several issues need to be addressed when implementing outcome based education. First, learning outcome software tools need to be easy to use. We recommend that new tools that allow teachers to find, link, use or assess learning outcomes are integrated and added as new functionalities into existing learning management systems, e.g. Moodle or dotLearn, that are really used. The teachers should not move to a new application to do the new outcome based education tasks and they should be spared from learning to work with a new

interface. This will decrease time to adopt the tools and new learning systems.

Key usability issue in educational environments that include numerous heterogeneous educational systems and tools is seamless access to those system, tools and resources. Teachers and learners require seamless access to the resources they are entitled to use, without a need to have a new username and password at each repository, tool or system. We recommend developing one single unified authentication system for all the tools that use personal achieved learning outcome data and other relevant systems in which those tools are integrated, such as social networks, LMSs, etc. This is the basis for enabling seamless access whenever and wherever needed.

Information about achieved learning outcomes is stored in learners' personal profiles and can be considered as privacy sensitive information. We recommend that tools should enable learners to decide if they want to share data about the achieved learning outcomes.

F. Training

Training activities are an important mean to achieve quicker adoption and better quality of outcome based education. We recommend providing teachers with training on how they design outcome based learning opportunities and learning designs using outcome based aware tools. This includes defining and linking learning outcomes to learning opportunities, learning designs, teaching methods and assessment. Furthermore, it includes training on the terminology used and best practice examples.

VII. CONCLUSIONS AND FUTURE DIRECTIONS

In this paper we have presented concepts and solutions evaluated in real educational environments that enable outcome based engineering education. In order for outcome based education to be widely adopted by educational institutions, some future research work and actions are still needed from the institutions themselves, technology providers, research community, policy makers, and standardization bodies, for example:

- Increasing availability of detailed descriptions of learning opportunities by higher educational institutions;
- Creating a unified framework for meaningful (semantic) comparison of achieved learning outcomes, qualifications, and job descriptions;
- Investigating trust issues related to recognition of achieved learning outcomes, e.g. how to verify authenticity of assessment records or how to verify assessment bodies that issued assessment records and trust them that they really assessed achievements;
- Improving outcome based search for learning designs, learning opportunities and assessments with mechanisms that go beyond keywords search.

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