An Ontological Model for Assessment Analytics

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Abstract: Today, there is a growing interest in data and analytics in the learning environment resulting in a highly qualified research concerning models, methods, tools, technologies and analytics. This research area is referred to as learning analytics. Metadata becomes an important item in an e-learning system, many learning analytics models are currently developed. They use metadata to tag learning materials, learning resources and learning activities. In this paper, we firstly give a detailed injection of the existing learning analytics models in the literature. We particularly observed that there is a lack of models dedicated to conceive and analyze the assessment data. That is why our objective in this paper is to propose an assessment analytics model inspired by the Experience API data model. Hence, an assessment analytics ontology model is developed supporting the analytics of assessment data by tracking the assessment activities, assessment result and assessment context of the learner.

1 INTRODUCTION

Learning analytics (LA) analyses the educational data derived from student interaction with the learning environment such as LMS (Learning Management System) and MOOC (Massive Open Online Courses) who generate large amounts of data (Big Data). In the literature, many definitions have been proposed for the term learning analytics. For example, according to (Siemens., 2011) learning analytics is the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding as well as optimizing learning and the environments in which it occurs. The majority of learning analytics definitions share a particular emphasis on converting educational data into useful actions to improve the learning processes (Lukarov et al., 2014).

Learning modeling is a key task in the emerging research areas of learning analytics (LA). A learner model represents information about a learner's characteristics, states and activities, such as knowledge, motivation and attitudes. In this research work, we investigate the existing learning analytics models by specifying some of their characteristics. In fact, these models focus essentially on modeling learning data (traces). However learning environments generate different types of educational data. Indeed, beyond the learning data there is assessment data and communication data, etc. Assessment is one of the major steps in the learning process. In addition, assessment traces must be well conceived in the same way as the learning traces, to build a flexible and correct assessment model that can support the analytic of assessment data. Our research questions can be summarized in two major questions:

- How can we model assessment data to build a flexible assessment analytics model?
- What are the different assessment data that can be conceived to build our assessment analytics model?

This paper is structured as follows: in section 2 we identify the most well known learning analytics models by detailing some of their features. In section 3 we explore the assessment analytics concept. In section 4 we present our assessment analytics scenario and its analysis and requirements then, we describe the assessment analytics process. Finally, in section 5 and 6, we propose more details and we describe semantically our proposed ontological data model for assessment analytics.

2 RELATED WORK

Actually there are various formats of data representation for usage data and they focus on the

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user's activities. The user activities and their usage of learning data objects in the different learning environment are called usage metadata. Indeed different models are proposed by researchers to characterize usage data across learning systems. Based on this data representation via models, learning analytics can realize different analysis and provide personalized and meaningful information to improve the learning process. (Niemann et al., 2012; Lukarov et al., 2014) present in their work the most commonly used data models representations such a CAM (Contextualized Attention Metadata) (Schmitz et al., 2012), Activity Streams (J. Snell, M. Atkins, W. Norris, C. Messina, M. Wilkinson, and R. Dolin., 2015), Learning Registry Paradata (Paradata specification., 2011) and NSDL Paradata (NSDL's TSPE., 2012).

2.1 CAM (Contextualized Attention Metadata)

The CAM Model (Schmitz et al., 2012) allows people to control the user interactions with the learning environments. This model focuses on the event itself rather than on the user or data object. So many attributes are assigned for each event such as its id, the event type, the timestamp, and a sharing level reference. Each entity and also each session can be described in a different and suitable way and no information is duplicated. Each event can be conducted in a session. The information can be stored with different formats such XML, RDF, JSON or in a relational database. In the literature we found various researches concerning CAM. (Najjar et al., 2006) discuss how CAM enables the collection of rich usage to enhance user's models, predict usage patterns and feed personalization. (Ochoa and Duval., 2006) provide a study showing how CAM can be used to rank and recommend learning objects. (Wolpers et al., 2007) propose a CAM framework that is able to capture the observations about the user activities with digital content from different applications such as web browser, multimedia player, LMS etc.

2.2 Activity Streams

Activity Streams (Snell et al., 2015) is a data format for encoding and transferring activity/event metadata published in 2011. An Activity Stream is a collection of one or more individual activities carried out by users. Each activity comprises a certain number of attributes such as verbs, ids and contents. An activity has three properties e.g. the actor, the object, and the target. Many social networks like facebook actually use Activity Streams to store and manage user's activities. Some learner management systems (e.g. Canvas) are also starting to develop analytics tools to generate activity stream profiles for learners and teachers.

2.3 Learning Registry Paradata

Learning Registry Paradata (Paradata specification., 2011) is an extended or modified version of Activity Streams for storing aggregated usage information about resources such as description, measure, and date. The three main elements of Learning Registry Paradata are actor, verb, and object. The verb refers to a learning action and detailed information can be stored. It's important here to clear the difference between metadata and paradata. Metadata describes what a resource is, while paradata records how the resource is being used. The learning registry is a metadata agnostic. This means that it adds the paradata about resource which is used, reused, adapted, contextualized, tweeted, shared, etc. Paradata complements metadata by providing an additional layer of contextual information.

2.4 Learning Context Data Model with Interest

The Learning Context Data Model with interest (LCDM) (Thus et al., 2015). It mainly describes the learner's activities and the characteristics of the learning environment. The learning context data model is based on CAM representation. According to (Thus et al., 2015) this data model considers two points: the first one is to take into account which type of learning activities that should be filtered and the second point is how to mountain the semantic of context information. The interest extension of LCDM takes into account the weights of the interests as well as their evolution over time. The authors follow an iterative approach to develop a new version of LCDM which satisfies specific interest because context and interests represent important features in the lifelong learner model.

2.5 The Experience API (xAPI)

xAPI called also Tin Can API is developed by Advanced Distributed Learning Initiative (ADL) (Experience API Working Group, 2013), and is aimed at defining a data model for logging data about students' learning paths (Kelly and Thorn., 2013). The xAPI presents a flexible data model for logging data about the learner experience and performance. The xAPI specification is suitable with the learning analytics purpose, since it tracks and stores the experience and the performance of the learner (learning traces).

The xAPI specification is based on two main parts. The first part is the format of learning activity statement and the second part is the Learning Record Store (LRS). LRS is the element responsible for storage and exchange of learning activities traces presented as activities statements. The activity statement is a key part of the xAPI data model. All learning activities are stored as statements such as: "I did this" of the form actor, verb and object and it can be extended with some optional properties like result and context.

The xAPI specification is flexible. Hence among web-based formal learning, xAPI is capable of tracking informal learning, social learning, and real world experiences. A wealth of examples related to the learning activities that can be tracked include reading an article, watching a training video or having a conversation with a mentor. As a result the LRS stores various statements concerning content view, video consumption and assessment result. As a result, it is possible to access and query the data stored in Learning Record Store (LRS) and therefore we could provide different services such as statistical service, reporting service, assessment service and semantic analysis.

In the literature xAPI has been widely implemented. Hence, we found a several research works related to learning analytics using xAPI. For instance (Kitto et al., 2015) present a solution for Learning Analytics beyond the LMS which is the Connected Learning Analytics (CLA) toolkit, which enables data to be extracted from social media such as Google+, Twitter, Facebook, etc and imported into a Learning Record Store (LRS), the way it is defined by the new xAPI standard. Many other works also can be founded in (Brouns et al., 2014), (Corbi and Burgos, 2014), (Del Blanco et al, 2013).

All data models mentioned above are learning analytics centric. That is to say that they focus on how to present well and to conceive learning activities, users and data objects. These models will be used for analytical purpose to improve the quality of the learning process. However learning environments generate different types of educational data. Among them there is assessment data and communication data, etc. Assessment is one of the major steps in the learning process. In addition, assessment data must be tracked as well and processed

According to our research, there is a lack of models that focus on assessment analytics, that is to say, a model which is interested in assessment data. The only learning analytics data model which is previously detailed and which can support analyzing assessment data is the TIN CAN API (xAPI) since it contains an optional property in its sentence format named result that records information about assessment result. But xAPI is presented as an e-learning standard for tracking data interoperability in the whole learning process and does not focus particularly on assessment. Besides, during our research we did not found any paper that focuses on tracking assessment data with xAPI specification. Is this due to the weakness of xAPI standard in tracking assessment data? When we investigate the result property which is an optional property, we noticed that is described with different metadata that can record information about the assessment result such as the score, the success, the completion the duration and the response. All these assessment results are very important, but according to our point of view, these results are insufficient and need to be extended and annotated to ensure a several assessment result tracked that can help later for assessment analytics. The investigation of the context property of the xAPI data model leads as to deduce that the context metadata of xAPI data model are not related to assessment context. In fact, all of them represent information about the context of learning activity such as the instructor and the team that the statement is related to, the platform used, the language of the statement recorded, etc. Any information is recorded about the context of assessment such as the type of assessment, the form of assessment and the technique of assessment.

Our contribution is based on the weakness of the existing xAPI data model dedicated to assessment data summarized into two major points:

- Insufficiency of information dedicated to the track of the assessment result.
- Lack of information dedicated to the assessment context.

3 ASSESSMENT ANALYTICS

One of the most important steps in the learning process is assessment; a successful learning environment must provide effective assessment of learners. Assessment is both ubiquitous and very meaningful as far as students and teachers are concerned (Ellis., 2013). Actually the new learning environments such as MOOCs generate big assessment data (Big Data) given the massive number of courses proposed and the great number of learners enrolled. These assessment data must be processed and analyzed too.

When we focus on assessment data that means, we study the assessment activities and the assessment result left by learners, we can launch a new source of data that can be analyzed and give new and different indicators to be interpreted and hence contribute to the improvement of the field of learning analytics. This research area is called assessment analytics. According to (Ellis., 2013) The role that assessment analytics could play in the learning process is significant. Yet it is underdeveloped and underexplored. Assessment analytics has the potential to make valuable contribution to the field of learning analytics by extending its scope and increasing its usefulness.

The assessment analytics is the analytics of assessment data within learning analytics strategy. (Cooper., 2015) offers an assessment analytics definition, which is based on the learning analytics definition of (Siemens., 2011) with a little modification: assessment analytics is the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments from which the data derives assessment. This open research area and development topic is addressed by this paper in order to propose an assessment analytics model.

4 ASSESSMENT ANALYTICS SCENARIO

4.1 Assessment Analytics Scenario Description

This section illustrates the context of our research using a use case scenario that includes an assessment analytics scenario. Let's consider the following situation:

Peter is very passionate of computer sciences, so he decides to register in a MOOC environment for studying a course on object oriented modeling. After the sign stage, Peter can start the learning process. A set of different learning activities are made by Peter when he starts interaction with the learning content such as watching course video, reading texts, commenting etc. Then Peter is invited to start the stage of assessment (formative assessment, summative assessment or it can be also diagnostic assessment and in this case it will be done before the learning step). Hence a set of assessment activities are triggered such as answering, completing, failing and scoring during the interaction with quizzes or MCQ (multiple choice question). The MOOC environment that Peter uses must keep track about every activity done by this learner including the learning activities and the assessment activities.

In our case we will focus only on the assessment data that are particularly the assessment activities and the assessment results left by Peter. Assessment data will be conceived and analyzed properly using analytics strategy, then interpreted for improving the quality of the learning process and identifying the opportunities for feedbacks, interventions, adaptations, recommendation, personalization, etc.

4.2 Assessment Analytics Scenario Analysis

According to the above scenario, we can identify the following challenges.

We suppose here that the learning standard chosen for tracking data interoperability is xAPI, hence all learning and assessment activities are stored in the LRS (Learning record store).

Since our objective here is to analyze the assessment activities, we will focus only on the set of assessment activities stored in the LRS.

Now here is an example of a set of an assessment activities stored in the LRS of the learner Peter:

1. Peter attempted quiz_1
2. Peter completed the quiz_1 with a passing score 75%
3. Peter passed the quiz_1
4. Peter completed the quiz_1 with completion false
5. Peter completed the quiz_1 in 6 minutes
6. Peter attempted quiz_2
7. Peter completed the quiz _2 with a passing score 15%
8. Peter failed the quiz_2
9. Peter attempted quiz_2
10. …

To ensure a consistent assessment analytics engine, it is necessary to track and manage a set of metadata in relation with assessment activities and results, the tracked assessment result by the xAPI specification seems to be insufficient and need to be more annotated. Besides the assessment activities and the assessment result it's necessary to track and manage also the assessment context data such as: the assessment types, forms and techniques, the assessment environment and session. Here is an example of the metadata values corresponding to the different assessment analytics that can be recorded by the specification of our proposed assessment analytics model:

Environment: MOOC
Assessment Form: Automated Assessment
Assessment Type: Formative Assessment
Assessment Technique: Closed question format: MCQ
Session: The date and the hour of the logging.
ID: a unique number given to each assessment activity

All these assessment data must be conceived in an appropriate format supporting analytics in such a way that it can help providing users with efficient personalization and adaptation services. An important question can be posed now, how can we conceive assessment data to build a correct and complete assessment analytics model?

5 ONTOLOGICAL MODEL FOR ASSESSMENT ANALYTICS

Our objective in this section is to propose an assessment analytics model dedicated to conceive assessment data such as assessment activity, assessment result and assessment context. This model will be inspired from xAPI data model specification. In this section, we propose an assessment analytics model based on the data derived from assessment. This model allows people to control user interaction with assessment resources. More precisely we will focus only on assessment data. According to (Moody., 1998) there are eight general requirements which describe data models. These are: completeness, correctness, integrity, flexibility, understandability, simplicity, integration and implementability.

To ensure a consistent representation of our proposed model for assessment analytics, it will be interesting to develop an ontological model for assessment analytics considering the several advantages given by the use of ontologies like improving reusability and interoperability, aggregation of the scattered data in the web, permitting inferences and contribute coherence and consistency rules. The proposed model is called assessment analytics ontology (AAO). In order to develop our ontology, we follow the most important steps detailed in (Noy and McGuiness., 2005), the first step is to enumerate the most important terms in our ontology through specification of classes such as: assessment type, assessment statement, etc. Then it's necessary to define the classes and the class hierarchy. After that, we need to define the class properties and attributes and finally determine the facets of attributes. To develop our AAO model, several tools are available and can be used such as SWOOP, Protégé and WebOnto. In our case, we used Protégé that offers a simple, complete and expressive graphical formalism. It also facilitates the design activity. All the figures below are designed with VOWL (Lohmann and al., 2014) plug-in, which can be integrated very easily to protégé and used to represent graphically the different types of properties such as object properties, data type properties and subclasses relations. Figure 2 below shows a graphical representation of our assessment analytics ontology with the tool Protégé.

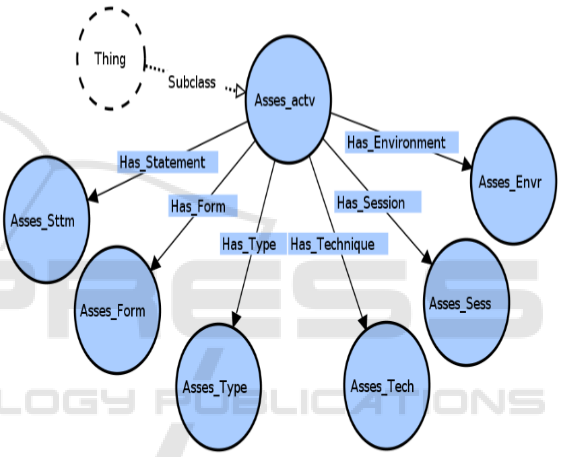

Figure 1: Graphical representation of assessment analytics ontological model.

The developed ontology gives us the opportunity to model the main concepts of our assessment analytics model in terms of its classes and its hierarchy. The main class of our assessment analytics ontology is the assessment activity class. This class is linked with has-a relations to a set of classes describing the assessment activity context metadata and the assessment activities. For instance, we cite the assessment environment class and his possible instances such as MOOC (Massive Open Online courses), LMS (Learning Management system) or PLE (Personal Learning Environment). Technically, it can be described by using the element of enumeration OWL:one Of.

```
<owl:class rdf: id = “Asses_Envr”
  <owl:oneOf rdf:parseType="Collection">
    <owl:Thing rdf:about="#MOOC"/>
    <owl:Thing rdf:about="#LMS"/>
    <owl:Thing rdf:about="#PLE"/>
```

```
</oneOf>
```

The second class is the assessment session class that contains information about the assessment session such as activity id and the date of logging as datatype properties. It serves to ensure that no information is duplicated.

Also we have the assessment technique class and his possible instances such as MCQ (Multiple Choice Question), MRQ (Multiple Response Question), T/F (True or False question) and Fill in Blanks question.

```
<owl:class rdf: id = “Asses_Tech”
   <owl:oneOf rdf:parseType="Collection">
    <owl:Thing rdf:about="#MCQ"/>
    <owl:Thing rdf:about="#MRQ"/>
    <owl:Thing rdf:about="#T/F"/>
    <owl:Thing rdf:about="#Fill in Blanks"/>
   </oneOf>
```

The third class is the assessment form class and its three possible instances: thediagnostic assessment, the formative assessment or the summative assessment.

```
<owl:class rdf: id = “Asses_Form”
   <owl:oneOf rdf:parseType="Collection">
    <owl:Thing rdf:about="#Diagnostic"/>
    <owl:Thing rdf:about="#Formative"/>
    <owl:Thing rdf:about="#Summative"/>
   </oneOf>
```

Then, we have the assessment type class that may consist of automated assessment, self assessment or peer assessment.

```
<owl:class rdf: id = “Asses_Type”
   <owl:oneOf rdf:parseType="Collection">
    <owl:Thing rdf:about="#Automated"/>
    <owl:Thing rdf:about="#Peer assessment"/>
    <owl:Thing rdf:about="#Self assessment"/>
   </oneOf>
```

It’s important to mention that all the instances of the classes cited above have exactly one value for a particular property such as has_Environment, has_session, has_form, has_type and has_technique. Technically, we can use the cardinality constraint owl:cardinality.

```
<owl:Restriction>
  <owl:onProperty rdf:resource="#Has_Form" />
  <owl:cardinality rdf:datatype = "&xsd;nonNegativeInteger">1</owl:cardinality>
</owl:Restriction>
```

All these metadata are very helpful for enriching our assessment analytics model. They are useful later in the stage of analytics.

Finally, we have the most important class and the core of our ontological model which is the assessment statement class used to represent the assessment experience of the learner. The assessment statement class of the proposed ontology is able to capture and formulate sentences of the form: Peter completed the quiz with a passing score of 80%, Jane completed the quiz in 10 minutes, and Daniel failed the quiz with 20%. This leads us to conclude that each assessment activity has at least one or more assessment statements.

```
<owl:Restriction>
  <owl:onProperty rdf:resource="#Has_Statement" />
  <owl:minCardinality rdf:datatype = "&xsd;nonNegativeInteger">1</owl:minCardinality> </owl:Restriction>
```

In the next section, we will focus on describing in details the different properties and data type properties of the assessment statement class of our proposed ontological assessment analytics model.

6 SEMANTIC DESCRIPTION OF THE ONTOLOGICAL ASSESSMENT ANALYTICS MODEL (OAA)

In this section we will present the semantic description of some classes of our ontological model for assessment analytics.

6.1 Assessment Statement Class

From figure 3 below, we can observe that the assessment statements have 4 required properties conform to its format such as Peter failed the quiz with 20%. From this example we can extract four properties: the verb, the actor, the object and the result. Let us began with the first property which is the actor property that refers to whom? e.g., Peter that means the learner in our context. The second one is the verb property which is a key part of an assessment analytics sentence; it describes the action performed by the learner when he interacts with an assessment resource. As examples of assessment verbs we may cite: answered, completed, and scored.

The third property is the object that form the third part of the statement, which refers to what was experienced in the action defined by the verb e.g. the quiz. And finally we have one of the most important properties of the assessment analytics engine which is the result property, that record information about assessment result such as score, completion and duration. Besides we can annotate the assessment statement class more thoroughly by some data properties like the record time of the assessment statement in the LRS (Learning Record Store).

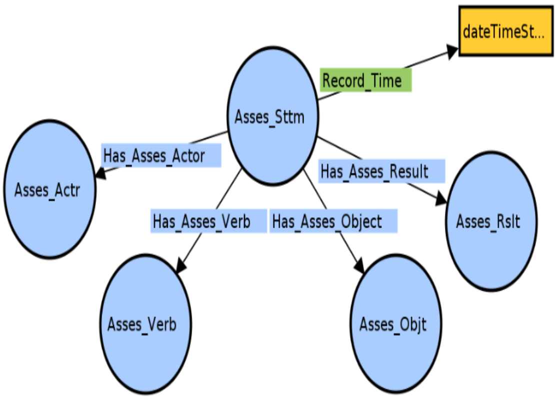

Figure 2: The semantic description of the assessment statement model.

6.1.1 Semantic Network of Agent Model

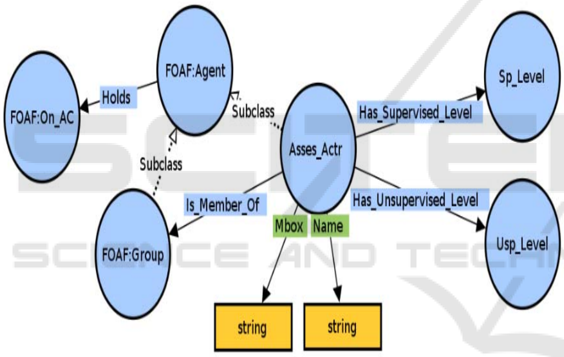

Figure 3: The semantic description of the actor model.

As described in the figure 4, the assessment actor class is described by using some classes of FOAF ontology (Brickley and Miller., 2014) which is an ontology describing individuals, their activities and relations with other people to define agent and group. Hence the assessment actor is a subclass of FOAF:Agent and is a member of FOAF:Group which is also a subclass of FOAF:Agent. Each assessment actor holds an online account which represents the provision of some form of online service. Each assessment actor has two different type of levels, the second one is the unsupervised level which is the level of the learner before starting the assessment process and the second one is the supervised level which is the real and the concrete level of the learner related to his performance in the assessment process identified automatically by analyzing the assessment traces of the learner.

6.1.2 Semantic Network of Verb Model

The verb class describes the action performed during the learning experience and more specifically in the assessment experience. Figure 5 below, shows that the verb class is described by 2 attributes. The first one is the language of the verb and the second one is the value of the verb. The assessment verb is an important class of this model. Its possible instances are the verbs related to the assessment experience like scored, failed and passed.

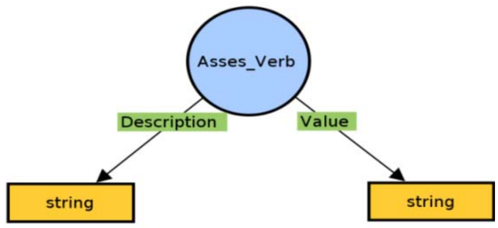

Figure 4: The semantic description of the verb model.

6.1.3 Semantic Description of Assessment Object Model

The assessment object can be annotated and described through using the standards LOM (Learning Object Metadata) (IEEE Learning Technology Standards Committee,. 2002) and Dublin Core (The Dublin Core Metadata Initiative., 2001) and can be described more thoroughly by some other attributes like the coefficient , the module and the level of difficulty of each assessment object.

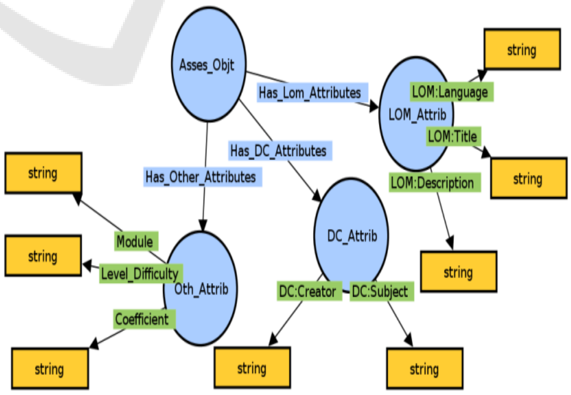

Figure 5: The semantic description of the assessment object model.

6.1.4 Semantic Description of the Assessment Result Model

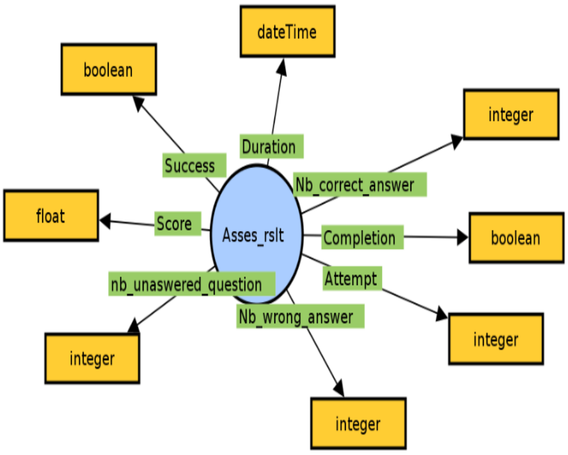

Figure 6: The semantic description of the assessment result model.

The assessment result class is one of the main classes in our assessment analytics models since it contains a several datatype properties that records information about assessment results such as score, completion, duration, success inspired from the xAPI specification and others assessment result metadata proposed such as the attempt, number of correct answer, number of wrong answer and number of unanswered question. This is particularly helpful for future assessment analytics. The assessment result class should be described with a rich metadata. These bits of information are important and we should record and use them since our objective is to conceive a complete, correct and flexible assessment analytics models. These attributes can be very helpful later in the stage of analytics.

The design of our AAO model brings some advantages for future use. For instance, one of the most important advantages of using ontology resides in its structure that is consistent with the logic description and its coupling with the inference engines allowing expert system to deduce logical reasoning and conclusions. In our case, the AAO model can be a consistent model supporting the assessment analytics purpose by deducing logical reasoning and conclusions about the assessment activities, result and context of each learner.

7 CONCLUSION AND FUTURE WORK

According to (Lukarov et al., 2014) learning analytics can perform different analysis and provide personalized and meaningful information to improve the learning and teaching process. In this paper, we presented a detailed presentation of the set of learning analytics models existing in the literature. The existing learning analytics models focus essentially on learning data, according to our research there is a remarkable lack of models that focus on assessment data. That means a model that is interested in data derived from assessment. That is why we tried to propose an ontological assessment analytics model (AAO) inspired by the Experience API data model. This model focus essentially on assessment data, meaning that it tracks the assessment activities of the learner, then tries to conceive them in a flexible and consistent way and finally store them in a specific module for assessment data storage to be later accessed for analytics purposes.

Concerning our further work we will try to extend our ontology with additional metadata and hence capture the semantic description to deduce logical reasoning and conclusions for assessment analytics.

REFERENCES

Brickley, D. and L. Miller (2014). FOAF Vocabulary Specification 0.99.

Brouns, F., Tammets, K., and Padrón-Nápoles, C. L. (2014). How can the EMMA approach to learning analytics improve employability?.

Corbi, A., and Burgos, D. (2014). Review of Current Student-Monitoring Techniques used in eLearning-Focused recommender Systems and Learning analytics. The Experience API & LIME model Case Study. *IJIMAI*, 2(7), 44-52.

Cooper, A. (2015). Assessment Analytics. In *Eunis E-learning task force workshop*.

Del Blanco, Á., Serrano, Á., Freire, M., Martínez-Ortiz, I., and Fernández-Manjón, B. (2013). E-Learning standards and learning analytics. Can data collection be improved by using standard data models?. In *Global Engineering Education Conference (EDUCON), 2013 IEEE (pp. 1255-1261). IEEE.*

Ellis, C. (2013). Broadening the scope and increasing the usefulness of learning analytics: The case for assessment analytics. *British Journal of Educational Technology*, 44, 4, 662-664.

Experience API Working Group (2013). *Experience API. Version 1.0.1.*

IEEE Learning Technology Standards Committee (2002).

Draft standard for learning object.

J. Snell, M. Atkins, W. Norris, C. Messina, M. Wilkinson, and R. Dolin (2015). Activity streams 2.0 w3c working draft. W3C Working Draft, W3C. http://www.w3.org/TR/2015/WD-activitystreamscore/

Kelly, D. and Thorn, K. (2013). Should Instructional Designers care about the Tin Can API? In *eLearn*, 3, 1.

Kitto, K., Cross, S., Waters, Z., and Lupton, M. (2015). Learning analytics beyond the LMS: the connected learning analytics toolkit. In *Proceedings of the Fifth International Conference on Learning Analytics And Knowledge* (pp. 11-15). ACM.

Lohmann, S., Negru, S., and Bold, D. (2014). The ProtégéVOWL plugin: ontology visualization for everyone. In *European Semantic Web Conference,* 395-400. Springer.

Lukarov, V., Chatti, M. A., Thus, H., Kia, F.S., Muslim, A., Greven, C., and Schroeder, U. (2014).Data Models in Learning Analytics. In *DeLFI Workshops* 88-95.

Moody, D. L. (1998). Metrics for evaluating the quality of entity relationship models. In *International Conference on Conceptual Modeling*, 211-225.

Niemann, K., Scheffel, M., and Wolpers, M. (2012). An overview of usage data formats for recommendations in TEL. In *2 nd Workshop on Recommender Systems for Technology Enhanced Learning*, 95.

NSDL's Technical Schema for Paradata Exchange. (2011). Retrieved from http://nsdlnetwork.org/stemexchange/paradata/schema.

Noy, N. F. and McGuinness, D. L. (2005). Développement d'une ontologie 101: Guide pour la création de votre première ontologie. Université de Stanford. Rapport technique.

Ochoa, X. and Duval, E. (2006). Use of contextualized attention metadata for ranking and recommending learning objects. In *Proceedings of the 1st international workshop on Contextualized attention metadata: collecting, managing and exploiting of rich usage information*, 9-16.

Paradata Specification. v1.0, (2011). Retrieved from https://docs.google.com/document/d/1IrOYXd3S0FUwNozaEG5tM7Ki4_AZPrBn-pbyVUz-Bh0/edit?hl=en_US.

Schmitz, H. C., Wolpers, M., Kirschenmann, U., and Niemann, K. (2012). Contextualized Attention Metadata'. *Human Attention in Digital Environments*, 186-209.

Siemens, G. (2011). What Are Learning Analytics? In *1st international conference on Learning Analytics and Knowledge.* 2015.

The Dublin Core Metadata Initiative. (2001) DC-Library Application Profile, Dublin Core.

Thus, H, Chatti, M.A, Brandt, R., and Schroeder, U. (2015) Evolution of Interests in the Learning Context Data Model. In *Design for Teaching and Learning in a Networked World*. Springer.

Wolpers, M., Najjar, J., Verbert, K., and Duval, E. (2007). Tracking actual usage: the attention metadata approach. *Educational Technology & Society,* 10, 3, 106-121.