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TRACKING LEARNING EXPERIENCES WITH XAPI

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TIIVISTELMÄ

Valtteri Väkevä: Oppimiskokemusten seuranta xAPI:n avulla
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Digitalisoituvan yhteiskunnan myötä myös koulutussektori on jatkuvien muutosten alla. Erityisesti viime vuosien aikana valtava määrä oppilaitoksia on – joko omasta aloitteesta tai pakon edessä – adaptoinut e-oppimisen kiinteäksi osaksi opetusta, mikä on näkynyt oppimisympäristöjen kehityksenä muodollisista ja staattisista ympäristöistä monipuolisempiin ja vaihtelevimpiin rakenteisiin, joissa opiskelijoilla on mahdollisuus kehittää omaa tietotaitoaan ajasta ja paikasta joustavin menetelmin. Analytiikan näkökulmasta tämä on avannut mahdollisuuksia kerätä yhä enemmän oppimiseen ja opiskelijoihin liittyvää dataa ja sitä kautta ymmärtää oppimista syvällisemmin. Tämä vaatii kuitenkin tiettyä joustavuutta ja yhteentoimivuutta järjestelmien ja sovellusten välillä, jotta erilaisia e-oppimisen sisältöjä voidaan seurata, tallettaa ja raportoida tehokkaasti. Monet nykyisistä e-oppimisstandardeista ovat kuitenkin verrattain jäykkiä ja tehottomia tarjoamaan mahdollisuuksia oppimistapahtumien online/offline seurantaan ja tallentamiseen LMS järjestelmien ulkopuolella sekä huomioimaan verrattain yksinkertaisten asioiden kuten suoritusten ja tulosten seurannan ohella myös monipuolisemmat oppimistehtävät kuten videoiden katsomisen, mobiilipelien pelaamisen ja erilaiset epämuodolliset oppimistapahtumat.

Tutkimuksessa selvitettiin, miten xAPI-teknologia kykenee vastaamaan e-oppimiseen kohdistuviin kehitystavoitteisiin ja odotuksiin kansallisella tasolla. Tutkimuksen tavoitteena oli selvittää kuinka xAPI:n ominaisuudet vastaavat digitalisaation myötä kehittyvän e-oppimisekosysteemin tarpeita ja mitä asioita on huomioitava xAPI:n kehityksessä, jotta siitä voisi muodostua kansallisesti merkittävä oppimistapahtumien seuranta- ja välitystyökalu. Tutkimuksen aluksi suoritettiin kirjallisuuskatsaus, jossa etsittiin tietoa e-oppimisesta, xAPI:sta ja näihin liittyvistä keskeisistä käsitteistä tutkimuskontekstissa. xAPI:n ominaisuuksia verrattiin myös muihin kansallisesti merkittäviin e-oppimisstandardeihin ja -spesifikaatioihin tutkimusaiheen kokonaisvaltaisen ymmärryksen kehittämiseksi. Kirjallisuuskatsauksen pohjalta luotiin yleiskäsitys xAPI spesifikaatiosta ja sen keskeisimmistä ominaisuuksista muihin kansallisesti merkittäviin e-oppimisen standardeihin peilaten. Näitä havaintoja verrattiin kansallisiin e-oppimisen ja analytiikkatiedon tulevaisuuden odotuksiin empirian avulla. Empiirinen aineisto kerättiin teemahaastatteluilla. Aineisto analysoitiin ja yhdistettiin kirjallisuuskatsauksen tuloksiin. Empiirisen aineiston avulla ymmärrystä sekä xAPI:n vastaavuudesta e-oppimisen odotuksiin, että sopivuudesta kohdeorganisaatiossa kehitettävän digitaalisen palvelualustan tarpeisiin kehitettiin lopulliseen muotoonsa.

Tutkimuksessa saatiin selville, että xAPI on e-oppimiseen liittyvä ohjelmointirajapinta, jonka välityksellä erilaiset oppimiskokemukset ja oppimisenseurantajärjestelmät voivat keskustella keskenään tehokkaasti. Erilaiset oppimiskokemukset kuten videon katsominen, verkkomateriaalin lukeminen tai mobiilipelien pelaaminen voidaan kokonaisuudessaan jäljittää ja taltioida xAPI:n avulla jatkokäsittelyä varten erilliseen tietokantaan nimeltä LRS. xAPI antaa yhteisöille ja organisaatioille mahdollisuuden analysoida oppimista syvällisesti – ei vain suorituksiin ja tuloksiin pohjautuen – ja tarjoaa näin arvokasta tietoa muun muassa oppimisen kehittymisestä oppimistavoitteisiin nähden ja mahdollistaa siten entistä paremman kokonaiskuvan muodostamisen koko oppimiskokemuksesta. Moniin muihin e-oppimisen standardeihin ja spesifikaatioihin verrattuna xAPI tarjoaa joustavan ja kansainvälisesti kehittyvän spesifikaation, jolla on selkeät mahdollisuudet kehittyä kansallisesti merkittäväksi e-oppimisen standardiksi ja joka kykenee tarjoamaan koulutusalalle mahdollisuuksia vastata paremmin tulevaisuuden oppimistarpeisiin.

Avainsanat: xAPI, e-oppiminen, e-oppimisen standardi, oppimiskokemus, oppimiskokemusten seuranta

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ABSTRACT

Valtteri Väkevä: Tracking learning experiences with xAPI
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Along with the digitalizing society, the education sector is undergoing changes. Especially in recent years, many educational institutions have - either on their initiative or out of necessity - adopted e-learning as an integral part of their learning process. This has been reflected in the development of learning environments from formal and static to more versatile and varied structures, where learners can develop their competencies flexibly regardless of time and location. The changes have provided opportunities to track and collect increasing amounts of learning-related data to understand learning and learners more comprehensively. This process however requires certain flexibility and interoperability between systems and applications, for diverse e-learning contents to be tracked, stored, and reported effectively. However, many of the current e-learning standards are relatively rigid and ineffective in providing capabilities for online/offline recording of learning experiences outside of LMS systems, as well as considering more versatile learning activities such as watching videos, playing mobile games, and informal learning tasks.

The study discussed the capabilities of xAPI technology to encompass the development objectives and expectations for e-learning at the national level. The objective of the study was to clarify how the unique functionalities of xAPI can respond to the needs of the developing e-learning industry and what issues should be considered in the development of xAPI for it to become a nationally significant framework for tracking and monitoring learning events. Initially, a literature review was conducted, to search for information about e-learning, xAPI, and related key concepts in the research context. The features of xAPI were furthermore compared to other nationally significant e-learning standards and specifications to develop a comprehensive understanding of the research topic. On the basis of the literature review, a general understanding of the xAPI specification and its key features was created. These observations were compared to national expectations for the future of e-learning and analytics using empirics. Empirical data was collected through thematic interviews. The material was analyzed and combined with the results obtained from the literature. The empirical material was utilized to develop an understanding of the xAPI's correspondence to the national e-learning expectations but also to test the suitability of xAPI for the digital service platform being developed in the target organization.

The study discovered that xAPI is an e-learning-related technical programming specification that can enable different learning experiences and learning monitoring systems to communicate with each other effectively. Different learning activities such as watching a video, reading online material, or playing mobile games can be tracked and recorded with xAPI in a common database called LRS for further processing. xAPI provides communities and organizations an opportunity to analyze learning profoundly - not only based on scores and results - and therefore can deliver valuable information about the development of competencies to form a better overall picture of the entire learning experience. Compared to many other e-learning standards and specifications, xAPI provides a flexible and globally developing specification that has clear potential to evolve into a nationally significant e-learning standard and therefore provide the education sector with opportunities to better comprehend future learning needs.

Keywords: xAPI, e-learning, e-learning standardization, learning experience, tracking learning experiences

PREFACE

Diplomityön teko on ollut mielenkiintoinen ja opettavainen prosessi, jonka aikana on käyty useaan kertaan läpi koko tunneskaala aina oivallusten kautta saadusta riemusta epätoivoon asti. Tämä kaikki on kuitenkin opettanut minulle paljon sekä substanssista että itsestäni. Diplomityömatkan aikana olen saanut valtavasti tukea ja apua monilta tahoilta. Toimeksiantajan puolelta haluan kiittää erityisesti esihenkilöäni Kristiania, joka mahdollisti tämän projektin tekemisen ja tsemppasi minua sen läpi. Kiitokset myös projektin yhteyshenkilölle Markukselle ideasta työn aiheeseen ja avusta prosessin edetessä. Lisäksi haluan kiittää diplomityöohjaajaani Samuli Pekkolaa hyvistä neuvoista ja avusta työn eri vaiheissa. Lopuksi vielä suuri kiitos perheelleni ja läheisilleni, erityisesti äidilleni, isälleni ja veljelleni kaikesta tämän työn ja koko opintojen aikana saamastani tuesta ja kannustuksesta. Opintojen, töiden ja erityisesti harrastusten yhteensovittaminen on välillä ollut haastavaa, eikä se olisi onnistunut ilman teitä. Tästä on hyvä jatkaa kohti uusia haasteita.

Opiskelujen aikana olen lisäksi saanut tutustua mitä mahtavimpiin ihmisiin ja viettää heidän kanssaan ikimuistoisia hetkiä niin opintojen kuin vapaa-ajan muodossa. Unohtumattomia kokemuksia ja seikkailuita on saanut kokea lukuisia ympäri Suomea. Vaikka opiskeluaika jää tältä osin taakse, siirtyy sieltä paljon myös mukanani elämän seuraaviin vaiheisiin. Nyt on kuitenkin aika kääntää uusi sivu elämässä – tässä vaiheessa voi vain arvailla mitä se tuo mukanaan ja mihin seikkailuihin sitä seuraavaksi päätyy.

Tuntuu hienolta nähdä valmis diplomityö. Prosessin aikana mielessä on kerran, jos toisenkin pyörinyt Ikuisen teekkarin laulun säe ”Unelma vain on diplomityömme --” – ja nyt tuosta unelmasta on tullut totta.

Tampereella, 18.03.2023

Valtteri Väkevä

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LIST OF SYMBOLS AND ABBREVIATIONS

ADL	Advanced Distribution Learning Initiative
API	Application Programming Interface
AICC	Aviation Industry Computer-Based Training Committee
CA	Caliper Analytics
CC	Common Cartridge
CMI	Computer-managed instruction
DS	Data Storage
IEEE LTSC	IEEE Learning Technology Standards Committee
IMS	Instructional Management Systems
LA	Learning Analytics
LIS	Learning Information Services
LMS	Learning Management System
LO	Learning Object
LOM	Learning Object Model
LOR/LORP	Learning Object Repository
LORF	Learning Object Referatory
LRC	Learning Record Consumer
LRP	Learning Record Provider
LRS	Learning Record Store
LTI	Learning Tools Interoperability
OCW	Open Courseware
QTI	Question and Test Interoperability
SCORM	Shareable Content Object Reference Model
xAPI	Experience Application Programming Interface

.

1. INTRODUCTION

1.1 Research background

Due to rapid digitalization and technical development, it is typical for learning today not only to take place in formal and static environments like physical classrooms. (Dumont et. al., 2010). As such, the education sector is facing an ongoing shift from traditional teacher-driven learning within single classroom boundaries, to more comprehensive digital learning environments where learners can perform learning activities anytime and anywhere (Groff, 2013). According to Spector et. al., (2020), digital learning environments can promote learners anytime, anywhere, and anyhow. Therefore, the context in which learners can undertake different learning activities can be considered rather diverse (Spector et. al., 2020).

To better comply with future learning objectives and expectations it is significant for the education sector to effectively track, collect and analyze increasing amounts of educational data (Groff, 2013; Nouira, 2018, pp. 566-568). This however requires certain flexibility and interoperability from systems and applications to provide uniform communication guidelines that can be used throughout the design (Adina, 2007). All in all, It can be considered a challenging concept for the e-learning industry today since the structures and functionalities of many current e-learning standards are limited to responding to these issues (Šimić, 2019).

DigiOne is a project initiated by the city of Vantaa, including the cities of Espoo, Jyväskylä, Lahti, Oulu, Tampere, Turku, and an in-house company Tiera. The objective of DigiOne is to create a nationwide digital service platform that can bring together different learning and education systems to effectively meet the future needs of the digitalizing society in the education sector including improved learning and well-being as well as more efficiently produced quality education services. As a part of achieving this objective, DigiOne aims to compile different learning events from various environments and other learning-related services to support analytics capabilities and therefore have aa educational parties a more comprehensive view of the learners' actions

Constantly developing learning environments, increasing demand to analyze learning at a more detailed level and the limitations of existing learning standards have made the DigiOne project become interested in discovering a more suitable standard, especially to comply with future e-learning objectives and analytics purposes. In this regard, one of the recent e-learning specifications called Experience API or xAPI has stood up. xAPI is identified as a potential solution for the DigiOne project since it provides tracking capabilities for educational data flexibly both online and offline as well as unique interoperability prospects with data collection to create new possibilities for improving the learning processes. (Nouira, 2018, pp. 566-567; Šimić, 2019)

The possible simplicity and flexibility provided by the xAPI, as well as the possibility to remove many of the limitations associated with previous e-learning standards, have made it a strong alternative for DigiOne. The adaption of xAPI as a part of the project organization's information system architecture, however, requires sufficient evaluation of its main functionalities and benefits compared to national e-learning objectives. Furthermore, the adaption requires different expectations, needs, and conditions of both DigiOne and the different stakeholder groups to be considered and reflected in the functionalities of xAPI.

1.2 Research Objectives, Questions, and Scope

The objectives of the research include identifying the expectations the target organization and different stakeholder groups have towards the xAPI-specification and its functionalities at the national level. To achieve these objectives, the research provides an overview of the xAPI-specification as well as its main functionalities. Furthermore, the research discusses the differences between the functionalities of the xAPI and other nationally identified central e-learning standards and specifications.

The research consists of both theoretical and empirical parts. The theoretical part discusses the fundamentals of the e-learning environment, e-learning standardization, and the xAPI – specification itself. It furthermore provides an overview of the xAPI-related concepts, technical structures, and functionalities that are needed to understand the main concepts deeply enough. Based on these perceptions, the theory part establishes a collection of key functionalities and benefits of xAPI compared to corresponding properties of other nationally significant e-learning standards and specifications.

The empirical part of the research discusses the expectations different stakeholders have for e-learning. It's also substantial to discover the possible concerns and bottlenecks different stakeholders can identify for e-learning and the utilization of learning data in the future. This is accomplished by interviewing the key representatives of the project organization and different stakeholder groups. Finally, through the analysis of the research results and conclusions, the observations collected in the theory part are endorsed and completed with the results obtained through the empirics.

The research work is carried out as case research for a target organization. The research supports the target organization's objective of clarifying that xAPI technology meets the expectations of both internal and external stakeholders and could therefore be adapted as a part of the target organization's information system architecture in the future. To achieve this objective, the main research question has been set for the research as follows:

- How does xAPI technology meet the e-learning development targets and expectations?

Due to the scope of the main research question, it's divided into three sub-research questions as follows:

- What are the key features of the xAPI in the information system architecture?
- What are the key differences in the functionality of the xAPI compared to other central e-learning standards and specifications?
- What kind of factors must be considered in the development of the xAPI as a means of transmitting learning analytics data?

With the help of sub-research questions, the research seeks answers to smaller entities, based on which the answer to the main research question is formed. At first, the literature review is utilized to discuss *what are the key features of the xAPI in the information system architecture.* This question is used to determine what is meant by the xAPI specification in this research, what are its main functionalities and how it relates to the e-learning concept. The second will be clarified *what kind of differences there are in the functionality of the xAPI specification compared to other central e-learning standards*. The purpose here is to gain a solid understanding of other key e-learning standards and their main functionalities compared to the xAPI. The third is to find out different *factors that must be considered in the development of the xAPI specification as a means of transmitting learning analytics data.* This question is determined, especially to evaluate the future aspects and possibilities of xAPI technology. The results obtained in the literature review are empirically tested through interviews, and finally, a synthesis desired to answer the main research question is formed based on these combined results.

1.3 Research Methodology

The research methodology utilized in the research is examined through a certain research philosophy, approach, strategy, and research epistemology (Saunders et al. 2019). In the early stages of research, different choices related to the research methodology should be made to plan the strategic direction of the research. This is an important part of the beginning of the research process for the research to be conducted consistently. (Eriksson & Kovalainen, 2008) Alternatively, making methodological choices transparent increases the reliability of the study (Saunders et al. 2019).

There are many different research methodologies, and they should be chosen to best suit the nature of the research. Before planning what kind of data is needed to answer the research questions and how to collect the data it's important to describe the issues underlying the choices of data collection techniques and analysis procedures. (Saunders et al. 2019) In this research work, the research methodology will be based on Saunders et al. (2019, pp. 130) research model. This layered model helps to explain research methodology-related decisions and aims to describe how different elements involved in the research could be examined to develop the final research design. The methodological choices of this study are presented in Figure 1.

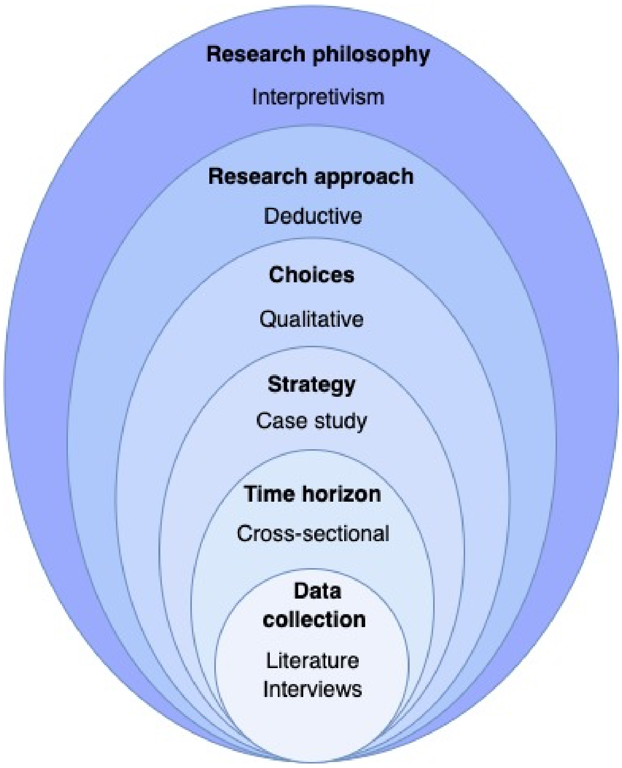

Figure 1. *Research methodological choices (Saunders et. al, 2019)*

During the research, several different assumptions are made that shape the course of the research. Together these assumptions form a certain way to look at the world and make choices in it, creating a solid philosophy for the research. (Eriksson & Kovalainen, 2008; Saunders et al., 2019) According to Saunders et al., 2019; O'Gorman & MacIntosh, 2015, there can typically be identified three to five main research philosophies: positivism, critical realism, interpretivism, postmodernism, and pragmatism. In this research, interpretivism has been identified as a research philosophy.

Interpretivism seeks to highlight human interpretation and subjectivity in making interpretations (Saunders et al. 2019). This research aims to describe and create a holistic understanding of the research topic to identify the subjectivity of the research and the importance of interpretations in forming the results. Interpretivism fits into this research philosophy because the theoretical part of the research is confirmed by an interview study specifically through human interpretation to deepen the theoretical model created through literature review. According to Saunders et al. 2019, it's however important to understand that although interpretivism understands the interpretability created by the values and motivation of the researcher, the researcher is still required to have a certain degree of objectivity to ensure the transferability, validation, and reliability of the research.

The second layer of Saunders et al. 2019 research model (fig. 1) considers the research approach. According to Saunders et al. 2019, there can typically be identified three main approaches to research called inductive, deductive, and abductive approaches. In inductive research, the starting point is empirical research, which is supplemented with theory, and the researcher utilizes observations to build an abstraction or to describe a picture of the phenomenon that is being studied (Saunders et al. 2009; Lodigo et. al., 2010). Unlike inductive research, deductive research typically deals with a theory first, after which it delves into the empirical level. In the deductive approach, the reasoning is based on a hypothetical theory that is tested. (Saunders et al. 2009, pp. 124-125, Greener, 2008) The abductive approach combines both above. The research is based on empirics, but the theory is utilized throughout the research in different situations. In this way, it's possible to draw broader conclusions on the subject. (Walton 2014) This research is recognized to follow a deductive approach.

The purpose of the research is to create a universal preliminary conception of the research topic based on a literature review. The starting point of the research is the formation of a theory about the consequence and functionalities of the xAPI – standard in transmitting learning data in an e-learning environment. After this, a case study is utilized in the empirics to address the expectations and user perspectives of the target organization's different stakeholders regarding the xAPI-specification. Finally, the framework created in the theoretical part is adapted to the specific expectations and characteristics of the different stakeholders observed through the empirics. Based on this, the choice of a deductive approach seems to be well-suited for research.

The third layer of the Saunders et al., 2019 research model (fig. 1) defines the research methodology. Based on the data, research can be divided into either qualitative or quantitative research. The objective of quantitative research lies in trying to validate a theory by conducting an experiment and analyzing the results numerically. Qualitative research instead seeks to arrive at a theory that explains the behavior observed. (Saunders et al., 2019) In this research, empirical data will be collected through thematic interviews, which refers to data being qualitative. Even though (Saunders et al., 2019) state that an inductive approach is usually utilized with the qualitative research strategy, it's, however, possible to use a deductive approach with a qualitative research methodology in certain situations like in this research where a certain theory is tested using qualitative methods. (Saunders et al. 2015, Greener 2008) Therefore, the research approach in this research is qualitative.

Both the literature review and the interviews utilized in this research are data collection methods of qualitative research (Greener, 2008). Research can be identified as a multimethod if it involves more than just one individual data collection method and a corresponding analytical procedure (Saunders et al., 2019). This research follows a qualitative multi-method research methodology (Saunders et al. 2019) as it consists of two different qualitative research sections, a literature review, and an interview study.

The fourth layer of Saunders et al. (2019) research model (fig. 1) defines the research strategy. A successful research design requires a choice of strategy, a decision to use experimentation, survey methods, archival analysis, histories, or case studies (Schell, 1992; Hirsjärvi et al. 2004). The objective of the research strategy is to define a plan for how research can be utilized to answer research questions. The previous choices in the research philosophy, approach, and methodology conduct the research strategy and create their own limitations on what kind of research strategy can be utilized. (Saunders et al., 2019)

In this research, a case study is utilized as a research strategy. It's typical for a case study to select a single case, situation, event, or series of cases in which processes are often of interest. (Saunders et. al., 2019) The objective is to study individual cases in their natural environment by describing in detail the phenomenon under investigation

(Yin 2014). Different descriptive methods however do not necessarily aim to explain the connections between phenomena, test hypotheses, and make predictions, but to create a systematic, accurate, and truthful description of the characteristics of the research subject. (Hirsjärvi et al. 2004, pp.125-126.)

Conducting successful research includes examining the temporal nature of the research which can be achieved through exploring the research time horizons. There are two types of time horizons called cross-sectional and longitudinal. When the time horizon of the study is cross-sectional, research is done by looking at the subject under study from a certain period. In longitudinal research, on the other hand, the research is conducted over a long period. (Saunders et al. 2015) In this study, the objective is to achieve the current understanding of the xAPI specification in an e-learning environment as well as future expectations for it. Currency is important because both learning ecosystems, different forms of learning, and related standards are constantly changing and developing. Due to this, a longitudinal study might not produce the desired result, and therefore a cross-section is utilized as the time horizon of the research.

1.4 Structure of the thesis

The research progresses logically from theory through empirics to analysis of results and conclusions. After the theory part, the first version of the functionalities and benefits of the xAPI specification is created and compared with the corresponding properties of other main e-learning standards. The functionality of these perceptions is then compared to expectations in the empirical part of the research. After that, the empirical and theoretical results are synthesized, and a detailed collection between xAPI functionalities, benefits, and expectations is created. Finally, the achievement of the research objectives and further research topics will be examined. The more detailed structure of the study is presented in Figure 2.

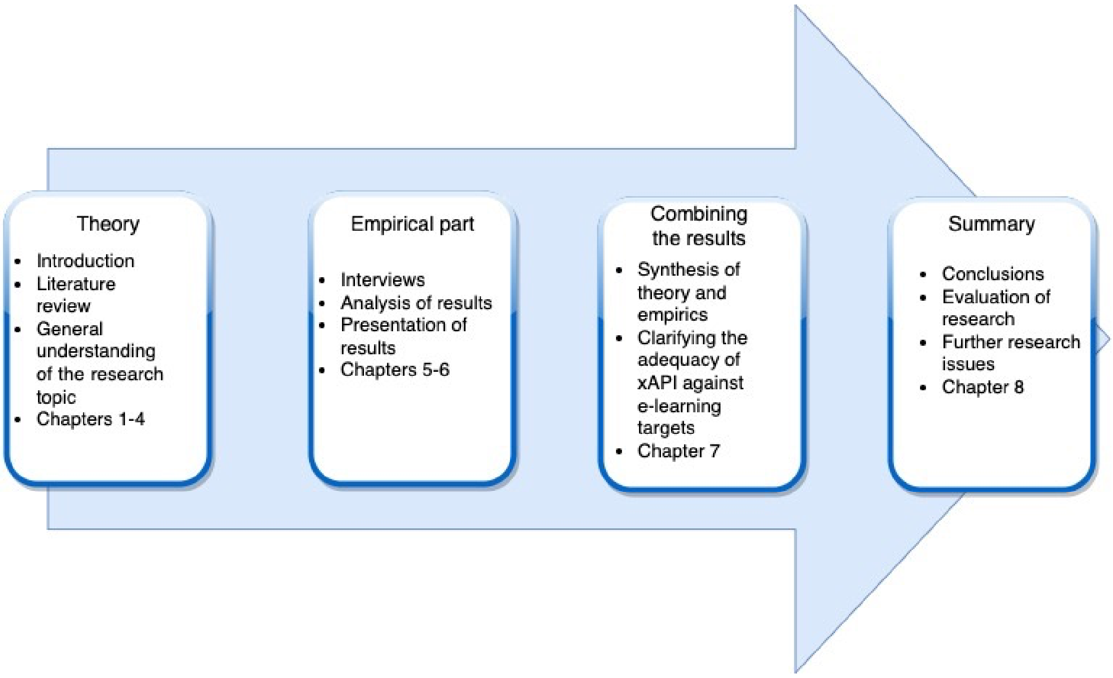

Figure 2. *Research structure*

Chapter 2 addresses the e-learning and standardization environments at a general level. It takes a stand for some key components the e-learning environment includes that are significant for the research topic. Chapter 2 also addresses the standard organizations and standards that are most utilized in the e-learning context. Chapter 3 discusses the xAPI-specification as well as its key components, related structures, and operating policy. At the end of the chapter, a synthesis of the theory chapters' content is formed to highlight the benefits of xAPI.

After creating the model, the empirical part including the expert interviews is carried out. Chapters 5 addresses conducting the interviews and analyzing the empirical data. In chapter 6 the empirical results are presented and discussed. Chapter 7 combines empirical results with the results achieved in the theory part. Finally, chapter 8 summarizes the research results and answers the research questions. This chapter furthermore includes evaluating the overall results of the research and discussing the topics for further research.

2. E-LEARNING STANDARDIZATION

2.1 E-learning

Due to the increasing level of digitalization, different technological advancements have started to have more and more impact on different parts of society and education is not an exception to this. Basically, every school and educational organization in modern society utilizes IT somehow to create new possibilities for learning and to make communication more efficient. (Dodds & Smith, 2002) Different technological solutions and digitalization create constantly new possibilities for learning by enabling learners to adopt renovate ways to learn and communicate with objects and people they encounter along the way as well as by making it possible to monitor and analyze learning more effectively. (Thareja et. al, 2015) On the other hand, increasing technological development in society requires educational organizations to consequently pay more and more attention to trying to find more efficient ways to develop learning due to future learning needs (Chicu, 2018).

E-learning is a complex concept that encompasses various definitions depending on context. Some parties consider e-learning to be limited to entirely within an internet browser without the demand for other software or learning resources (Phillips et. al, 2011). For others, it can include for example uses of different learning-related technologies and therefore encompass a wider context (Bahrain, 2013). Due to the lack of unequivocal explanation, e-learning can be deliberately open-endedly described as a kind of umbrella concept including the utilization of information and communication technology in learning (Donnelly et. al, 2012). This definition does not take a stand for any authoring tools or management systems and allows absolute freedom as to how different activities are formulated, organized, and created. (Thareja et. al, 2015; Bahrain, 2013)

E-learning contributes to the shifts from traditional face-to-face learning to the utilization of digital tools to enhance collaborative learning. It provides a learning environment contributing with distinguishing features that set it apart from traditional classroom-based learning. (Chicu, 2018) A fundamental feature of e-learning is that it takes place online. Therefore, the primary source of information in e-learning is based on online content which differs from traditional learning forms where the information is mostly provided by a teacher or a trainer. (Horton, 2011) In the e-learning context, it’s furthermore entirely up to the person when, where, and at what time they want to take up a learning content.

There is no need for a person to be in the same space to view online content. (Thareja et. al, 2015)

The features distinguishing e-learning from traditional forms are not exclusively related to time and location independence. They can relate to multiple other factors such as learning pace, style, content, and the level of interaction during the learning process. E-learning is considered to have a more flexible pace compared to traditional learning which is typically more imposed and determined. It is also common for e-learning to take place more independently compared to traditional classroom-based learning which typically occurs firmly from and with each other. (Chicu, 2018) There can furthermore be identified differences in levels of interaction between e-learning and traditional learning. Traditional learning includes more extensive interaction between trainers and colleagues whereas the interaction in e-learning is more limited due to the lack of constant human contact (Thareja, et. al., 2015)

Compared to traditional forms of learning, e-learning has its unique features and varieties, but the same overall objectives as traditional learning. These objectives include improving the efficiency and quality of learning and teaching, meeting the changing learning needs and requirements, and improving the accessibility and flexibility of learning to engage learners. (Chicu, 2018) In our rapidly developing society, the education system is constantly under increasing pressure. However, it must be able to guarantee sufficient resources and competence for education to be able to meet the learning needs of the future. Therefore, instead of comparing the features and superiority between e-learning and traditional learning, they should be seen more as unified and mutually supportive entities (Phillips et. al., 2011). Due to the increasing requirements for the learning sector, e-learning should not be seen as a competitor or contender to traditional learning, but rather to support overall learning and improve its quality (Horton, 2011).

2.2 Learning objects

E-learning operations are based on the transmission of learning content across various digital environments and platforms. With the emergence of internationally recognized specifications and standards, the exchange of learning content has become possible. (McGreal, 2004) To enable this kind of data exchange, e-learning content must be described at a structural level by standardized schemas and defined by a suitable structure unit for this action. Therefore, a certain learning object notion has been adopted to set in a common form all the didactical material. (Downes, 2000)

Learning Objects (LOs) are at the heart of e-learning operations. They can be identified exclusively as digital objects, but nearly all proposals include every digital or physical object with learning content. (Stratakis et. al., 2003) Generally, the LO would be described as a learning event, for which all related properties are defined for easy and effective reuse. At broadest the LOs can simply be described as any digital resource that can be reused to support learning. These resources (e.g., electronic text, an image) can vary in size but are typically referred to as being smaller than an entire learning course. According to the IEEE Learning Technology Standards Committee (LTSC):

LOs are interactive resources that support learning specific concepts by enhancing, amplifying, and/or guiding learners' cognitive processes.

The Learning Objects Network Inc uses an equal but little more expanded definition:

LOs are small stand-alone "chunks" of information designed to be easily reused and repackaged to meet the needs of different audiences. They are usually designed to achieve a certain narrow learning objective and may contain an assessment to determine success against that objective.

Based on the broad definition field of LOs, it is confidential to state that they cover a wide area of different kinds of learning resources. In general, LOs can be distinguished into two separate categories (Stratagis et. al, 2003):

1) Physical LOs, which include all non-digital entities, such as a simple textbook. These objects must have a digital surrogate for their online representation.
2) Online LOs such as web pages which relate straightly to online environments.

The LOs described by the metadata in an e-learning concept are to be those available on the web so, therefore, the term “Learning Object” or “LO” is utilized in this research to refer to online LOs. (Stratakis et. al., 2003)

LOs are typically utilized in the education of challenging concepts or to describe specific content and engage learners. LOs can support addressing a certain learning objective, assist learners in problem-solving, allow learning instructors to give learners access to materials they may otherwise not physically be able to access, or simply make learning content more engaging and interesting. (Downes, 2000) Utilizing LOs can provide educational institutions with opportunities to collaborate and engage in a community of practices to improve learning environments and therefore overall learning (McGreal, 2004).

Breaking e-learning content down into smaller, more manageable LOs that utilize a variety of learning mediums allows educational designers to make content more effective. LOs can for example boost learner engagement, improve learning retention, and help create more customized learning paths. (McGreal, 2004) However, the effective implementation and utilization of LOs require them to be created and stored in a way that makes them easy and practical to share and store for different purposes. (Yassine et. al., 2016) Table 1 describes essential requirements that should be considered when designing LOs.

Table 1. *Functional requirements of Learning Objects (Yassine et. al., 2016).*

Granularity	Refers to size, decomposability, and the extent to which the learning object is intended to be used as part of a larger resource (level of aggregation)
Accessibility	Refers to the availability of the learning object to a wide and diverse audience
Interopeability	Refers to the implementation in different learning and content management systems. How easy is to plug and play in different platforms
Reusability	Refers to the ability of the learning object to be shared and function in different instructional contexts
Standards	Refers to the designing standards that the learning object should met in order to be able to integrate with other learning objects developed by different producers
Metadata	Information needed to describe the learning object in order to support the reusability of learning objects, to enhance their accessibility, and to facilitate their interoperability

The learning environment today requires sending, storing, and retrieving a variety of records about learning experiences and subsequently sharing that data across independent platforms. The decisive objective for these environments is a LO economy characterized by searchable digital repositories of reusable LOs that can be shared, exchanged, and reused across systems. The development of LOs must therefore consider different applicability, and interoperability issues, as well as the adaptability and reusability of LOs in different contexts. (Moisey & Ally, 2013)

2.2.1 Granularity & reusability

A typical feature for LOs is to exist and interoperate at different levels of granularity. Granularity generally relates to the size of LOs and is an indispensable feature for them to be shared and reused (Moisey & Ally, 2013). It is a key factor in measuring the reusability of a certain object (Rodríguez et. al., 2008, pp. 175-179). The metric for granularity ranges between different factors such as instructional time and amount of learning achieved, and content covered (Moisey & Ally, 2013; Schoonenboom, 2012, pp. 249–265). The general form for the LO granularity level hierarchy is described in figure 3.

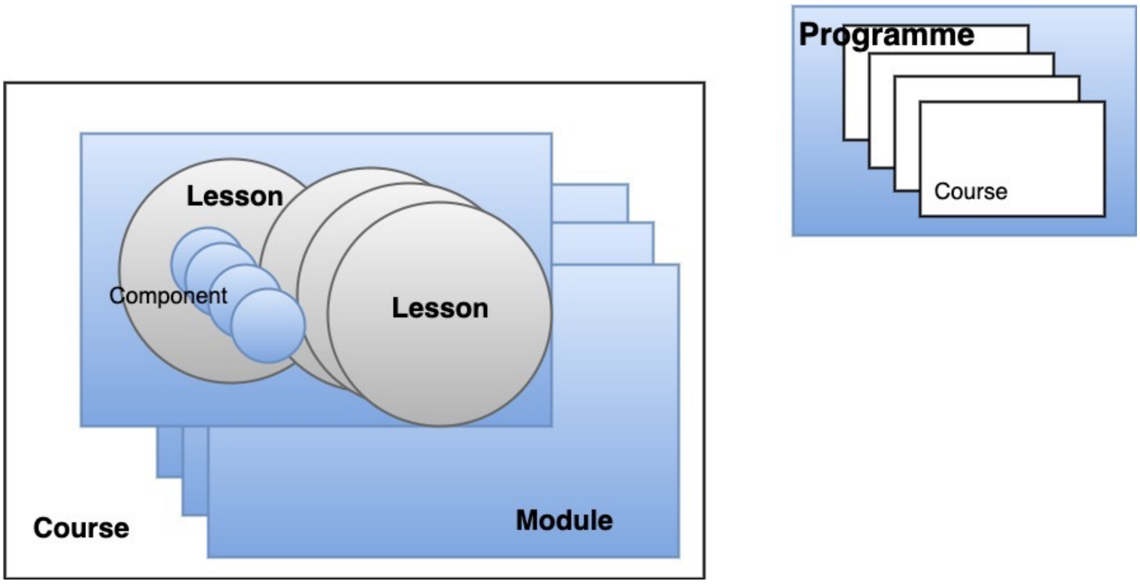

***Figure 3**. Learning Object granularity (Stratakis et. al., 2003)*

The first and simplest level in the granularity hierarchy is the component. It describes all objects possibly utilized in the learning process. For example, a page from an e-book can be considered a single component. This page becomes a lesson when a grouping of components with a relative theme is added to it. (Stratakis et. al., 2003). With the same formula, the lesson rises in the granularity hierarchy as a grouping of other lessons with a relative theme is added to it. A group of courses leading toward a certificate or diploma finally considers the highest level in the granularity hierarchy called a program. (McGreal, 2004)

Reusability is generally considered as a possibility and adequacy of a specific object to be usable in perspective educational settings (Sicilia & Garcia, 2003). In the e-learning context the reusability can be considered as the ability of the LOs to be modified and versioned to utilize in different contexts for different purposes (Duval et. al., 2008) Practically, this refers to the adaptation of the LO itself to better compromise on particular circumstances. Ideally, all LOs should be portable and self-contained meaning that they can be dipped into by a learner independently of a larger course and be ported to different learning systems without losing value. (Wiley, 2009).

The reusability of LOs can be treated differently according to individual demands and expectations. From the developer-derived perspective, reusability generally considers establishing the LO in a different context than the one it was designed for. Practically this refers to unplugging and plugging the same LO in different contexts without any editing or modification. (Yassine et. al., 2016). From the learner-related perspective, reusability typically concerns the content of the context. The learners should be able to learn the context hands-down and effectively regardless of the elaboration and detail of context.

This means maximizing the pedagogical reusability by enabling LOs to contain more context. (Wiley, 2009)

2.2.2 E-learning standards and metadata

The global attraction in implementing e-learning operations has raised challenges relating to different propositions for e-learning prototyping that are resulting in different interoperability issues (table 1). These challenges require some standard ways for creating and transmitting e-learning content, facilitating seamless content distribution, and providing smart metrics across various learning platforms to overcome. Therefore, the e-learning industry has designed and adopted a certain standardization framework to be utilized. (Lockyer et. al., 2008)

The origin of e-learning standardization dates to the early 1990s military and commercial training, to enable LOs generated by different providers to run on different technical platforms and systems. Subsequently, these issues have led to increased interest in the possibilities offered by e-learning standards for enabling the sharing and reuse of LOs and designs in education contexts. In the e-learning context, standards are generally developed for ensuring interoperability and reusability in systems as well as the management of content and metadata. (Queirós & Leal, 2013) E-learning standards refer to a system of common rules for content and e-learning systems - rules that specify how e-learning content can be created and delivered over multiple platforms for all of them to run seamlessly together. They are designed to ensure that the investment in time and intellectual capital could move between systems effectively. (Adina, 2007) E-learning standards are needed for (Stratakis et. al., 2003; Fernandes et. al., 2006):

- **Durability** (no need for modification as versions of software change)
- **Interoperability** (Across different e-learning systems)
- **Accessibility** (Admission to information to enable the search, access, and delivery of the e-learning content in a distributed fashion)
- **Reusability** (Modification and utilization by different development tools)

E-learning standards allow distinguishing the pedagogical properties of LOs to ensure modularity, interoperability, and discoverability of them to satisfy the reusability, durability, accessibility, and interoperability objectives (Rodríguez et. al., 2008; Yassine et. al., 2016). They are generally considered to be multi-part, consisting of certain major elements called “data model”, “binding” and “API” (Application Programming Interface). “Data model” and “binding” elements abstractly specify the standard contents and describe how the data model is expressed in a formal idiom. “API” instead to provides contact points between systems, or between content and runtime software. (Fernandes et. al., 2007) “Data model” and “binding” elements are strictly related to the content of the standard whereas the use of the API is usually restricted to software and has relatively little or no impact on the publication of the content itself (Downes, 2000; Fernandes et. al., 2007).

E-learning standards apply not only to LOs and designs but also to different e-learning software such as learning management systems (LMSs) and virtual learning environments (VLEs) (Adina, 2007). They can enable correspondence between different systems and software, by providing uniform communication guidelines to be utilized throughout the design, development, and delivery of LOs. Therefore, they must be designed to support compatibility so that content and designs conform to a particular specification or standard and can interoperate with LORs or LMSs that also conform to the standards (Queirós & Leal, 2013).

The uniform intention of e-learning standards is to provide fixed structures and communication protocols for LOs to meet the durability, interoperability, accessibility, and reusability (table 1) requirements (Stratakis et. al., 2003; Fernandes et. al., 2006). Therefore, they must address both the LO structure, as well as the sharing or packaging of e-learning content. The LO structure can be addressed with the use of metadata that comprises the most significant descriptive properties of LOs of various granularity levels. The packaging property instead can be considered with the use of different interoperable content structure models (CSM) that comprise the composition structure of LOs at various granularity levels to exchange and share them between platforms and applications. (Adina, 2003; Yassine et. al., 2016)

Generally, every content to be identified using a search engine must be described in a sufficiently efficient manner, by a set of different learning resources, called metadata. These resources such as keywords, attributes, and descriptive information provide educators, learners, and systems information about LOs. (Fernandes et. al., 2006) The standardized metadata resources grouped into sets designed for a peculiar objective are considered metadata standards. (Adina, 2007) The objective of them is to support the reusability of LOs, aid discoverability, and facilitate their interoperability, generally in the context of e-learning systems (Fernandes et. al., 2006).

The metadata layer is only an addition of data to the content. To be accessible to third parties and meet the interoperability requirements, content must be described at a structural level by standardized schemas. (Downes, 2000) Learning content should be labeled in a consistent way to support the indexing, storage, search, and retrieval of LOs by multiple tools across various platforms (Adina, 2007). This is crucial for the learning content to be created or utilized in one system, retrieved to another system, and again transported to and reused in the third distinct environment. Therefore, a certain content structure notion has been adopted to set in a common form all the online didactical material (Downes, 2000). The content packaging notion refers to a set of standards to enable transferring e-learning content from one learning system to another (Kavčič, 2016). Content packages include both LOs and information about how they are to be put together to form larger learning units (Adina, 2007).

2.3 Learning object repositories

LOs are, fundamentally identified as digital learning resources. The substantial features of them include reusability, accessibility, interoperability, and durability (table 1) for users to be able to search and make use of them. (Littlejohn, 2007) Therefore, it's conclusive that LOs are stored in a way that makes them easy to share, source, and adapt for different purposes. To be efficiently utilized, LOs require an environment that does not only provide safe storage but is also capable of enabling the administration of LOs in terms of updating, identifying, utilizing, sharing, and re-using them. (Retalis, 2005) These factors have led to the adaption and escalation of Learning Object Repository (LOR) systems to support the sharing and reuse of LOs (Rehak & Mason, 2003).

LOR system is a general term for an online collection of LOs. More specifically LOR refers to a digital library or electronic database which can be utilized to share, use, and reuse different LOs versatile. The main objectives of LOR systems consist of providing a storage platform for updating, identifying, utilizing, sharing, and re-using educational content comprehensively (Retalis, 2005). These include delivering services to designated communities by hosting collections of digital resources for learning and teaching (Heery & Anderson, 2005). LORs can either consist of a single floated database or multiple linked databases. (Yassine et. al., 2016) They cover different educational levels and are designed with various technologies and tools for a variety of educational purposes (Tzikopoulos et. al., 2007).

The structure and operational policy of LORs is typically based on different metadata standards (Tzikopoulos et. al., 2007). To comply with the LO reusability, accessibility, interoperability, and durability requirements it is essential for LOR systems to inherently provide the levels of support for different e-learning standards (figure 5) (Littlejohn, 2007). However, standard support within repositories specifically for LOs is highly variable, and different repositories tend to provide distinct features not found in others. (Cervone, 2012, pp. 14-16)

LOR systems can be described by various factors such as the characteristics of the repository and contents provided as well as the technical and quality characteristics. (Tzikopoulos et. al., 2007). McGreal (2008) classifies LORs into three basic types:

1. Centralized systems with content stored on the site
2. Digital portals that generally store links and metadata to content
3. Repositories with an equal role as a content provider and portal

The classification of LOR systems enables the identification of different types of LORs (Duval & Ochoa, 2008). These types generally consider the infrastructure and acknowledge the different classification properties of LORs (McGreal, 2008; Clements et al., 2014, pp. 929-939). Different LOR types are described in table 2:

Table 2. *LOR types (Harman et. al., (2007); Yassine et. al., 2016)*

Repository	Type of LORs	Description
ARIADNE	LORP	A distributed library of digital, reusable educational components called the Knowledge Pool System (KPS) used actively in both academic and corporate contexts
MERLOT	LORF	Provide interactive e-learning objects for higher educatio faculty and students. MERLOT rely on voluntary contributions from external users to assess and evaluate the quality of its resources
MIT OCW	OCW	Web-based free publication of MIT courses content. It is a permanent MIT activity which include illustrations with course materials to almost all the undergraduate and graduate subjects taught at MIT
MOODLE	LMS	Open source and web-based LMS developed on pedagogical principles. It is used to facilitate online, blended, and distance learning

Learning Object Repositories (LORPs) has a primary objective of collecting digital educational resources offered by creators for open access and potential reuse. They can typically be considered centralized models with digital LOs and/or their associated metadata descriptions stored on the site. (McGreal, 2008). Learning Object Referatories (LORFs) instead point directly to online objects. (Duval & Ochoa, 2008) These systems store only the indexing and metadata and point to various contents on the web and other databases to allow federated access to different resources. (Duval & Ochoa, 2008)

Open Courseware (OCW) initiatives are free and open digital high-quality educational materials organized as courses. OWC sites provide open access to the primary teaching materials for educational courses, enabling educators to draw on the materials for teaching purposes, and on the other hand learners to utilize these materials for their own knowledge development purposes. (Avineni & Pusapati, 2012). Even though OCW sites comply with the definition of LORs they do not identify themselves as actual LORs. (Duval & Ochoa, 2008)

Learning Management System (LMS) is a broad term utilized to describe systems designed to manage learning interventions and provide access to e-learning services for different educational parties. Generally, LMSs can be considered software systems, that allow the development and delivery of educational courses utilizing online services as a delivery system. They are designed to control a variety of issues ranging from learning content management to student interaction assessment. LMSs enable storing of different learning content to be shared in a specific community of students, teachers, and other defined members. (Harman et.al., 2007) Despite being open, they are considered as LORs (Duval & Ochoa, 2008).

LMSs are launched to improve the learning experience and facilitate teaching. With digitalization, such supportive learning platforms and systems are becoming increasingly significant for schools and educational institutions in transitioning from in-person to online education. (Duval & Ochoa, 2008, pp. 39-62) As LMSs can be considered to include learning systems, course management systems, content management systems, etc., and be responsible for course creation, assessments, reporting, analytics, etc., they can in many ways be defined as comprehensive software applications designed to cover every aspect of online education. (Tzikopoulos et. al., 2007)

2.4 Standard environment

The primary function of standard organizations is to develop, coordinate, promulgate, revise, interpret, or otherwise contribute to the usefulness of technical standards to those who employ them (Ping, 2011). There can be identified numerous organizations, consortia, etc., that are working around e-learning standards and closely contributing to their evolution and development. For instance, organizations like the Institute of Electrical and Electronics Engineers (IEEE), the IMS Global Learning Consortium (IMS), the Aviation Industry CBT Committee (AICC), the Advanced Distributed Learning Initiative (ADL), etc. are dedicated to, or have committees and working groups active in, the establishment of different e-learning standards. (Paramythis & Loidl-Reisinger, 2003)

It is beyond the scope of this research work to consider all different entities involved in the establishment of e-learning standards, or the standards themselves. Instead, this research opts to make selective references to some of the standards and specifications that are widely adopted in the e-learning field and where such references are relevant to the possible research results (Paramythis & Loidl-Reisinger, 2003):

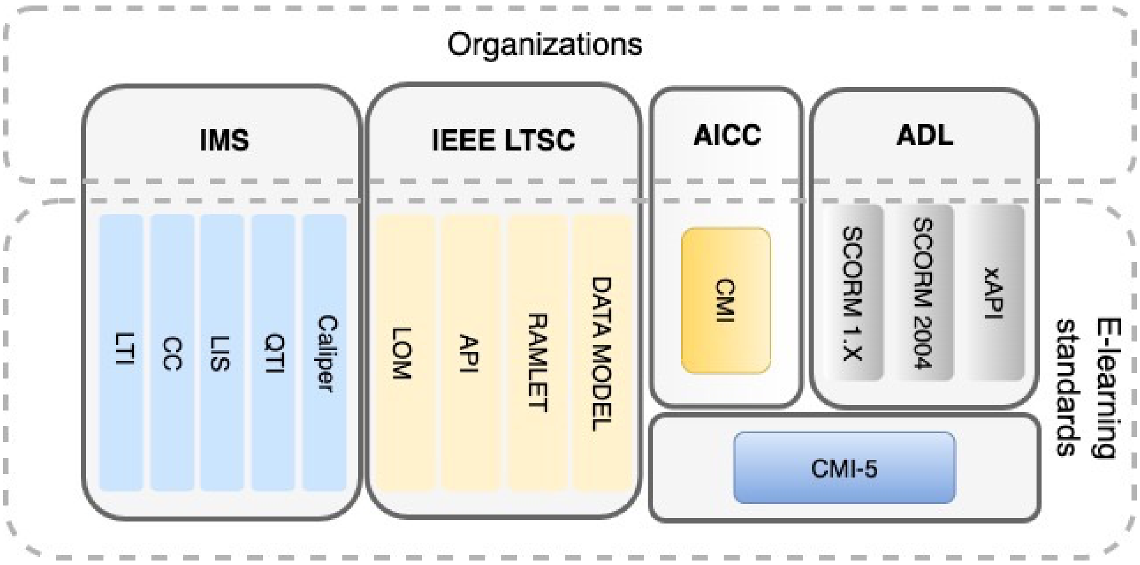

Figure 4. *E-Learning System Standards and Organizations (Bakhoyi et. al., 2017)*

In this research work, the four main organizations illustrated above (IMS, IEEE LTSC, AICC, and ADL) are considered as well as certain key standards and specifications developed by these organizations that are somehow significant for the research work.

2.4.1 AICC

The first standards for e-learning systems were created by the international association called AICC already in 1988. AICC develops and supports standards and guidelines that create the learning technology specifications for reuse, adaptability, and interoperability in various e-learning fields such as higher education. AICC publications include the delivery, monitoring, and tracking of learning outcomes to e-learning management systems and due to these properties, they have become widespread across training systems. (AICC, 2006)

The AICC CMI (Computer Managed Instruction) specification describes the communication between a lesson and the learning environment, the storage of the data communicated, and the movement of a course between multiple CMI learning environments. AICC standards are not based on XML format but instead on the HACP (HTTP AICC Communication Protocol) for communication between the learning content and the LMS. (Behringer, 2013) The HTML form is utilized to send data to the LMS which in turn sends information back as a text string (Bianco et. al., 2004).

In addition to its own standard representations, AICC actively cooperates with other organizations in the field of e-learning standards technologies such as IMS, ADL, and IEEE LTSC (Shariat et. al., 2014). In recent years, AICC has for example opted for a new CMI-5 specification that aims to provide an alternative to the SCORM (Shareable Content Object Reference Model). CMI-5 has expected to replace both AICC and SCORM specifications with a more feature-rich and robust solution. (AICC, 2004; Bakhouyi et. al., 2017).

2.4.2 IEEE

The IEEE is a standardization organism, primarily known for developing standards for different industries. The IEEE includes e-learning a dedicated committee called the IEEE LTSC (IEEE Learning Technology Standards Committee) which is an IEEE CSSAB (Computer Society Standards Activity Board) chartered organization established in 1996 to develop and publish internationally accredited technical standards, recommended practices, and guides for learning technology. As well as AICC, IEEE LTSC cooperates closely with other learning technologies organizations, both formally and informally to constantly develop a standardization environment. (Fernandes et. al., 2006)

The IEEE LTSC has developed several internationally recognized e-learning standards. According to Fallon & Brown, (2016), the most cited of these standards are the CMI (Computer Managed Instruction), RAMLET (Resource Aggregation Model for Learning Education and Training), and LOM (Learning Object Metadata) specification (figure 3). CMI standard is a multi-part standard consisting of three different entities (Data Model for Content to LMS Communication, Application Programming Interface for Content to Runtime Services Communication, and XML Schema Binding for Data Model for Content Object Communication). RAMLET in turn defines a conceptual model including an ontology for enabling the interpretation of externalized representations of digital aggregates of resources for learning, education, and training applications. LOM specification is a set of metadata to describe the teaching and learning resources and define the elements and element groups describing them. It defines learning object metadata as well as a conceptual data schema that defines the structure of a metadata instance for LOs. (Barker, 2011)

2.4.3 IMS

IMS is an industry consortium of vendors founded in 1997. It aims to develop specifications based on the requirements identified by its supporting members. Up to this point IMS has developed and supported approximately 50 standards, emphasizing e.g., metadata, content packaging, enterprise services, and facilities. (IMS, 2003). These standards are developed to describe the main characteristics of e-learning content, aiming to assure the interoperability of systems that support e-learning, education, and training improved by technology (Bao & Castresana, 2012).

The most notable standards of IMS called LTI (Learning Tools Interoperability), CC (Common Cartridge), LIS (Learning Information Services), and CA (Caliper Analytics) are presented in figure 3 (Bakhoyi et. al., 2017). The IMS LTI specification is the most widely adopted standard that standardizes protocols between the e-learning system and external learning software. IMS CC instead is a packaging standard for content that simplifies the exchange of digital content between systems. (Bao & Castresana, 2012). The IMS LIS (figure 5) provides an integration between the student management systems and the e-learning systems by standardizing the data for student information to be exchanged between system systems. Furthermore, IMS LIS offers a subset called OneRoster (figure 5) which centers around the needs of organizations to exchange information through a CSV file format. (Bakhoyi et. al., 2017) The last standardization described in figure 5, IMS CA, instead provides a flexible standard that aims to capture learning events in a standardized and interoperable way (Bakhoyi et. al., 2017). It is a technical specification that identifies a structured set of vocabulary assisting institutions in collecting learning data from digital resources and learning tools.

2.4.4 ADL

The most recent e-learning standard definitions were published in 1997 by the ADL, which is a creation of the White House Technology Department (Bakhouyi et. al., 2017). The overall objective of ADL is to implement and develop an effective next generation of distributed learning science techniques and technologies via research, development, and collaboration. Furthermore, the ADL seeks to develop and assess prototypes that can enable more high-impact, efficient, and affordable learner-centric lifelong learning solutions. (ADL, 2010) As well as IMS, the ADL initiative also utilizes the elements and structures of IEEE's LOM (Stratakis et. al., 2003)

Notable ADL e-learning contributions include the SCORM and xAPI (Experience API). SCORM is a widely identified and accepted collection of standards built upon the work of other standardization bodies such as previously discussed AICC, IMS, and IEEE (Adina, 2007). SCORM was created in 2001 to respond to the high-level standards of DoD (Department of Defense) systems - enabling online learning material to become accessible, interoperable, reusable, and durable. SCORM defines standards for interoperability between LMSs and learning content for learning content can be exchanged among LMSs (Poltrack et. al., 2012).

Even though the evolution of SCORM has been imposingly positive, the increasing demand for more advanced practice guidelines regarding the capabilities to exploit the tracing data and tracking of learning experiences has made it become in many ways inefficient. (Bakhouyi et. al., 2017) These challenges have been the driving force for ADL to grant a Broad Agency announcement to Rustici Software to contribute the research for the creation of the new standard as a new generation of SCORM. As a result, a Tin Can API or xAPI has been designed to better meet the needs of monitoring, tracking, and analyzing learning experiences more efficiently and replace SCORM. (Poltrack et. al., 2012; Šimić. et. al., 2019)

Despite providing multiple enhancements and updates to SCORM, xAPI has its limitations, especially in determining the content to contain in an LMS. These challenges have led to the joint effort of ADL and AICC to develop the CMI-5 specification (figure 3) to combine the features of xAPI and SCORM to provide a more robust, flexible interoperability solution adaptable to today's technologies. Essentially CMI-5 is a specification with the purpose to provide all the functionality of xAPI while resolving gaps identified in earlier versions of SCORM. Both the xAPI, SCORM, and CMI-5 specifications are discussed more deeply in the next chapters. (Bakhouyi et. al., 2017; Pérez-Colado et. al., 2021)

3. XAPI

3.1 Tracking data

Learning institutions today more than ever require accurate data to continually assess performance and improve the increasing number of e-learning experiences they are providing. The analysis of learner interactions in an e-learning context facilitates the visualization and understanding of their behaviors to improve the learning experiences, better meet the changing learning requirements and needs and enhance overall learning. By tracking and analyzing e-learning data, learning institutions can obtain valuable insights into how learners are interacting with learning content, how long they're spending on each task, and what topics they need more support with. This information can be utilized for example to understand learners more comprehensively, tailor teaching strategies, and identify at-risk learners. (Blancko et al., 2013)

Learning Analytics (LA) refers to the collection, measurement, analysis, and reporting of learner-related data with the objective of understanding and optimizing learning and learning environments. The high-level purpose of LA is to analyze educational data obtained from learner interaction for different intentions such as searching patterns or issues in learner performance. (Blancko et al., 2013) LA is a broad concept covering various aspects and processes. However, there can be identified five fundamental steps common for LA regardless of approach: collect, report, predict, act, and refine. Each of these steps builds on the previous ones; therefore, data collection can be identified as critical to successful analysis. (Campbell et al., 2007, pp. 42-57)

Learning experiences today are increasingly taking place within LMSs deployed by educational institutions (Paulsen, 2003, pp. 134–148) Within these versatile environments, learners can interact with different types of digital content such as social media, online exercises, and games. Each individual interaction provides one or more data points, to enable learning systems to collect vast amounts of data on learner actions, learning content, and tools. However, many of the LMSs today are lacking standardized data structures to manage this data properly; thus, multiple LA tools prefer to be bound to explicit implementations of LMS. This sets up several issues: data collected across different systems, LMSs, or even different versions of the same LMS, are difficult to transfer and unify; cross-system data comparison is rigid, due to installation-specific data model differences; and adoption of required tools for LA can remain relatively low. (Blancko et al., 2013)

The growing interest in LA is a direct consequence of the increased access to e-learning systems, to harness the large amounts of data that these systems generate for educational purposes. To improve the effectiveness of LA it should be considered broad-based, multi-sourced, contextual, and integrated. (Siemens et al., 2011) To fulfill this objective, multiple issues ranging from data access and acquisition to network relationships should be tackled. Therefore, there is a certain demand for common and standardized structures into which these data can be stored, managed, and associated services to query it. (Blancko et al., 2013)

The primary objective of e-learning standards and specifications is to provide interoperability for digital content and learning tools among different e-learning systems (Santos et al., 2015, pp. 976-996). When these standards describe models for learner interaction data, their adoption can't be considered anything but beneficial for LA. Conversely, development costs can be reduced since tools can be expected to continue to run if they adhere to the standards. Conversely, the decoupling of LA tools from specific systems facilitates data reuse and broadens the pool of data that can be analyzed and explored. furthermore, stable data standardization-enabled data sources and structures can allow adopters to bear down on other issues, such as better analysis of data. (Blancko et al., 2013)

Multiple educational organizations and institutions have combined efforts to develop standards for e-learning content (Friesen, 2005, pp. 23–31, 2005). To take maximum advantage of LA, e-learning standards should however respond to defined interoperability and flexibility issues. First, the data model structure should be able to represent both student-performed actions with a given outcome and student profile. With these two basic categories, as well as suitable means of aggregation and summarization, more complex data can be built. Furthermore, there should be data structures to provide API methods to access and share data among systems, repositories, and reporting tools efficiently. (Blancko et al., 2013)

3.2 What is xAPI

For well over a decade, SCORM and AICC before it, have provided the e-learning industry standards for tracking data about e-learning events. SCORM, in all its incarnations, has been a constant within the e-learning industry offering, universal and extremely versatile reporting and recording standards, which have ensured compatibility across most platforms. (Torrance & Houck, 2017) However, the learning process today is becoming more and more digitized, and can consider more advanced activities such as online and offline training, social collaboration, and games. With the increasing heterogeneity of learning activities, the tracking of learning and learner behavior is becoming more challenging. Therefore, many e-learning standards and specifications have started to become in many ways outdated and lack the capabilities to respond to the demands of the digitalizing learning community. (Bakharia et. al., 2016)

Even though the development of the SCORM has been favorable it has still started to lack mechanisms and means for monitoring learning experiences, tracking learning data, and mobile supporting features and services efficiently. To overcome these limitations and challenges, the ADL Initiative decided to begin investigating more standardized experience-tracking capabilities to be capable of supporting emerging devices and more advanced technologies. In 2011 a contract to Rustici Software was issued to refine a proposed baseline technology approach called Project Tin Can, which resulted in the first designs for xAPI. The Tin Can API was realized by Rustici Software and renamed to Experience API (xAPI) in April 2013. (Torrance & Houck, 2017)

xAPI is a technical specification to facilitate how to send, store, and retrieve a wide range of different learning and performance activities or experiences and subsequently share them across platforms. xAPI defines a structure for describing learning activities and specifies how these descriptions can be exchanged electronically. (ADL, 2020) Different experiences or learning record statements are sent from a variety of sources known as learning record providers (LRP) or activity providers, and they can be exchanged electronically by transmission over HTTP or HTTPS to a specific database called a learning record store (LRS) (Labba et. al., 2020)

The symbol “x” in xAPI refers to “experience.” According to Torrance & Houck, (2017), this implies the capability of xAPI to deal with learning experiences that are not only limited to e-learning, unlike SCORM and AICC but cover a much wider variety of learning experiences. The “API” part in xAPI instead stands for application programming interface, referring to the rules for data interchange across software systems as they interact and share data. (Torrance & Houck, 2017) xAPI has four REST (REpresentational State Transfer) APIs. A Statement API focuses on how to input a statement into an LRS or transfer statements into another system. Different activities are identified in the Activity Profile API which is utilized in any scenario where interaction between learners is required to store activity-wide documents that aren’t specific to an individual learner. Activity states are managed by the State API, which enables resuming an activity between sessions. Different users are identified by the Agent Profile API, even if using different accounts and statements are managed by the Statement API. (Manso-Vázquez et. al., 2018) xAPI provides a standard for tracking and collecting data on events that are linked to different learning experiences. It is designed to underpin the standardization and collection of distributed learning activities, both formal and informal, enabling simple discovery of learning behavior, and making it possible to formalize, store and retrieve learning experiences in a virtual environment. (Hamzah et. al., 2015, pp. 113-118; Kevan & Ryan, 2016, pp. 143-149; Bakharia et. al., 2016, pp. 378-382) Even though designed based on SCORM xAPI differs in many ways from it and other previous interoperability specifications. Instead, it is by itself a different definition, allowing the collection, distribution, and retrieval of information about a learner's experiences either offline or online. xAPI extends the functionality of SCORM by enabling more advanced data collection, versatility with platform transitions, and tracking of numerous types of learning experiences and resources such as mobile learning, simulations, games, and real-world activities flexibly (Zapata-Rivera & Petrie, 2018)

The operational policy of xAPI is based on tracking a wide range of different learning experiences (Kevan & Ryan, 2016, pp. 143-149). These activities are tracked and collected by Learning Record Provider (LRP) in a specific form to an LRS for different Learning Record Consumers (LRC) to comprehend and compare across a wide range of contexts, systems, and technologies (Torrance & Houck, 2017). This learning records tracking flow is described in figure 5.

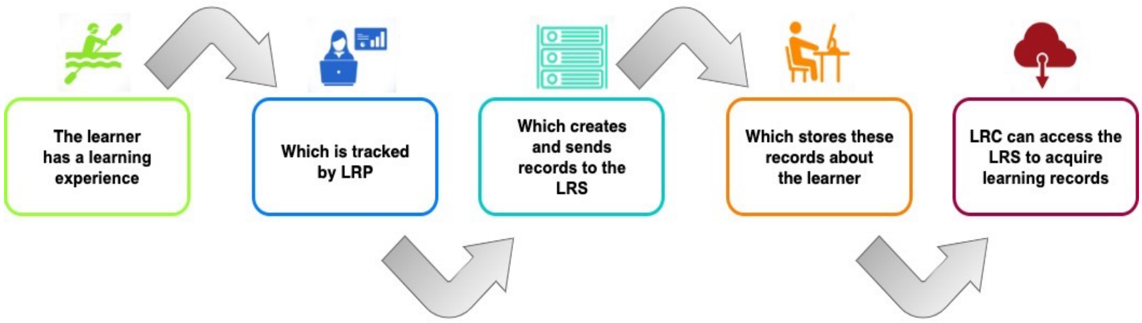

Figure 5. *xAPI data flow*

Initially, a learner is considering some sort of learning experience taking place independently online or offline (fig. 5). This experience is tracked, on the learner's behalf, by a dependable LRP. The LRP can furthermore oversee a trusted relationship between the activity and the learner which might even include launching content for the learner and managing digital rights associated with the content. The LRP makes learning records based on the tracked experiences and sends them to one or more LRSs which can store these records and make them available to any authorized client. Finally, these clients called LRCs can access learning records and utilize them for different purposes. (ADL, 2013)

In xAPI, a learning experience is captured as a statement in the form of a sentence ‘‘I did this’’ by LRP and then stored in an LRS in chronological order. The main elements or properties of the statement are called *the actor, the verb, and the object*. (Manso-Vázquez et. al., 2018) The actor represents performing an action within an Activity and therefore refers to "I" in "I did this". The verb is the action performed by the actor within the Activity within a statement and represents the "did" in "I did this". The object is the element on which an action was taken by the actor and forms the “this” part in “I did this”. As the actor properties typically refer to existing individuals, and the verbs prefer to have an explicit existing definition, objects are more likely to be defined by the systems reporting statements. (ADL, 2013) These three properties form the basis of the xAPI statement, but they can be completed with different optional elements that contain detailed information about the statement. (Manso-Vázquez et. al., 2018)

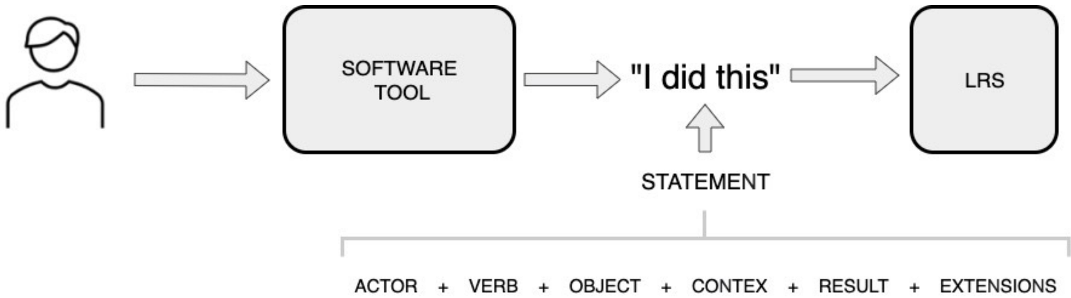

Figure 6. *xAPI Activity design (Manso-Vázquez et. al., 2018)*

Understanding how a single Activity is defined and described plays a major role with xAPI. An Activity is a type of object describing something with which the actor element interacted and can therefore be a unit of instruction, experience, or performance that is to be tracked in meaningful combination with the verb. Interpretation of single Activity is wide, referring that Activities can even be tangible objects. In the statement "I did this", the “this” constitutes the Activity in terms of the xAPI Statement. Activities can however include almost anything worth tracking such as movies, e-learning courses, or simulations. (ADL, 2013)

Unlike its predecessors, xAPI can track any online or offline learning activity such as watching a video, reading an e-book, or even real-world job performance, that a learner undertakes. With xAPI, basically everything the learner does which is considered worth tracking can be tracked. For example, experiences or events like video parts a learner skipped through the economy course or tools that were used first in a VR simulation of a neurosurgery procedure can be tracked and collected for educational purposes. (Torrance & Houck, 2017) The stored data can be utilized by learning providers to monitor learners' progress in general activities or more specific skills, facilitating their evaluation (Betts & Smith, 2016).

3.3 xAPI – activity statement design

xAPI enables learning activity to be captured as a statement in terms of a sentence. Generally, these statements are considered structured data about different learning activities. They constitute the core of the xAPI and describe the learning events of an LMS. At the very least, a single xAPI statement includes data about the actor (e.g., student), verb (e.g., participated, played), and object (e.g., video, e-book) but also contextual information about almost anything else worth tracking. (Manso-Vázquez et. al., 2018) Much like the grammar of a language, the shared rules of the structure of the statement provide the mechanism by which humans can understand each other more easily, no matter what they are saying (Torrance & Houck, 2017). xAPI statements could be for example:

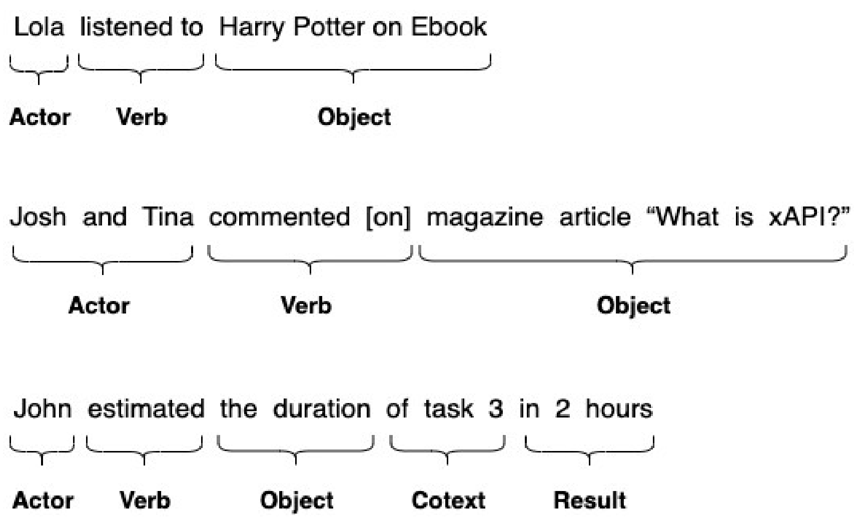

Figure 7. *xAPI Activity Statement*

xAPI inherits from Activity Streams the nomenclature and the concept of the statement, but the overall structure is diverse (Torrance & Houck, 2017). Figure 7 describes the main properties of a statement including *the actor, the verb, and the object*. The actor property describes the subject of the statement. It captures the persons that triggered the event, e.g.," Lola" and" John" of the examples presented above. The verb property stores the predicate of the statement, e.g.," read" or" interacted with". The object property includes information about the activity that the user(s) is completing in different forms.

xAPI can be identified as learner-centered, meaning that the actor is always the learner, the verb is the action of the learner, and the activity is relatively flexible to include only limited information about the learning environment and process. (Manso-Vázquez et. al., 2018)

The main properties of the statement (the actor, the verb, the object) can be completed with different optional properties such as the context, the result, and the extensions. There can furthermore be identified several other formal properties, such as the authority, the attachments, the id, and the timestamp, that can be included as parts of the xAPI statement. (Torrance & Houck, 2017) All these generally identified statement properties as well as their specific descriptions and necessities are listed in table 3 which gives a high-level view of the xAPI statement content.

Table 3. *xAPI Statement properties (ADL, 2013)*

Property	Type	Description	Required
id	UUID	UUID assigned by LRS if not set by the LRP.	Recommended
actor	Object	Whom the Statement is about, as an Agent or Group Object.	Required
verb	Object	The action taken by the Actor.	Required
object	Object	The thing that was acted on as an Activity, Agent, or another Statement	Required
result	Object	Further details representing a measured outcome.	Optional
context	Object	Provides a place to add contextual information to a Statement that gives the Statement more meaning	Optional
timestamp	Timestamp	Timestamp of when the events described within this Statement occurred. Set by the LRS if not provided.	Optional
stored	Timestamp	Timestamp of when this Statement was recorded. Set by LRS	Set by LRS
authority	Object	Agent or Group asserting that the Statement is true. Verified by the LRS based on authentication. Set by LRS if not provided or if a strong trust relationship between the Learning Record Provider and LRS has not been established.	Optional
version	Version	The Statement's associated xAPI version	Not recommended
attachments	Ordered Array of Attachment Objects	Headers for Attachments to the Statement	Optional

As table 3 describes, the only required properties in a proper xAPI statement are the actor, the verb, and the object. These three elements are essential, but a statement can furthermore include other properties to complement it (Vidal et. al., 2015). According to ADL (2022), it is in many ways recommended to populate optional properties on top of the essential ones whenever it is possible and relevant. Table 3 also represents some properties that are not included in the statements during the actual designing phase but are added to the statement later. For example, when the statement is returned from the LRS it is included with some additional properties such as the stored property added by the LRS. (ADL, 2013)

Statements form the core of xAPI. They dictate the format for the specific moments in a stream of activity. They express an activity that has transpired, or may be transpiring, and generally have a desirable human-readable translation such as the ones described in figure 7. (Simao et. al., 2018) The xAPI statements are built using XML language where the syntax used is JSON (JavaScript Object Notation). Code example 1 below describes an example of a simple xAPI statement where all statement design required properties are represented (table 3). (Bakharia et. al., 2016)

```
"actor" : {
      "mbox" : "mailto:example@hostname.com",
},
"verb" : {
      "id" : "http://hostname.com/xapi/verbs/completed",
      "display" : {
            "en-US" : "completed",
      }
},
"object" : {
      "id" : "http://hostname.com/website"
}
```

Code 1. *Simple xAPI statement with the required properties*

3.3.1 Actor

The xAPI specification is designed for recording information related to experiences. This however requires the assumption that someone, or a group of someone's, must be the experiencer of this information. (Torrance & Houck, 2017) In the xAPI statement structure, the experiencer can be identified with the *actor* value, which describes who is completing the experienced action. The actor is the subject of an xAPI statement that can be a single individual or a group of named or anonymous individuals. When the actor describes a single individual, it can be referred to as an *Agent*. When consisting of multiple individuals, it can be considered a *Group*. A Group property is therefore either a collection of identified Agents, or it can be defined as "anonymous." (ADL, 2013)

The actor property object can be considered either an Agent or a Group depending on the number of individuals or systems it describes. As already discussed, an Agent is either an individual persona or a system. Ultimately xAPI statements are made up of different properties that have values assigned to them. (ADL, 2013) Table 4 represents these main properties as well as their clarified descriptions when the actor property is an Agent.

Table 4. *Actor object properties when the objectType is an Agent (ADL, 2013)*

Property	Type	Description	Required
objectType	UUID	(Agent). Optional except when the Agent is used as a Statement's object.	Optional
name	Object	The Agent full name	Optional
IFI (Inverse Functional Identifier)		An IFI unique to the Agent.	Required

A Group value behaves much like an Agent and can be used in most of the same situations an Agent can. However, unlike an Agent, it describes a collection of individuals or Agents. The xAPI specification identifies two different types of Groups called *Anonymous Groups* and *Identified Groups*. An Anonymous Group describes a cluster of individuals where there is no ready identifier for this cluster, e.g., an ad hoc team. (ADL, 2013) Table 5 represents the main properties of the actor property having an *objectType* of Anonymous Group as well as other related properties and values.

Table 5. *Actor object properties when the objectType is an Anonymous Group (ADL, 2013)*

Property	Type	Description	Required
objectType	String	(Group)	Required
name	String	Group name	Optional
member	Array of Agent objects	The members of this Group as an unordered list.	Required

Unlike an Anonymous Group, an Identified Group is utilized to uniquely identify a cluster of Agents. It can be used for example when the LRPs wish to issue multiple Statements, aggregate data, or store and retrieve documents relating to a group. Table 6 represents the main properties of the actor property being an Identified Group as well as the related values and types. Compared to the Anonymous Group, an Identified Group does not require a “member” property listing constituent Agents. Instead, it must include exactly one IFI to refer to the unique Identified Group. (ADL, 2013)

Table 6. *Identified Group properties (ADL, 2013)*

Property	Type	Description	Required
objectType	String	(Group)	Required
name	String	Group name	Optional
member	Array of Agent objects	The members of this Group as an unordered list.	Optional
IFI (Inverse Functional Identifier)		An IFI unique to the Group.	Required

As tables 4 and 6 describe, the Agents and Identified Groups are uniquely identified by certain *IFI*s (Inverse Functional Identifier) for data to be stored and retrieved against them. These identifiers can take several forms for Agents and Identified Groups, with an e-mail address or mbox typically being the most easily understood. (ADL, 2013) Along with the raw human readable e-mail address, an Agent or Group can be identified by some other IFI properties that are described in table 7.

Table 7. *IFI properties (ADL, 2013)*

Property	Type	Description
mbox	mailto IRI	Only email addresses that have only ever been and will ever be assigned to this Agent, but no others.
mbox_sha1sum	String	The hex-encoded SHA1 hash of a mailto IRI (i.e. the value of an mbox property)
openid	URI	An openID uniquely identifying the Agent.
account	object	A user account on an existing system e.g. an LMS

Finally, a code example below illustrates an actual JSON formed xAPI statement Agent identified by an abstract mbox that can be shared with LRS.

```
actor" : {
       "ObjectType" : "Agent",
       "name" : "Test Learner",
       "mbox" : "mailto:example@hostname.com"
}
```

Code 1. *The Actor object with main properties in JSON format*

3.3.2 Verb

Verbs describe the action performed during the learning experience. They are crucial statement elements, as they describe just what has happened between the actor and object. (Kevan & Ryan, 2016) The operating policy of xAPI is generally based on reporting the different actions in past form; therefore, the verbs are universally expressed in the past tense. The xAPI specification does not individually specify any specific verbs but instead defines how to create them for the communities of practice to establish meaningful verbs for their members and make them available to anyone. (ADL, 2013)

Verbs appear in xAPI statements as objects consisting of two fundamental properties called an *IRI* (Internationalized Resource Identifier) and a *Language Map*. IRI resembles a typical URL (Uniform Resource Identifier) but is more general. Practically it is a distributed and structured identifier used to describe the location or unambiguous name of a particular piece of information. (Shieh & Reese, 2016) Language Map instead refers to a set of display names corresponding to multiple languages or dialects, providing human-readable meanings of the verb (Vázquez et. al., 2015; (ADL, 2013). Table 8 below describes both properties as well as their descriptions.

Table 8. *Verb object properties (ADL, 2013)*

Property	Type	Description	Required
id	IRI	Corresponds to a Verb definition. Each Verb definition corresponds to the meaning of a Verb, not the word.	Required
display	Language Map	The human readable representation of the Verb in single or multiple languages. Aims to provide a human-readable display of the meaning already determined by the chosen Verb.	Recommended

Such as the actor, the verb property is also a required part of the xAPI statement. As table 8 describes, the verb object can however consist only of an *id* property pointing to a specific IRI. The *display* property that consists of a Language Map is not required but anyhow a recommended value to have since they are central to giving the xAPI specification API internationalized data interoperability. (ADL, 2013) The actual JSON formed xAPI statement example below describes the verb object with the discussed required and recommended properties in table 8.

```
"verb" : {
       "id" : "http://hostname.com/xapi/verbs/completed",
       "display" : {
              "en-US" : "completed"
       }
}
```

Code 3. *The Verb object with main properties in JSON format*

The xAPI specification (1.0.0) allows any full IRI to be utilized as a verb. Originally the xAPI specification provided a specified list of verbs, which became a part of the initial versions of the xAPI. This however raised a challenge that a predefined list of the verbs would be limited by definition and might not be able to effectively capture all possible future learning experiences. Therefore, now the process of creating verbs is defined so that communities of practice can establish semantic verbs for their members and make them freely available to anybody. The only exception for this is the reserved verb “voided”, which is utilized to invalidate a statement. Even though the process of creating verbs is outsourced to expand the possibilities of capturing experiences, the xAPI provides a specific “Experience API Registry” that provides an initial set of verbs published by ADL. Furthermore, the registry works as a place to store and add verbs, along with a place for verbs’ IRIs to resolve.

3.3.3 Object

The object property defines the thing that was acted on. If the actor element describes the people and the verb element the action, the object or activity is related to what is being acted on. (Manso-Vázquez et. al., 2018) It can be a single learning experience, an entire course, or any component within it, such as a quiz question, an interaction, or a media element. An object can furthermore be another individual, such as a teacher or coach. Like the actors, the objects are uniquely identified and like the verbs, they should have commonly clarified definitions to reduce ambiguity. While the actors are related to people and the verbs are typically carefully selected, the objects are much less finite and therefore provide a lot of room for growth and creativity. (Torrance & Houck, 2017, pp. 6-7)

The object property can be either an Activity, Agent, Group, or Statement. Agent and Group values behave as the corresponding actor values in tables 4, 5, and 6. The statement objectType instead can have two distinct values called *SubStatement* and *Statement Reference*. If not specified, the ObjectType is assumed to be Activity. (ADL, 2013) Some examples of different object types:

- "Jerry read a book about coding." (Activity)
- "Lola discussed with Jerry." (Agent)
- "Josef commented on 'Jerry read a book about coding.'" (SubStatement or Statement Reference)

As the example above represents, the properties of the object property change according to the objectType. The following table 9 below lists the object properties when the objectType is an Activity.

Table 9. *Object properties when the objectType is an Activity (ADL, 2013)*

Property	Type	Description	Required
objectType	String	Have to be Activity when present	Optional
id	IRI	An identifier for a single unique Activity	Required
definition	Object	Metadata	Optional

As table 9 describes the id property pointing to a specific IRI is generally the only required value to have when the objectType is Activity. Therefore, it must be unique and always reference the same Activity. However, even though the objectType property is considered optional property, it must always be identified as an Activity when the Activity is present. (ADL, 2013)

The last optional property for objectType Activity is the Activity definition object which consists of metadata. Metadata in this context refers to different properties such as name, description, and type that aim to expand and explain the visual name and other information related to specific Activity. Metadata can furthermore consist of certain interaction properties or extensions such as interactions with possible responses. (ADL, 2013)

The code example below illustrates a simple JSON-formed xAPI statement object field with the main properties when the objectType is defined as Activity.

```
"object" : {
        "objectType" : "Activity",
        "id" : " http://hostname.com/website"
        "definition": {
                "name": "en-US": "An xAPI Statement Example"
        }
}
```

Code 4. *The Object field with objectType of Activity in JSON format*

As discussed before, an objectType can also be an Agent or Group. In that case, the properties of the object field follow the details of the actor object regarding Agents and Groups listed in tables 4, 5 ad 6. In the case of objectType being a Statement, there are generally two possibilities. First, the object can take on the form of a statement that already exists by using a Statement Reference. A typical use case for Statement References is grading or commenting on an activity that could be tracked as an independent event. (ADL, 2013) Table 10 describes the properties of a statement when the object type is StatementReference.

Table 10. *Object properties when the objectType is StatementReference (ADL, 2013)*

Property	Type	Description	Required
objectType	String	Must be StatementRef	Required
id	UUID	The Statement UUID	Required

As table 10 describes both the objectType property with the value StatementRef and the id property with the UUID of a Statement are required values and therefore must be specified. For example, assuming that some statement has already been stored with the id “9f95eede-bb56-3c2e-ab93-33992cf22df0” the code example below simply illustrates how a simple comment could be issued on the original JSON formed statement, using a new statement.

```
"object" : {
```

```
            "objectType" : "StatementRef",
            "id" : "9f95eede-bb56-3c2e-ab93-33992cf22df0"
      }
```

Code 5. *The Object field with objectType of StatementReference in JSON format*

In addition to a Statement Reference, the object property can form a completely new statement by using a SubStatement. The JSO formed xAPI statement example below describes an example of the object field with the objectType of SubStatement.

```
"object" : {
      "objectType" : "SubStatement",
      "actor" : {
            "objectType": "Agent",
            "mbox" : "mailto:example@hostname.com"
      },
      "verb" : {
            "id" : "http://hostname.com/intended",
            "display" : {
                  "en-US" : "will watch"
            }
      },
      "object" : {
            "objectType" : "Activity",
            "id" : "http://hostname.com/website",
            "definition" : {
                  "name" : {
                        "en-US" : "A Test Video"
                  }
            }
       }
}
```

Code 6. *The Object field with objectType of SubStatement in JSON format*

A SubStatement reminds a Statement Reference in that it is included as part of a containing Statement, but unlike a Statement Refefence, it does not describe an event that has occurred. Instead, it can be utilized to represent, for example, a prediction of a potential future statement. Because the SubStatement generally refers to a brand-new statement, its properties are equal to statement properties already discussed in tables 3-10 depending on the situation. (ADL, 2013)

3.3.4 Other statement elements

So far, the three required properties of the xAPI statement, the actor, the verb, and the object, have been discussed. The proper statement however can consist of multiple other properties that can include other descriptive information, conditions present, people involved, time, score, correct values, and more. Other properties can even include references to other objects such as images, videos, and documents in other storage locations. (Torrance & Houck, 2017) Therefore, even though the emphasis in the xAPI statement design focuses on the actor, the verb, and the object fields, the other property fields with optional or recommended values can store a great deal of additional data in these parts of the statement (ADL, 2013). These properties and their values are represented in tables 1, 11, 12, and 13.

The id property (table 1) stores a UUID (Universally Unique Identifier) value. Practically the UUID stands for statement identification to guarantee their interoperability and can be utilized for example for retrieving specific statements. For xAPI statements to provide interoperability they first must be transferrable between LRSs. Therefore, the id properties must be universally unique or never collide with ones generated by other systems. Furthermore, all statements stored in an LRS must have an id property. The statement id's are highly recommended to be generated by the LRP, but they must at least be generated by the LRS itself if a statement is received without them. (xAPI, n.d.)

The *result* property describes a measured outcome related to the statement it is included. For example, in the statement "Thomas started the exam," proper result property can't be identified. Thomas did start the exam, but it is impossible to know at that time how well he is going to do. However, later it might be possible to see the statement "Thomas passed the exam with a score of 80." The *score* value is one of the properties of the result object in an xAPI Statement to indicate the outcome of the Agent in relation to the success of the experience. (ADL, 2013) All result object properties as well as their values are described in table 11.

Table 11. *The result object property values (ADL, 2013)*

Property	Type	Value	Required
Result	Object	score	Optional
	Boolean	success	Optional
	Boolean	completion	Optional
	String	response	Optional
	Duration	duration	Optional
	Object	extensions	Optional

Another optional statement property containing multiple optional values is the *context* property. It provides optional information related to the context of the action such as parent activity, instructor, or platform as table 12 describes. (Manso-Vázquez et. al., 2018) Practically it enables adding contextual information to a statement by storing information such as a trainer for an activity if the activity took place as part of a team-based Activity. (ADL, 2013) Any activity that is set as context can be classified into different optional groups including *parent, grouping, category*, or *other*. For example, for the statement ''Jesse answered 4/6 to question 2 of Physics test from 3rd-grade course'', the object is the question, the parent context is the test, and the grouping is the course. (Kevan & Ryan, 2016)

Table 12. *The context object property values (ADL, 2013)*

Property	Type	Value	Required
Context	UUID	registration	Optional
	Agent or Group	instructor	Optional
	Group	team	Optional
	contextActivities Object	contextActivities	Optional
	String	revision	Optional
	String	platform	Optional
	String	language	Optional
	Statement Reference	statement	Optional
	Object	extensions	Optional

The *timestamp* property (table 1) is a single mechanical item of xAPI specification that enables xAPI to work in an offline mode. It is a string value that indicates when the statement was created and whose intention is to capture when the experience occurred. When offline, statements can be created with an accurate timestamp value even though they will not reach the LRS immediately. (ADL, 2013) Different reporting tools can then exploit this property to efficiently order what happened. Along with the timestamp, the *stored* property (table 1) follows the same ISO8601 format as the timestamp but has a very different meaning. It describes the mechanics of the API and as such is set by the LRS when that LRS receives the statement. It is later utilized via the statement API's query resource to provide the statement stream in one specific order and optionally include only a range of statements. (xAPI, n.d.)

The *authority* is a formal property, which specifies who assures the truthfulness of the statement and Attachments (Manso-Vázquez et. al., 2018). Generally, it represents how that statement ended up in the LRS and correspondingly suggests the level of trust of that statement. The Authority property is typically set by the LRS, but it has an object value. Practically, it contains either an Agent or Group object described in tables 4, 5, and 6. When the statement is stored using 3-legged Oath Authentication, the value contains a non-identified Group with members for the user and application. Otherwise, it contains an Agent value describing the user connecting to the LRS. (xAPI, n.d.)

In the xAPI context, attachment processing is handled through the *attachments* property (table 1) (xAPI, n.d.). An attachments object is considered an extra part or extension that is or may be attached to the statement to perform a particular function. It could include for example an essay, a video, or a certificate that was granted because of a certain experience. The attachments object is expedient property to store different attachments and retrieve them from an LRS. (ADL, 2013) Table 13 below lists all properties of the attachment object.

Table 13. *The attachments object property values (ADL, 2013)*

Property	Type	Value	Required
Attachments	IRI	usageType	Required
	Language Map	display	Required
	Language Map	description	Required
	Internet Media Type	contentType	Required
	Integer	length	Required
	String	sha2	Required
	IRL	fileUrl	Optional

The last described property in table 1 is the *version*. According to xAPI (2022), as one of the latest additions to the xAPI statement specification, it can support LRCs to get their bearings. As its name suggests – it refers to the version of the API that was in use when the statement was recorded. It can be utilized by systems consuming the statement stream to properly parse and otherwise handle the statement structures without having to make assumptions about the statement version from its structure. (xAPI, n.d.) Generally, the version property is set by the LRS, reserving pre-setting of its value for LRS-to-LRS transfers. It was introduced by the 1.0.0 xAPI specification and therefore statements retrieved from an LRS using the prior draft specifications do not include this property. (ADL, 2013)

The code example below describes a full JSON-formed xAPI statement with already discussed required properties as well as multiple optional ones.

```
{
      "id" : "12345678-1234-5678-1234-567812345678",
      "actor" : {
            "mbox" : "mailto:example@hostname.com",
            "name" : "Test Learner",
```

```
            "objectType": "Agent"
      },
      "verb": {
            "id": " http://hostname.com/xapi/verbs/attended",
            "display": {
                  "en-US": "attended"
            }
      },
      "object": {
            "id": "http://www.example.com/meetings/occurances/12345",
            "objectType": "Activity",
            "definition": {
                  "name": {
                        "en-US": "test appointment "
                  },
                  "description": {
                        "en-US": "A test appoitment with example learner"
                  }
            }
      },
      "result": {
            "success": true,
            "completion": true,
            "response": "Few test actions were made."
      }
       "context" : {
            "platform" : "Test virtual meeting software",
            "language" : "tlh"
      }
      "timestamp": "2022-12-01T12:00:00"
      "stored": "2022-12-T12:00:00",
}
```

Code 7. *A full xAPI statement with required and optional properties in JSON format*

The basic xAPI statement (code 1) is very useful for storing general information about learning activities and outcomes. However, as code example 7 illustrates a huge amount of additional information can furthermore be stored and accessed by using different optional property fields. When additional data is mixed with learning experience data, a lot more opportunities for understanding additional characteristics about the learner or learning environment can be discovered, which can lead to formulating more comprehensive and accurate learning analytics.

3.4 LRS

The LRS is at the heart of the xAPI infrastructure. It is responsible for receiving, storing, and returning all learning activities-related data, achievements, and work performances. All experience-based records generated from xAPI are exchanged and stored in LRS. (Bakhouyi et. al., 2017, pp. 1-8; Zotova et. al., 2021). These records can then be accessed by different educational parties and e-learning systems like LMSs or other reporting tools and be subsequently utilized for example as a data source for analytics. (Labba, et. al., 2020)

Fundamentally, LRS is a required tool to do anything with xAPI. (xAPI, n.d.) LRS databases utilize the xAPI format and consider the xAPI statement form of “Actor + Verb + Object”. Therefore, the data obtained by LRS is already broken down into very easily understood chunks when it is being reviewed. (Zotova et. al., 2021) Furthermore, LRSs enable the hosting of activities by various activity providers. Therefore, it doesn’t matter whether the data comes from a real-life work experience, a mobile application, or an offline activity, it can be stored in the same statement format in the LRS. (Labba, et. al., 2020)

An LRS enables modern tracking of a wide range of learning activities time and location independently both online and offline. They can store learning data from a variety of activity types ranging from mobile apps and games to real-life working experiences. Data stored in the LRS from these activity types as a series of statements can then be shared with other management information systems that provide advanced reporting or support adaptive learning experiences. (Bakhouyi et. al., 2017) In addition to tracking, storing, and sharing capabilities, the functionalities of LRS can furthermore include various analytical features like dashboards and reports to interpret and extrapolate insights from the data. (xAPI, n.d.)

3.4.1 LRS vs LMS

Even though LRSs can include analytical features they are based on a cloud-based service that only covers the storage and retrieval of learning data (Bakhouyi et. al., 2017). Therefore, LRSs do not share many of the LMSs functionalities discussed in previous chapters and generally can’t act as a substitute or replacement for them (Berking, 2016). The following list provides a few general functions of LMS complemented with the main LRS functions bolded (xAPI, 2022; Berking, 2016):

- Delivery – on-demand delivery of learning content and activities
- Integration – data exchange between both internal and external systems to facilitate monitoring of learner performance and transfer of learner data
- Interaction – interaction between learners and the content as well as communication between learners, learning providers, and other relevant parties
- **Record keeping – storage, retrieval, and maintenance of learning data**
- Registration – identifying, and assigning content, courses, etc. by learners and their supervisors.
- Reporting – a system of data collection and analysis about learners and courses, etc.
- Structure – centralization, and organization of different learning-related functions into one system
- Security – protection from unauthorized access to learning content, learner records, and administrative functions.
- **Tracking – tracking learner-related activity and event data for exploitation**
- Administration – concentrated management of all already discussed functions.

Even though LMS and LRS resemble each other, and their features have some overlap they distinguish from each other in many ways and therefore form two very different products. Generally, an LMS is at the core of online education activities enabling the management, documentation, monitoring, and reporting of courses, e-learning, and learning content during the learning process. In the context of delivering and tracking e-learning experiences, the LRS can instead be a valuable tool to support storing and processing xAPI data. Even though the LRS might replace and go beyond the reporting and analytics capability of the LMS, there are many other functions of the LMS that aren’t included in an LRS. (Labba, et. al., 2020; SCORM, n.d.)

3.4.2 LRS operating policy

The LRS can store the xAPI data via the already discussed four REST APIs of xAPI called a Statement API, a State API, an Activity API, and an Agent API (Manso-Vázquez et. al., 2018). A Statement API provides a way to pitch a statement into an LRS or transfer it into another system. The State API instead is responsible for saving the learning activities in progress. For example, a person could be watching a video as a learning activity and this video could be saved in an LRS with a state API. The Activity API provides storing of different scores across the users in the LRS as a document for the activity. The Agent API is in many ways similar to the State and Activity APIs, but it has a bit different purpose. It adds extra data to the LRS about individual learners. Particularly, it assists an LRS to identify users by assigning them a unique ID. (ADL, 2013)

Even though tracking and storing data in LRS is all quite technical, the basic idea behind this process is quite simple since the LRS is basically just a database. The learning records and experiences are received from multiple sources, stored, maintained, and sent forward for other tools such as LMSs to utilize. (Torrance & Houck, 2017) Figure 8 below illustrates this process at a general level.

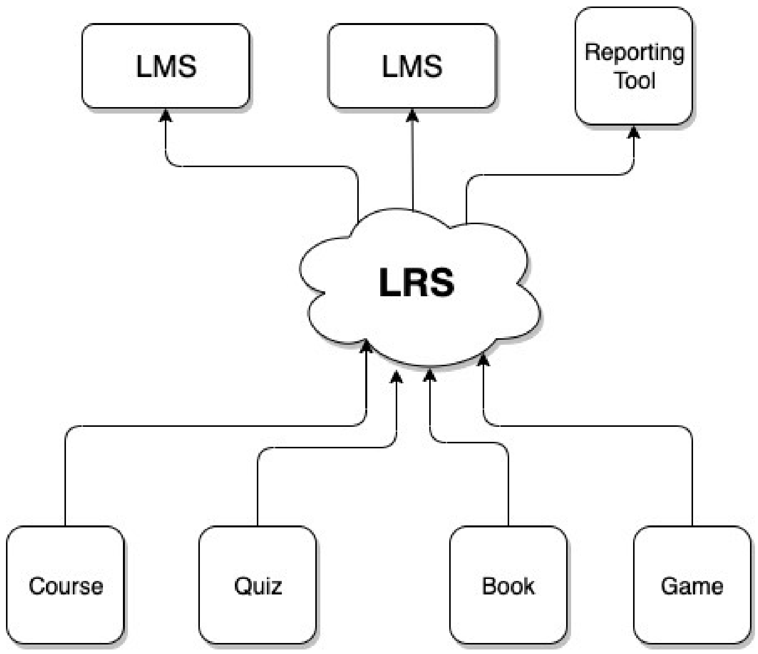

Figure 8. *LRS operating policy (SCORM, n.d.)*

After being experienced, learning activities are sent to and stored in LRSs as xAPI statements (fig. 8). These statements can be stored as individual learning records and/or entire transcripts and be accessed, retrieved, and managed by other systems such as LMSs, reporting tools, that provide advanced reporting or support adaptive learning experiences. (Zotova et. al., 2021) LRSs play a significant role in the xAPI ecosystem as every other tool which sends or retrieves learning activity data will interact with the LRS as the central store. With the xAPI statement structure the LRS is recording, there can be identified multiple data points to be reported against. Different reports can be pulled on any number of combinations of "the actor", "the verb" and "the object". (Bakhouyi et. al., 2017)

When considering the need for an LRS, it’s important to understand certain requirements and expectations. Choosing the right LRS to track the learners’ behavior and performance is essential and requires considering some key factors such as functionality, durability, and scalability of the LRS system. (Zotova et. al., 2021) Due to the increasing interest in profound tracking of learning experiences and xAPI architecture, more LRS products such as Learning Locker5, and Watershed LRS6 have made their appearance in the market. All these LRS systems offer the same basic features including recording and retrieving learning records. However, some of them provide substantiative and volatile functionalities such as visualization functions and interfacing with various external systems. (Labba et. al., 2020)

4. XAPI FEATURES

The e-learning environment includes several e-learning standards and specifications which all have their fundamental pros and cons. Many of these standards include both coherent and dissenting properties and cover multiple different concerns. Therefore, choosing the best standard or standards for use depends on the community's learning objectives and requires an adequate understanding of different e-learning standard features and peculiarities. (Bakhouyi et. al., 2017) In this research context, the evaluation of xAPI features and properties has specifically focused on comparing them with three e-learning standards—SCORM, CMI-5, and IMS Caliper Analytics. These standards and specifications play major role in the national educational e-learning context and can provide different options to meet the increasing e-learning requirements more comprehensively (Bakhouyi et. al., 2017).

4.1 Communication

For over a decade, SCORM has been the most widely used e-learning standard. It has played a significant role in e-learning by providing a set of technical standards that allows digital content to move seamlessly between different LMS at the same time giving the ability to track some data. (SCORM, n.d.) Simply put, SCORM is a web-based collection of standards that enable functionality between different course authoring software and LMSs. It consists of IMS CP for packaging and IMS LOM for metadata, and then adds a simple communication layer (Pérez-Colado et. al., 2021) (table 15). Exporting content as a SCORM package enables different e-learning systems to share it between them. (Poltrack et. al., 2012)

The main advantages of SCORM are in the field of popularity, interoperability, durability, and in supporting the reusability of LOs. SCORM enables flexibility to incorporate instructional components in multiple applications and contexts and allows different instructional components developed in one location with one set of tools to be utilized in another location with a different set of tools or platforms efficiently. (ADL, 2006, p.14) While the majority of content authoring tools today can be considered relatively straightforward and user-friendly, making SCORM content is relatively convenient. There is no necessity to have significant programming abilities for example to take a PowerPoint slideshow and add some interactive elements to turn it into a genuine e-learning course. Furthermore, as one of the main e-learning standards, SCORM is still widely supported. Whether the e-learning content is created by the learning authors themselves or it is bought from certain third parties, it is fairly common for an authoring tool or course vendor to support SCORM. In return, almost all LMS vendors support SCORM, which does content integration between legacy and new systems relatively easy. (Miller et. al., 2021)

Since SCORM was already introduced a while ago, technologies have however evolved, and learning has become more and more versatile. Therefore, many of the SCORM features that were once considered the advantages of the standard are now rather becoming limitations. Compared to newer standards such as xAPI, SCORM can’t provide enough support to adequately track both learning and performance data efficiently. (Miller et. al., 2021) It is limited to tracking browser-based online learning content and is not extensible enough to track more advanced technologies, such as games, and mobile learning activities. Furthermore, it is fundamental for SCORM content to reside in the same domain as the LMS. This can be identified as a possible bottleneck for tracking learning comprehensively enough since learning today can take place everywhere regardless of location and should be recorded whenever and however it happens. (Werkenthin, 2015)

Table 14. *Summary of xAPI and SCORM features together (xAPI, n.d.)*

Feature	xAPI	SCORM
Completion	X	X
Time	X	X
Pass/Fail	X	X
Report a single score	X	X
Report multiple scores	X	
Detailed test results	X	
No LMS required	X	
No internet browser required	X	
Use mobile apps for learning	X	
Platform transition	X	
Games & simulations	X	
Informal learning	X	
Real world performances	X	
Interactive learning	X	
Adaptive learning	X	
Blended learning	X	
Long term learning	X	
Team based learning	X	

SCORM is a great option for a technical standard to get up and running ability since the content is generally accepted by most platforms, and e-learning content creators can choose from many authoring tools and LMSs. (SCORM, n.d.) As e-learning and technologies have evolved, it however hasn't been flexible enough to stay up to date with changes (Johnson & Hruska, 2013). When comparing SCORM with xAPI (table 14), the main difference between these standards considers the capabilities of xAPI to enable the tracking of learning activity from multiple contexts online and offline, not just on the LMS. Where SCORM only enables the tracking of desktop LMS activity, xAPI allows pulling data from several sources into one common LRS. This translates to a more complete data set that demonstrates where and how learning is taking place, and, especially, where it is not. (xAPI, n.d.)

As table 14 describes xAPI enables tracking, evaluating, analyzing, and improving learning activities in a much more responsive and nuanced manner compared to SCORM (xAPI, n.d.). Generally, SCORM only enables a limited number of metrics such as course completions, total time spent, and single scores to be tracked. Compared to this, not only can xAPI track and collect more advanced activities such as mobile apps, or informal learning, but it can furthermore report and monitor things like multiple scores and open-answer responses in real-time. Insights from this kind of data can afterward provide more opportunities for example educators to analyze learning more comprehensively and build richer e-learning content. (Miller et. al., 2021)

Even though SCORM and xAPI overlap in many features they are essentially different protocols. xAPI can integrate mobile and offline learning in a way that SCORM can't. According to Clinefelter et al., (2019) report, an estimated 56% of US online college students utilized a mobile device for at least some of their learning-related activities in 2019 and the numbers were considered to increase in the future. Furthermore, learners today highly value mobile devices as collaboration tools (Dabbagh et al., 2019; Heflin et al., 2017; Tang & Bradshaw, 2016), allowing them to engage with instructors or peers at any given time or place (Ahmad, 2020; Anshari et al., 2017; Clinefelter et al., 2019; Cross et al., 2019; Fraga & Flores, 2018). While SCORM is not extensible enough to track mobile or offline learning and does not support LMS-independent content tracking it is inefficient to track all this data. Instead, xAPI enables tracking and collecting this kind of more nuanced, and more informative learning data coming from a variety of sources (Miller et. al., 2021).

4.1.1 CMI-5

Compared to SCORM xAPI enables the tracking and recording of any learning activities, wherever and however they occur in a way that SCORM simply cannot respond (Torrance & Houck, 2017). However, while the statement structure of xAPI allows capturing all kinds of data, it is only a matter of time before different systems start to meet challenges to extrapolate and analyze that data in a meaningful way without a defined vocabulary and instructions. As one solution the AICC working group has proposed a CMI-5 protocol aimed at defining how xAPI activities can be approached in launched scenarios while having the tracking flexibility of xAPI and maintaining the structure of SCORM that learning technologies have relied upon. (xAPI, n.d.)

CMI-5 specification is an xAPI Profile for using xAPI in the context of traditional launching systems or LMSs. It provides a packaging and communication layer for xAPI-based content and defines how learning resources can be tracked, imported, and launched, in a similar way to SCORM while providing more enhanced possibilities by conforming to the xAPI specification (ADL, 2013). xAPI's data tracking capabilities are virtually limitless, but without any rules, compatibility, and interoperability across systems easily become nearly impossible. To combat this, the CMI-5 specification employs controlled vocabulary, contexts, and rules for how xAPI data can interact within a specific domain and utilizes xAPI as the communication and data layer. (Miller et. al., 2021). Table 15 provides an overview of CMI-5 features compared to xAPI ad SCORM with columns grouped into metadata.

Table 15. *E-learning standards and their features (Pérez-Colado et. al., 2021)*

E-L Standard	Feature					
	Metadata	***Packaging***	***Delivery***	***Protocol***	***Report***	***L.A***
SCORM	LOM	CP	-	X	x	-
xAPI	-	-	-	-	-	X
CMI-5	Basic	X	X	X	X	X

CMI-5 replicates the functionality of SCORM, with an intention of replacing SCORM as the metadata format while incorporating xAPI. Beyond integrating xAPI, CMI-5 furthermore specifies interoperability rules for content launch, authentication, session management, reporting, and course structure definition similar to SCORM. This is necessary since the structure of xAPI defines communication between a learning experience and an LRS but does not consider the structure of e-learning content or the communication between the learning content and the system hosting that content. Furthermore, the xAPI alone does not include any authentication protocols to connect the learner to the content. Therefore, CMI-5 is a significant addition to incorporate and extend the best practices of SCORM and natively integrate them with xAPI. (ADL, 2013)

CMI-5 can record activities performed outside of an LMS just the way xAPI does, but unlike xAPI, those activities must be launched by an LMS. xAPI on its own is highly generalized and requires a defined rule set to ensure plug-and-play interoperability between different learning activities and LMSs. (Miller et. al., 2021) CMI-5 solves the LMS use case where the learning content must be launched from an LMS-based system and therefore demands defined certain rules (ADL, 2013). Despite having this feature, CMI-5 can however be implemented with all the same use cases of xAPI, including tracking learning activities completed with newer technologies and actions performed offline. Therefore, potential use cases for choosing the CMI-5 standard might include integrating learning content for example with simulations, virtual reality, gamification, or mobile applications launched from, and tracked in, an LMS. (Miller et. al., 2021)

When defining the objectives and goals for learning intentions it is important to understand the features of different standards and on that basis to choose the right standard for the right learning activities (xAPI, n.d.). Table 16 lists a few key features that organizations or communities creating or acquiring learning content should be aware of and which standards support those features.

Table 16. *Comparison of key SCORM, xAPI, and CMI-5 features (xAPI, n.d.; Miller et. al., 2021)*

Feature	SCORM	xAPI	CMI-5
Defined content launch	X	-	X
Track "anything"	-	X	X
Normalized reporting	X	-	X
Mobile apps	-	X	X
Distributed content	-	X*	X
Data portability	-	X	X
Extensibility	-	X	X
Normalized satisfaction criteria	X	-	X
Multiple lesson support	X	-	X

As table 16 describes, CMI-5 can add some SCORM functionalities to xAPI by having xAPI's tracking flexibility while maintaining the structure of SCORM (xAPI, n.d.). xAPI does not include any instructions for launching content in an LMS but CMI-5 has defined instructions for this. Due to normalized reporting, CMI-5 establishes certain rules for records or statements to include identifiers for a learner session for them to be more easily grouped for normalized reports. Furthermore, unlike SCORM, xAPI has no defined satisfaction criteria or multiple-lesson support. CMI-5 solves these by establishing interoperable rules for determining the completion or mastery of learning activities and allowing for multiple AUs in a defined hierarchy with criteria for progression, much as SCORM does with multiple SCOs. (Miller et. al., 2021)

The design of CMI-5 specification focuses on being more extensible, robust, and adaptable to today's technologies than SCORM while having all the main xAPI benefits and maintaining interoperability across systems. (AICC, n.d.) Practically, CMI-5 aims to provide xAPI's flexibility for tracking any kind of learning activities while maintaining the structure of SCORM that different learning technologies and systems have traditionally relied upon. It is specifically designed for organizations and communities to benefit from xAPI's advanced tracking capabilities while still being able to launch and use content from an LMS as well as incorporate and track learning experiences with newer technologies. (Pérez-Colado et. al., 2021)

4.2 Learning Analytics

The modern learning environment today represents social collaboration and growing technological trends where new tools and technologies have completely changed the concept of learning. As learning is taking place more and more in digital environments, the data collected and stored digitally has consequently been increasing. This has caused many legacy learning analytics tools to become many ways burgeoned and the stored data not to be able to fulfill the requirements for input data. (Nouira, 2018) Due to these challenges, ADL has defined a representation for all tools to use the same data set which has led to the development of xAPI. In response to this, the IMS has released a specification called Caliper Analytics in October 2015. IMS Caliper is xAPI related standard that enables institutions to collect learning data from digital resources to better understand and visualize learning activity and product usage data and present this information to related groups in meaningful ways. The Caliper framework can be utilized to (IMS Global, 2015):

- Establish practices for consistently tracking and collecting learning activity measures for the development of LA features in learning environments
- Determine a mutual language for labeling learning data
- Provide a standard way of measuring learning activities, to allow learning designers and providers to analyze, compare, and improve the quality of learning.
- Exploit various data science methods, standards, and technologies

Generally, Caliper is the manifestation of the 1EdTech Learning Analytics Framework to enable the creation of quantitative metrics for learning (IMS Global, 2022). Caliper aims to enable the collection of high-rate real-time event data to enable responsive learning engagement as opposed to just archive-based metrics and to provide details on student engagement in different learning activities. The main elements of the specification are the Learning Activity, Sensor API, Metrics Profiles, and Caliper Sensors. They define basic learning events and standardize the gathering of learning metrics across learning environments as well as establish an extensible common format for presenting learning activity data. (Griffiths & Hoel, 2016) This structure furthermore enables Caliper to leverage and extend other IMS standards and specifications including IMS LTI, LIS, and QTI standards (IMS Global, 2015).

There can be identified remarkable resemblances between xAPI and Caliper features and objectives (table 17) which have caused adopters and vendors to clarify implementation differences between these specifications. Both specifications enable implementers to track and collect learning-related data from digital resources to understand learning behavior more profoundly and present this information in meaningful ways. Such as xAPI, IMS Caliper supports activity streams. These activity streams are however utilizing defined events instead of statements each with an actor, action, and object which align with xAPI's actor, verb, and object structure. (Pérez-Colado et. al., 2021) While both xAPI (Actor/Verb/Object) and Caliper (Actor/Action/Activity) utilize a data model based upon a triple definition, there are desirable differences in the structure and usage of the Object and Activity definitions. Despite that, the consistencies between structures enable each specification to utilize the other's Verb/Action definitions. (Griffiths & Hoel, 2016; IMS Global, 2022)

Table 17. *Main xAPI and Caliper features (IMS Global, 2015)*

Feature	xAPI	Caliper Analytics
Use-cases	• Reporting experiences instead of just performance data data storage and sharing between several systems • The data related to individual can be combined with the data related to certain group • An updated version of the SCORM standard	• To enable the creation of quantitative metrics for learning • To provide details on student engagement in learning activities • Enabling the development of quantitative measures of learning • Focus on learning analytics in higher education institutions
Data models	• <actor>, <verb>, <object> • Can be considered an 'Activity Scripting Language'	• <actor>, <action>, <activity/object> • Can be considered an 'Event Scripting Language'.
Data transfer and its limitations	• HTTP/HTTPS, JSON • Supports both writing and reading data to the learning database	• Use of API Key • HTTP/HTTPS, JSON-LD • Very little discussion related to security.
Encryption	• Basic HTTP Authentication • Use of 2-legged and 3-legged OAuth 1.0 (HMAC-SHA1, RSA-SHA1 and PLAINTEXT) • Lot of information on Authorization.	• Use of API Key • Use of HTTPS/TLS 1.3 is recommended to secure the message exchange. • Very little discussion of security.
Profiles and Metric Profiles	• An xAPI Profile is similar to an Application Profile • Profile is a definition of how to use the xAPI specification in a specific application domain • No established process for the definition and/or modification of a Profile.	• A Metric Profile describes a learning activity • Profiles are composed of events which specify both a controlled vocabulary of actions, a set of entities that provide a representation of the actor, object of the interaction and other elements that together comprise the learning context. • No established process for the definition and/or modification of a Metric Profile.

Even though both specifications xAPI and Caliper resemble each other in many ways there can be identified certain differences between them (table 17) which are intended to spark the reflection on the strategic implications of specifications for adopters (Griffiths

& Hoel, 2016). The core of xAPI is to enable any type of experience and evidence tracking, both online and offline for learning to be performed within the SCORM context, beyond the browser, and outside of the LMS (Torrance & Houck, 2017). Therefore, any type of delivered learning content or experience can be stored and shared across systems (Zapata-Rivera & Petrie, 2018). The core usage of Caliper instead is to enable the creation of quantitative metrics for learning. Caliper aims to provide details on student engagement in learning activities and real-time data messaging to enable responsive learning engagement as opposed to just archive-based metrics. Compared to xAPI, the fundamental objectives are therefore very much alike but include some nuance differences that the adopters should consider when comparing the specifications. (IMS Global, 2015).

Some governance issues and derivative works between xAPI and Caliper differ from each other. The licenses acquired by IMS Caliper and by xAPI are remarkably diverse with respect to the ability to create derivative versions of the specification. Caliper has been created through a closed process in a membership organization, while xAPI has appeared from an open process allowing all concerned parties to contribute (Haag, 2016). Therefore, the intellectual property of Caliper is retained by IMS whereas xAPI is made freely available to all parties due to Apache 2.0 license. This implies that there is no demand for ADL to give permission to make a standard from the specification. Furthermore, there is not any obstacle to derivative specifications, should there emerge community demands that are not well met by the current specification. In this regard, adopters should consider whether the development of actual standards is essential to them and whether the capability to create derivative specifications is valuable. (Griffiths & Hoel, 2016; IMS Global, 2015)

The difference in approach with xAPI and Caliper is reflected in a different emphasis in the approach to the fit between the specifications and their user groups. Caliper is based on a set of metric profiles. (Griffiths & Hoel, 2016) The development work for it is not public, but generally, the metric profiles cover the typical use cases put forward by the vendors who make up most of IMS' contributing members. Caliper primarily focuses on use cases gathered from different IMS member organizations, while making provisions for extensions. xAPI instead provides an open framework and doesn't support specific vocabularies from the specification itself. (Haag, 2016) For any given domain, different communities of practice are expected to define and share the structure of xAPI statements and vocabulary as profiles or recipes. This has substantive repercussions for adopters, who therefore possibly need to contemplate whether the flexibility provided by xAPI is respectable to them, compared to predefined functionality provided by the major LMS providers who prefer to be prominent users of Caliper. (Griffiths & Hoel, 2016)

As data is becoming a more and more valuable asset, the role of data protection is becoming a more significant and important issue (Panian, 2010). A potential concern related to this addresses data privacy having a significantly different profile in Europe than in the USA, where both xAPI and Caliper have their provenience. For example, there exist strong overall legal controls on both the collection and storage of data in Finland whereas US data legislation lacks a comprehensive GDPR. Therefore, it should be relevant for adopters to address the importance of data protection issues and in this regard pay sufficient attention to the emerging support provided by these two ecosystems. (Griffiths & Hoel, 2016; Haag, 2016)

There can be identified marked similarities between xAPI and Caliper in performing functions and exploiting concepts. They are, however, rather diverse in their approaches to development and governance. xAPI can be considered a relatively strong option in the professional learning context, and for recording events that take place beyond the LMS. (Griffiths & Hoel, 2016) Caliper instead provides a more standardized solution for more defined parts of the learning ecosystem, such as organization-sized LMSs and large-scale applications that want to interact with them trivially (Haag, 2016). Furthermore, there appears to be a split in the market, which is causing both standards to become de facto in some segments. Caliper is potentially becoming more of a de facto standard in the US higher education market and xAPI in turn in enterprise training and education, especially in Europe. (Griffiths & Hoel, 2016)

Regardless of different references, it is important that the features and outputs of xAPI and Caliper are mapped against each other for communities to take a stance regarding the ecosystems growing up around these two specifications. (Griffiths & Hoel, 2016) This may influence adopters to commit to one or the other or even make use of both. There have already been indicated some efforts towards harmonization of the xAPI and Caliper, but it is not clear yet to what extent this is going to be possible. For LA to fully respond to the increasing demand of collecting, storing, analyzing, and reporting learning data, it should be an attainable objective to enable these specifications to interoperate with each other. In this regard, it is encouraging that one of the objectives of xAPI and Caliper communities is to assess whether a convergence into one convergent specification is possible and if not then whether a crosswalk of specifications is an applicable alternative (Haag, 2016; Griffiths & Hoel, 2016)

5. EMPIRICAL PART

The target project of the research is creating a nationwide digital service platform that integrates learning and education systems to improve learning and efficiently produce high-quality educational services. This chapter discusses the design and implementation of empirics in the research. First, the implementation of both, the interview research and the actual interviews are carried out, and finally, the methods of analyzing the results are discussed.

5.1 Implementation of interview research

The empirical part of the research is carried out as a semi-structured interview. A semi-structured interview is a qualitative data collection method generally used to determine respondents' opinions, attitudes, and reasons. It is typical for the semi-structured interview to have certain subject-approaching perspectives already been decided in advance, but still allow the interview to live by the interviewees' answers. (Hirsjärvi & Hurme 2008; Saunders et al. 2019) The free form of the semi-structured interview enables the interviewees to share their interpretations and does not bind the answers to be too much guided by the layout of the questions.

In the research context, semi-structured interviews are typically defined as qualitative by the nature. They are generally used as exploratory tools in different research fields for deciding "Why" rather than "How many" or "How much". During the semi-structured interviews, it is furthermore possible to discuss with the interviewees to clear out their experiences, thoughts, and feelings. The empirical part of this research emphasizes exploring the opinions and expectations towards the development of e-learning from the perspective of more advanced data tracking and analytics capabilities, and therefore the semi-structured interview appears to be a good choice. (Miles & Gilbert, 2005)

It is typical for semi-structured interviews to be open-ended, therefore allowing certain flexibility. Unlike in a structured interview form, the phrasing and order of the questions are not set. A structured interview with pre-set questions in a pre-set order enables fluent comparison between respondents but on the other hand, can be restrictive. Having less structure can support finding different patterns, however at the same time still allowing comparisons between respondents. (Miles & Gilbert, 2005) This way it is furthermore possible to clarify issues that the interviewer has possibly not been able to reflect on or realize beforehand. (Saunders et al. 2019) The interview situation is supposed to be conversational during semi-structured interviews; therefore, the interviews should be recorded or written down by taking notes. (Hirsjärvi & Hurme 2008; Saunders et al. 2019) In this research, the interviews are recorded since they are conducted remotely.

In this research, the interviewees are selected using judgmental sampling. In judgmental sampling, the interviewees are selected based on the pre-established criteria to identify the best possible interviewees according to the research question. Interviewees are selected from a larger population being fully aware that some population members have no chance of being selected for the survey. The selection criteria can be, for example, a homogenous or heterogeneous group of interviewees, a typical case, or a critical case. (Saunders et al. 2019) With the help of the project organization's contact person, the most important interviewees for the research are mapped. The interviewees are divided into different categories based on the stakeholder group they represent. The interviewees will be employees in the project company's stakeholder groups, but in addition, two persons from the target organization of the research will be interviewed to obtain more comprehensive empirical material.

5.2 Conducting the interviews

The interviewees were selected with the target organization's contact person. The interviewees were first contacted using general communication channels to discuss the research and arrange the interviews. After that, the interview questions were sent to the interviewees via e-mail (APPENDIX A). All interviews took place over a three-week period. The interviewees were sent the questions beforehand to allow them to. prepare for the interview. In this way, more extensive answers were obtained, because especially for some of the stakeholder representatives, standardizations and xAPI architecture were unfamiliar, and therefore they were able to contemplate the topics and answers in advance. Submitting the interview questions in advance also allowed the overall interview situation to become more pleasant.

The interviews were conducted remotely. Interviewees were asked for permission to record the interviews at the beginning of the interview, and all interviews were recorded for later transcription. The interviewees were emphasized that they are expected to answer the discussed questions based on their own experience, regardless of whether or how things should be done according to textbooks. All interviews were held as individual interviews and a total of seven were held. The interviewees are presented in more detail in table 18.

Table 18. *Interviewees*

		Work description	Experience in e-learning and learning ecosystems
National Management of Education	**I1**	Ministerial Adviser	Muncipal online services, training and educational information systems
	I2	Counsellor of Education	Multiple years with digitalization of education and development of e-learning systems
Publishers	**I3**	Chief Expert Officer	Development of digital learning materials and customer experience in educational sector
Target Project	**I4**	Program Manager	Elementary school tearcher and principal
	I5	Prduct Owner	Multiple years in education IT, special education, school management and physical education
	I6	Project Specialist	Digi-pedagogical development of learning environments

Interviewees 1, 2, and 3 participated in the interviews as consultants external to the target project. The objective with them was to obtain a more general perspective on e-learning and the future expectations with the e-learning ecosystem, especially in the context of tracking and analyzing learning activity. Interviews 4, 5, and 6 work in the target project in different roles and have been involved in the development of the project more extensively. Therefore, they were interviewed to understand more profoundly the reasons to consider new e-learning standardization. All the interviews were recorded and during them, notes were made about matters relevant to the progress of the interview. The interviews were transcribed into written form within a couple of days of the interviews and an explicit overall picture of the interviewee's answers was tried to form based on them.

6. EMPIRICAL RESULTS

6.1 Digitalization in education

The evaluation of digitalization and e-learning were the first topics discussed in the expert interviews. Both, the strong growth rate of digitalization and technological development in society especially in the last decade were identified by all interviewees and the effects of these on the learning ecosystem were considered significant and indispensable.

Digitalization has affected the overall development of education and allowed it to become more versatile to better meet the expectations and requirements of today's society more comprehensively.

I1

All experts agreed that e-learning has been on the rise for the last decade, especially due to the COVID-19 pandemic which has accelerated the digitalization in the educational sector. Due to this growth online learning was perceived as a necessary part of today’s learning ecosystem. The interviewees agreed that e-learning and the advent of digital tools and applications have enabled learners to become empowered to learn and develop skills in new and more efficient ways. As other main benefits of e-learning, the interviewees identified extending learning to more people, supporting individual learning styles and needs, removing place and time limitations, and improving the quality of overall learning

Online learning does not form a unified learning path through the education levels, although at best digitalization could increase equality when all learners have equal opportunities to utilize technology

I2

Despite the rapid development of digitalization, the current state of online learning was overall found rather volatile among all interviews, especially at the national level. Evaluating the state of e-learning unambiguously was considered challenging mostly due to varying utilization possibilities of digitalization in different education levels as well as local differences in technological capabilities and competencies. Especially the lack of technological literacy, and lack of sufficient monitoring were noted as key issues by different experts. It was agreed that digitalization has led to a certain inequality in technological literacy as everyone was not experienced to have equal access to technology or resources to utilize the possibilities of digitalization.

The interviewees agreed that e-learning and digitalization of education are progressing unevenly at different levels of education. Many of the experts highlighted that currently the capabilities to utilize digital tools and technology in learning are highly dependent on where the learner receives his or her education. The national control of digitalization was not considered sufficient to provide educational equality in this regard. Major concerns referred to not everyone having equal access to technology or resources. Developments in technology have provided new technologies such as mobile devices and cloud services for learners to access learning in new ways anywhere and anytime. However, a large section of society in the educational sector was considered unable to gain equal access to these tools which was discussed to cause challenges in the utilization of digitalization.

Many of the interviewees discussed the importance of monitoring learners and learning comprehensively as online learning is becoming more common. In addition to technological literacy, digitalization was discovered to increase the risk of many well-being issues such as social isolation but also learning matters such as falling behind the studies due to the increased lack of concrete presence of teachers, and fellow learners. Larger scale utilization of monitoring learning was considered as an opportunity to obtain valuable information about learners and their behavior which might support identifying these issues efficiently and on time.

Based on the interviews some key observations that should be considered with the development of e-learning in the future came up. The interviewees emphasized the development of digital competence, understanding learning more comprehensively, interoperability, and improvement of information quality as key objectives for the digitalization of education in the future. As digitalization in society is increasing the competence of individuals to use digital tools was found important. Interoperability was considered necessary for learning environments and ecosystems to efficiently work with other products and systems and therefore improve the quality and possibilities to utilize information in enhancing the learning processes.

Children and young people acquire a significant part of their knowledge and skills online through the internet and social media. In the future, we must be able to provide them with high-quality education services and abilities that a while ago might not even have been required. These include experiential learning, critical media literacy, informal learning, and handling the differences between values and cultures.

I6

All interviewees agreed that e-learning is becoming an integral part of the future of education with the increasing pace of digitalization and the shift to the knowledge era in society. As learners today are beginning their school journey, information is available without limits, technology is becoming more and more transparent to everyone, the use of mobile devices is increasing and the use of digital technologies such as video games, and simulations is changing the way how people learn. Therefore, the interviewees considered the importance of education to be able to keep up with development and adapt to these changes in the future.

In the future e-learning was most of all discussed to be about meeting the expectations and the learning needs of students as they were considered the primary driver for digital transformation. At the same time, the learning environment was however considered to become more and more a combination of different forms, open to everyone, communal, and learner-centered, where the development of more versatile competencies such as media literacy and information skills is emphasized - in both school and work life.

The interviewees agreed that digital qualifications and skills are one of the most important conditions for success in digital change, growth, citizens' well-being, and the development of society. Prioritizing the improvement of digital skills and utilization of ICT technology in the national education sector were discussed as key issues in today’s education system. At this point, the responsibility however was found not only laying with the learners but also with the teachers and other education authorities. All parties were considered to have adequate working conditions and frameworks as well as sufficient competence and attitudes for digitalization to be considered an opportunity

6.2 Tracking data

The role of data in learning was discussed with the interviewees. It was identified that analytics is becoming a more and more important development targets in education development. Interviewees agreed that analytics have already provided a remarkable potential for the development of education and therefore confidently becoming a more significant part of learning ecosystems in the future.

The interviewees identified several points on why it would be important to pay attention to tracking and collecting more data about learning in the future. More data was identified to provide possibilities to determine learning-related issues such as student retention, performance, engagement, employability, progression, and attainment more efficiently. Accessing more data was furthermore considered a significant tool for developing overall digital competency.

Technological development is providing more and more data and tools for making analytics. The educational needs form the basis of analytics, but grades or time spent on tasks alone are not enough to express the quality of the learning process. The analytics should also be capable of capturing different learning forms and styles, progression, and the level of achievement of learning objectives

I5

Above and beyond traditional completion and record tracking we should be able to track and analyze learning more versatile, such as what assignments the learner has done, at what stage is he taking the course, the number of hours *she has spent learning, how is he performing, and how it has affected the overall learning success.*

I4

The interviewees agreed that there is a lot of pressure on the education sector and institutions to provide educational actions to respond to the development expectations set by the complex future. Many educational institutions are reforming their educational conventions to provide learners with better competencies to be utilized in emerging future contexts. The demand for obtaining professional, subject-specific skills was discovered as rather punctual among the interviewees, but instead, a demand to master more generic competencies such as social activity and networking applicable to emerging working-life contexts was discovered as highly important in the future. Tracking and mastering such generic skills were however considered to require collecting data in more versatile and extensive ways than currently.

As more versatile learning forms such as informal and blended learning were discussed to become a significant part of future learning, they were furthermore considered important to be utilized from the perspective of analytics. Without the capability to track learning activities that happen within both a physical classroom and virtual environment and via different technologies such as mobile applications, social learning, e-books, and games it was found difficult to measure learning effectiveness accurately. Furthermore, the possibility to utilize a variety of activities taking place both within e-learning content and in physical classrooms as a data source for analytics was considered a tool to improve the quality of the information and lead to a better comprehension of actual learning process.

At the moment, the learning outcomes are linked to competencies largely manually by the teacher. However, the objective with regard to analytics data would be that the learning results appearing in the curriculum could be tied to the objectives without the teacher's actual interpretation

I5

In many cases, monitoring the actual learning instead of exclusively learning outcomes was found tied to the teacher and therefore difficult to access by different parties. The interviewees felt that currently, the teacher is by far responsible for monitoring the learning progression and linking the learning outcomes with competencies. The data relating to learning was considered merely restricted to the completion of modules or courses, the time taken, pass/fail in assessments, or the score and the information about how well the competencies actually meet the learning outcomes was found limited and difficult to access. Having the capability to track and monitor the learning and development of learning skills in wider scope in addition to learning outcomes alone was considered significant to provide valuable data about what competencies are relevant for learning outcomes and how the progress towards these outcomes has gone.

The interviewees agreed that the overall well-being of students should be considered more carefully in the future. Students were considered to undergo more mental issues, isolation, lack of sufficient assistance, and loss of motivation in the future as the development and digitalization of society remain responsible. These issues were already identified to become particularly crucial during the COVID-19 pandemic, as a unique demand for prevalent online learning, and communication became general. In this context, a lot of potential was discovered with more comprehensive tracking and monitoring of learning behavior, such as at what stage the learner is in the course, how much time he or she has spent learning, or how time use has affected learning success. The interviewees found effects on improving students' learning outcomes, optimizing their educational technology, reducing dropout rates, and improving overall well-being.

To build and develop successful analytics nationally in an educational context, the importance of cooperation with different educational parties and stakeholder groups was highlighted. As the learning ecosystem was discussed to become more diverse and complex there should be unified and clear practices for general issues such as what are the objectives of analytics but also for more practical issues such as how to explore the data collected from the various systems in the learning ecosystem and how to unify data coming from multiple sources. All interviewees agreed that to achieve this, it is critical to engage all educational parties in the development process, listen to their needs, and educate them all on how to consume and utilize the data that’s available.

6.3 Systems and standards

The interviewees discussed the functionalities of the current e-learning systems and standards. Several interviewees agreed that the current e-learning systems perform sufficiently at required tasks and can help teachers, instructors, and other learning authorities to create, deliver, and measure the usage of learning materials. However, the rapid development of e-learning and online learning systems was discussed to make learning become more dynamic in the future allowing learners to learn more and more anywhere outside the traditional classroom and in different forms.

The interviewees found complexity and inflexibility with current e-learning systems and standards especially when comparing them with future e-learning objectives and expectations. Especially tracking granular learning data in software, measuring learner activity and activities in mobile, offline, and informal learning, and combining data from different sources were identified as possible bottlenecks with current standards and systems. To meet the standard requirements for the future, the current systems were found to need more flexibility, cross-device functionality, and interoperability properties.

There is a lot of learning and learner-related data already available, but it is not utilized comprehensively enough.

I3

*We are missing out on a substa*ntial amount of valuable data*, meaning we can't have a full picture of what our learners are doing and how they are actually learning.*

I5

Even though the interviewees agreed that acquiring more data would provide more possibilities to track and monitor learner and learning-related activities, they pointed out that there already exist great amounts of unexploited learning data available which have a lot of potential in them. A significant quantity of data was considered to be available in current educational software and platforms. The interviewees however found merely a finite set of that data to be tracked and recorded. Many of the current systems and standards were identified as inefficient in this sector due to the design. The interviewees stated that current systems and standards are generally capable of tracking small or decent amounts of data such as course completion and test marks. Exposing much more data by default was considered complicated and could rely on third-party workarounds.

*To meet future analytics expectations, we should be able to collect considerably more flexible and open-ended learning data that are unstructured and c*onsider a wider scope compared to *traditional, formal learning activities.*

I2

The interviewees discussed the relevance to capture a wider range of learning activities in the future. Many of the interviewees stated that learning is constantly becoming more diverse, especially in higher education and it can take place offline or online anytime and anywhere. For instance, it could take place as learners observe or discuss with each other or watch videos. It could even occur through trial and error once learners begin an assessment and experiment with new approaches. These kinds of non-formal and informal learning forms were considered more significant in the future as they are more self-directed with no rigid pathways, clear objectives, and time restrictions. Therefore, not all of the learning can be recorded in the form of scores on formal assessments, so having access to other ways of tracking learning activity and progress was perceived as valuable.

The interviewees found that online e-learning today is by far reliant on LMSs because they can track learning that considers digital devices. While this was found to suit best for formal learning, the interviewees thought that many current e-learning standards and systems can’t properly support other learning forms such as informal and non-formal learning without some upgrades. Many current standards such as SCORM was discussed to enable delivering and tracking of learning that takes place within the LMS. However, other learning forms were considered to occur mostly outside the LMS, and therefore, to ensure successful tracking of informal learning, concerns towards tracking learning experiences based on non-formal and informal learning activities were identified.

The ability to integrate data from multiple sources is in a key role to open silos and achieve a more holistic view of learning.

I4

The increasing utilization of digital tools in education was considered to generate more data sources. The interviewees agreed that currently the data is in many cases siloed in different systems and therefore it cannot be utilized properly. To improve data availability and quality the capability to integrate data from multiple different sources such as different learning environments and other e-learning solutions into one place was considered necessary. The interviewees found a great amount of the current systems and standards somehow inefficient to provide sufficient interoperability capabilities required for the learning content to be integrated or distributed across multiple sources efficiently.

The interviewees discussed the improvement of educational cooperation, especially with other Nordic and European countries. As learning was considered to become increasingly open and transparent in the future the demand for global collaboration in the educational sector was furthermore found increasing. From a system perspective, this was found to require interoperability capabilities with systems not only at the national level but also at the global scale.

In addition to interoperability requirements, the interviewees highlighted the importance of security and privacy issues. With digitalization and technological development, more personal data can be tracked, collected, and shared with cloud services. Many of the interviewees brought up the significantly high profile of data privacy in Europe. The importance of GDPR, privacy, and legal controls on data collection in Finland was paid attention to. All the interviewees agreed that when designing systems, a firm stance on data privacy and security considerations should be paid sufficient attention at both national and global levels.

7. XAPI IN E-LEARNING

This chapter presents the empirical results combined with the theory. The chapter progresses in accordance with the topics covered in literature and empirics starting with digitalization and e-learning development in education and progressing to the comparison of xAPI functionalities with future e-learning and analytics expectations. As a result of comparing the empirical results deductively with the findings achieved in the literature, both similarities and differences can be discovered, to either generalize the results more broadly to the research context or to make new types of conclusions to answer research questions.

7.1 Tracking learning experiences

Given the changes that have transpired in the last decades, the educational sector is a profoundly different concept for learners today than it was a while ago when e-learning was still in its infancy (Bahrain, 2013). Based on the theory part, it can be summarized that the significance of online learning has increased phenomenally, and it has a very large importance in learning and skill development today. This was also discovered in the empirics where online learning was considered undeniably one of the key competence development tools in the future as the value of digital expertise is increasing in every sector of society.

The main advantages of e-learning consider liberating interactions between learners and instructors, from limitations of time and space through the asynchronous and synchronous learning network (Sun et al., 2008, pp. 1183-1202). The interviews found support for this by discussing the capability of learners to choose where and when they learn as one of the key advantages of e-learning. The empirics furthermore highlighted flexibility, scalability, and accessibility as the main benefits that e-learning can provide for education.

Based on the interviews there were identified several objectives for the future of e-learning and some pivotal of these were:

- Develop digital competency
- Understand the learning more comprehensively
- Improve the quality of information

These discoveries corresponded well with the observations made in theory as they covered the following key objectives (Mahanta & Ahmed, 2012, pp. 46-51; Jethro et al., 2012)

- Meet the learners' learning requirements and needs
- Enhance the efficiency of the overall learning
- Engage learners more comprehensively in the learning process

To meet future e-learning objectives the empirics discovered multiple features to pay attention to and consider carefully. Especially considering technological literacy, improving systems, and monitoring learners more efficiently were identified as key issues that should be considered in the national development of e-learning. The empirics highlighted that digitalization has caused the learning environment to undergo changes and become a more diverse and complex system. The modern learning environment is becoming a combination of social collaboration and growing digital technologies. New technologies and tools such as organizational flexibility, digitalization, cloud technologies, virtual reality, etc. are changing the way how people learn. The internet, mobility, and diverse learning forms are enabling learners to learn anytime and anywhere. (Thareja et al., 2015) The interviews highlighted that increasing the awareness of these future changes, needs, and expectations requires educational institutions to design new methods to respond to them.

The empirics found analytics as one of the key development targets in accomplishing the national e-learning objectives. For learners, enhanced monitoring of learning was discovered to have effects on improving their learning outcomes, optimizing their educational technology, and improving overall well-being. For teachers, the interviews agreed that it could support them to automatize many manual chores and understand learners on a more personal basis, and therefore help them for example to identify potential pitfalls in learning well in time. The empirics furthermore discussed different learning competencies that today are by far linked to learning outcomes manually by the teacher and therefore difficult to access by other parties such as students and their guardians. More diverse analytics was discovered to enable the learning results appearing in the curriculum to be tied to the learning outcomes without the teacher's interpretation. This would allow especially learners and their guardians to have valuable information about the development of competence related to learning outcomes and have a more comprehensive overall picture of what is involved with competence instead of interpreting merely the results and scores.

Currently, the e-learning industry is experiencing a revolution due to advancements in technology. The introduction of new technologies and digital tools is providing possibilities to collect a wide range of learning-related activity data with high volume and variety (Clow, 2013, pp. 683-695). More accurate data tracking and collection capabilities form the basis of efficient and successful analytics (Santos et al., 2015, pp. 976-996). The interviews identified the utilization of this data to become more significant in the future to provide more possibilities for analytics for example to understand the learner and learning behavior more comprehensively. However, the types of activity data that can be collected by current learning platforms, such as Moodle, that have been widely adopted by different educational institutions all around the educational sector were identified as rather limited due to the limitations of current standards and systems. This data limitation constrains the utilization and applicability of many learning activities and forms that could be used to refine and further adapt online content.

Many current standards such as SCORM are designed to track a limited range of activity data such as single score, pass/fail, completion, and time. They are relatively stiff to track more advanced learning activities such as offline learning, informal learning, and mobile-based learning which empirics found to become significant parts of learning ecosystems. (Bakharia et al., 2016; Johnson & Hruska, 2013) The theory introduced an xAPI specification as a possible solution to capture data from a variety of more advanced technologies and activities. xAPI allows the utilization of all kinds of learning forms such as offline and mobile learning and facilitates social and collaborative learning, as well as different technologies such as simulations and games. Compared to many previous standards it utilizes more modern technologies, is more mobile-friendly, and enables the tracking of limitless amounts and types of complex data from a variety of activities for online education to benefit from. (Torrance & Houck, 2017)

7.2 Flexibility

The empirics discovered a demand for flexibility with current systems to track data more versatile. xAPI allows tracking a wider range of learning activities to gain a more comprehensive understanding of a learner's behavior, progress, and engagement with e-learning content (Torrance & Houck, 2017). To guarantee more versatile monitoring of learning the xAPI specification is built with flexibility in mind, and it allows for great freedom with the structure of the statements when it comes down to the details. xAPI is considered a dynamic but loose specification where JSON + actor-verb-object structure gives a lot of possibilities. (Zapata-Rivera & Petrie, 2018) For example, xAPI data can be used to determine things like (Torrance & Houck, 2017):

- Which content do learners access and how much time do they spend viewing this it
- Which notes and responses people type in social media platforms
- Which actions a student takes in a flight simulator (control wheel movements, eye movements, etc.)

Flexibility allows xAPI to track limitless amounts and types of complex data. The functionality of xAPI enables all different activities to be seen as learning activities by xAPI and defined as statements described in theory. Therefore, an action performed by a learner anytime and anywhere on an xAPI can be received and stored and can be returned for further utilization. (Zapata-Rivera & Petrie, 2018) The empirics however found the capability of merely "storing everything" very inefficient and highlighted the importance of defining and discovering the data that has the most value for users. The tracked data was discovered valuable only if it would actually benefit different parties and provide them concrete benefits in practice. To address these challenges a sufficient understanding of the xAPI statement structure is important to easier decide what to track. Furthermore, the empirics discussed the importance of cooperation in specifying what data and what types of data are generated and stored, and what are the objectives with it. Data integrity is paramount and begins with unified and solid data practices and data management techniques (Gal & Aviv, 2020, pp. 349-391).

The empirics discussed the importance of unified practices with the flexibility of standardization. Compared to many other standards in the analytics field such as IMS Caliper Analytics, xAPI provides an open framework with a more dynamic but loose structure that doesn't support specific vocabularies from the specification itself (Haag, 2016). Therefore, the freedom and flexibility of the statement structure can provide multiple possibilities for adopters but at the same time require defining certain practices as the communities adapting xAPI as a part of their information system architecture are tended to define and share the structure of statements and vocabulary independently. (Haag, 2016)

The empirics discussed the importance of considering technological development in learning more carefully in the future. Along with the rest of society, the educational sector is moving towards mobile, and cloud, and therefore the utilization of new technologies. is becoming more common (Chicu, 2018). The empirics found possible challenges with current learning systems and standards like SCORM to function inside modern technologies such as offline learning and mobile apps. Systems were considered rather rigid as they generally require a browser, an LMS login, and a constant internet connection. xAPI instead provides flexibility with data sources as it does not require a permanent internet connection or a web browser – learning can take place online or offline through smartphones, tablets, and other mobile devices (Torrance & Houck, 2017).

With digitalization and technological development, empirics found learning to fade away from a structured, formal environment towards more informal forms such as networking, collaboration, and social media. It is typical for informal learning not to occur inside LMSs or other traditional e-learning platforms (Downes, 2010). To ensure the successful tracking of this kind of activity, the empirics highlighted the rigidity of current standards to provide a framework for tracking learning outside LMSs. Interviews discovered online learning by far reliant on the LMSs as they are able to track learning happening on digital tools. While this is generally best suitable for formal learning, the traditional LMSs are not designed to support other than formal learning without some important upgrades (Duval & Ochoa, 2008).

As many current standards such as SCROM remain inefficient to track learning experiences outside LMSs, the theory found the flexibility of xAPI as a possible solution for this issue. In SCORM, the learning content has to be imported and registered with the LMS before it can be delivered and tracked. This feature restricts the data that can be tracked to e-learning content. xAPI instead can track and record learner activity not just on the LMS but across all different platforms where learning occurs, and therefore, it is not necessary for the learning experience to be tracked to be originated in the LMS. (ADL, 2013)

A variety of commonly utilized e-learning standards such as SCORM enable the tracking of learning experiences by logging in to an LMS, registering for an e-learning event, and launching it from within the LMS. The tracking of learning experiences is by far limited to a single learner within a single online content, browser, and learning environment. The flexibility of xAPI enables the tracking of learning experiences flexibly from a wide range of sources to LRS no matter where or when the learner discovers and begins them. (Torrance & Houck, 2017) This includes traditional e-learning systems, but also modern technologies such as mobile apps, and virtual reality environments. Even though xAPI doesn't need the LMS to track learning, this does not take the existence of LMS pointless. LMSs provide multiple properties the LRS lack and the flexibility of xAPI enables LRS to communicate with LMSs (ADL, 2013).

7.3 Interoperability and security

As learning is becoming more and more digitized and complex, the deficiency for an order of regulations for content, authoring software, and LMSs is increasing (Johnson et al., 2020). The empirics discovered that as e-learning is getting more popular the e-learning environment is becoming more diverse and complicated. Increasing digitalization, new technologies, and more diverse learning styles were discovered to provide more systems, data sources, and data to be available. Therefore, a need for a set of more efficient rules to provide guidelines for designing and developing content, deploying it across platforms, and ensuring interoperability across devices was discovered. According to Johnson et al. (2020), these rules or standards are critical to responding to the demands and expectations of an e-learning industry for learning data to be interoperable between different systems.

The theory discussed an xAPI as an interoperability specification fore-learning that provides the learning industry a flexible way for systems to communicate and work with one another. The empirics found that even though there already exist great amounts of learning data in different systems, it is in many ways siloed and therefore cannot be utilized efficiently to support educational purposes. The release of learning information from different silos into one common and open storage was discussed to provide more versatile and accurate data to be utilized in reporting and analytics. xAPI provides the ability of diverse data sources and systems to exchange information by enforcing a consistent data structure in the form of *statement objects*. This structural interoperability provides a framework for the integration of learning data from different systems, applications, or platforms (ADL, 2013; Johnson et al., 2020).

Many of the current standards such as SCORM specify that all e-learning content must be hosted along with the LMS on the same domain (Miller et. al., 2021). As empirics discussed learning to become more informal and take place outside traditional LMS the utilization of SCORM was discovered to possibly cause interoperability issues. According to Johnson et al. (2020), xAPI provides interoperability by standardizing the API transfer methods utilized when communicating learning activity-related information between software that agrees with the specification. As a part of this compliance, xAPI simplifies both the format of requests and the expected responses as well as defines requirements for the storage and retrieval of statements. All these statements can be validated and stored by an LRS to gather and store learning results which theory found a key factor especially if the learning takes place in different environments. (Manso-Vázquez et. al., 2018; Johnson et al., 2020)

The empirics highlighted the ability to utilize both traditional e-learning domains and content that stands outside of a web browser becomes necessary in the process of developing e-learning systems. Despite the interoperability capabilities that xAPI can provide, the theory found certain limitations, especially in determining the content to contain in

LMSs. Even though xAPI provides a communication framework between a learning activity and an LRS, it neither defines the structure of e-learning content nor the communication between the learning content and the hosting system. Furthermore, it does not provide authentication protocols to connect the learner to the learning content. In this context, the theory discussed the CMI-5 specification as an extension for xAPI to combine the structure of SCORM with the tracking capabilities of xAPI and therefore add a robust dimension to LMSs. (Miller et al., 2021)

The empirics discovered defining unified practices and regulations for different types of activity data available across different platforms, apps, events, and situations as a possible challenge with standardization. xAPI provides semantic interoperability using shared vocabularies and xAPI Profiles which assures different e-learning systems not only be capable of exchanging the data but also have shared interpretations of the data's intent. However, the flexibility and transparency of xAPI by far hand over the responsibility to define and share the structure of statements and vocabularies for different communities of practice. Therefore, to assure semantic interoperability, certain cooperation, and clear practices on how to define and share Profiles and vocabularies are required from adopters. (ADL, 2013; Johnson et al., 2020)

The interviews discussed the increasing globalization of education. As learning was discovered to become more open and flexible in the future the empirics found increasing considerations in developing cooperation and mutual frameworks in the educational sector, especially with Nordic and European countries. The empirics discovered the interoperability between systems at a global level as an important issue to support collaboration and the unifying of learning outcomes. According to Griffiths & Hoel (2016), especially in the global learning analytics sector xAPI alongside with IMS Caliper Analytics has started to attract increasing interest among educational institutions and other adopters. Caliper was however discovered to potentially become the de facto standard, especially in the US education sector whereas the xAPI was discovered to become more popular in enterprise training and education, especially in Europe.

As data is becoming a more and more valuable asset, the role of data protection is becoming a more significant issue (Panian, 2010). The interviewees paid attention to privacy and data protection issues as key issues with e-learning development. The capability to track and collect vast amounts of data with xAPI was discussed to require a respective amount of security in the storage of, and access to, data. Tracking and collecting increasing amounts of data was discovered to possibly cause issues with information corruption, compromise, and loss as well as control of personal information utilization which should be considered in the design of systems and standards.

xAPI provides multiple controls designed to improve information assurance such as instructions and practices for authorization, authentication, anonymizing data, and encryption to consider information assurance concerns (ADL, 2013). The transparency and flexibility of xAPI enable communities and institutions to control security and privacy issues rather freely. In the xAPI ecosystem LRSs are accountable for storing data at rest and the related security and therefore as secure as desired and designed. Behind the LRS endpoints which are visible to external parties, adopters can utilize any architecture, technology, or security controls desired. (Johnson et al., 2020) Furthermore, even though xAPI provides multiple controls to provide information assurance the theory highlighted that xAPI has its origin in the US where data privacy has a significantly different profile compared to Europe. For example, the US data legislation lacks a comprehensive GDPR that applies to all types of data. Therefore, the importance of privacy and data protection issues should be considered carefully and paid attention to the emerging support provided by it. (Griffiths & Hoel, 2016; Haag, 2016)

8. CONCLUSIONS AND SUMMARY

8.1 Summary of the results

xAPI is a technical interoperability specification that enables tracking and collecting data about an extensive range of learning activities a learner has online and offline. It provides an interface for tracking data on events linked to different learning activities and experiences. xAPI is designed to endorse the standardization and collection of both formal and informal distributed learning activities, enabling flexible discovery of learning behavior, and providing the possibility to track, collect and store learning experiences in a virtual environment. (Hamzah et. al., 2015, pp. 113-118; Kevan & Ryan, 2016, pp. 143-149; Bakharia et. al., 2016, pp. 378-382)

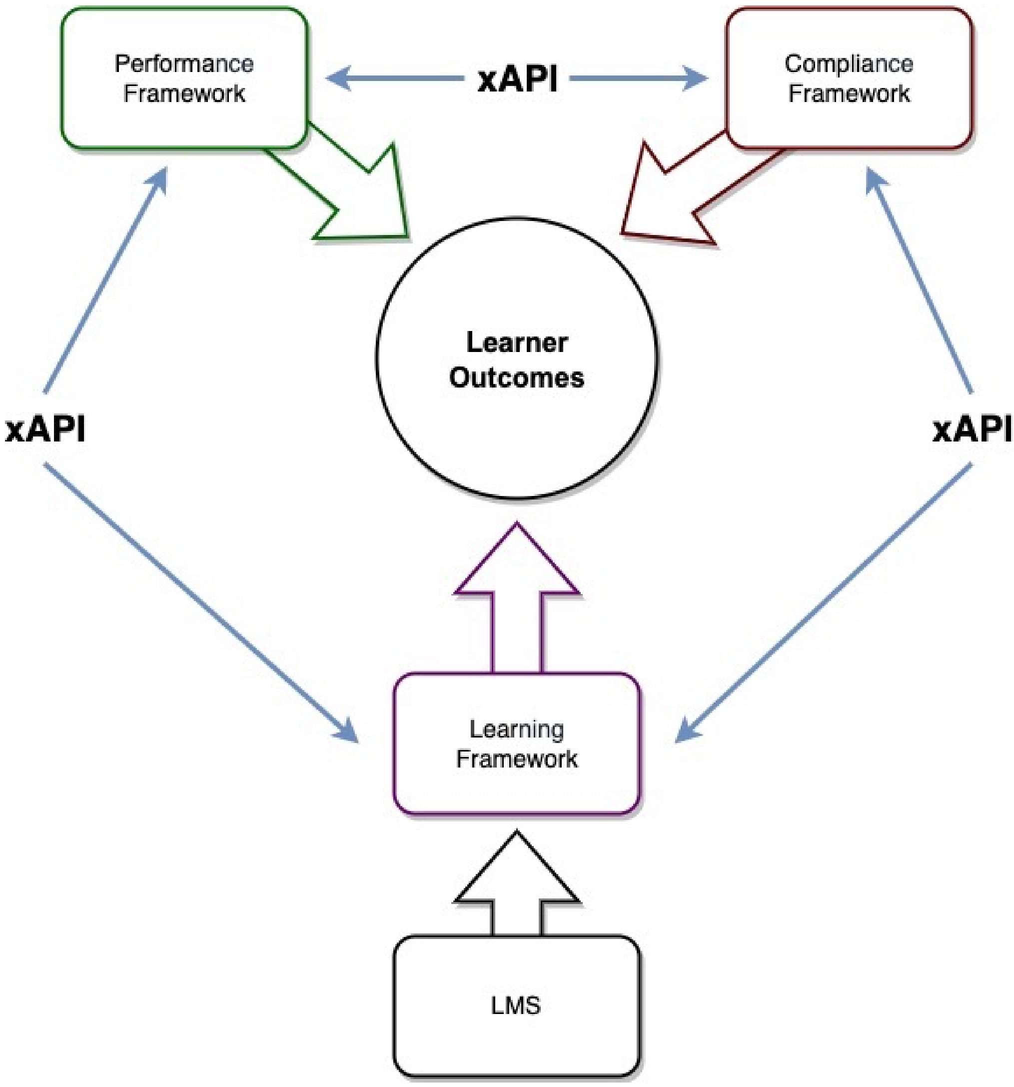

Figure 9. *xAPI framework*

Designed in 2013 to address interoperability, and compatibility issues of previous standards, xAPI is simple and flexible. As figure 9 represents it can eliminate many previous limitations and act as a common language between previously siloed datasets. Furthermore, different learning experiences can be tracked effectively which provides possibilities to analyze a range of cause-and-effect relationships and competence development requirements such as harmonizing training and observation assessment frameworks to tackle different compliance demands (fig. 9).

xAPI provides adopters with modern tracking of learning activities and rich analytics capabilities. The statement structure, flexibility, and decoupled nature of the LRS make it an efficient tool for tracking, storing, and retrieving data. Nonetheless, certain issues such as flexibility, GDPR, incoherence in the LA field, lack of specific support for learner profiles, etc. can raise concerns and hinder its adoption as a universal solution. While many of these issues remain ongoing research topics as xAPI is still under development and possibly subject to change they should be concerned carefully when reflecting on the adaption of xAPI. However, by paying sufficient attention to these issues together with the possibilities xAPI can provide in e-learning and LA fields, there is a strong chance for a nationally significant standard to emerge from it. This could provide education sector opportunities to deliver comprehensive solutions to schools and educational institutions to avoid laborious and expensive one-on-one integrations and better respond to future learning needs.

8.2 Answering research questions

The first sub-research question of the study was defined as *what are the key features of xAPI-specification in the information system architecture*? xAPI is an open-source interoperability specification for tracking and reporting learning activities and experiences. It enables the tracking and collection of data with high volume and variety from a wide range of sources including e-learning systems, mobile apps, and informal learning experiences, and the sharing of that data with a common LRS.

The idea behind xAPI is to offer maximum flexibility with minimum complexity by enabling user activity to be tracked anytime and anywhere. The utilization of xAPI technology provides learning institutions and organizations contingencies to access a range of modern learning activities and therefore gain a more comprehensive understanding of a learner's behavior and engagement with e-learning content, personalize the learning experiences, provide more significant insights and in this respect progress towards the national e-learning objectives.

The second sub-research question was determined to understand *the key differences in the functionality of the xAPI specification compared to other central e-learning standards and specifications*. There can be identified numerous organizations, consortia, etc., working around e-learning standards and closely contributing to their evolution and development. In addition to xAPI, this research work made selective references to SCORM and IMS Caliper Analytics as nationally central e-learning standards and specifications to be discussed and compared with xAPI.

SCORM is a group of technical standards for e-learning that provides the communication method and data models for learning content to operate with LMS. Even though designed based on SCORM xAPI differs in many ways from it and other previous communication standards. xAPI enables the tracking, storing, and retrieving of data from a vast array of different sources, both online and offline. SCORM instead is in many ways more rigid with interoperability and data collection as it is not extensible enough to track more advanced technologies, such as mobile and informal learning, and the tracking of learning content is limited to browser-based activities online. Furthermore, it is critical for SCORM content to reside in the same domain as the LMS to work. This restricts the possibility to track data from a range of different sources and enables it to remain siloed in systems.

The structure of xAPI does not define rules for activities approached in launched scenarios such as traditional launching systems or LMSs. As a great part of e-learning is still taking place in these environments the packaging and delivery of traditional courseware and content is still necessary. As an instantiation of xAPI, a CMI-5 protocol defines how xAPI activities can be approached in launched scenarios while maintaining the tracking flexibility of xAPI and having the structure of SCORM that takes over traditional learning technologies and systems. Therefore, CMI-5 instantiation enables xAPI to be used in traditional e-learning environments as well as the integration of e-learning systems with other systems and specifications.

While SCORM provides the communication method and data models for e-learning content to work with LMS, IMS Caliper Analytics is a technical specification that describes a structured set of vocabulary to support collecting learning data from digital resources and learning tools. In the analytics field, xAPI and Caliper by far share the objectives for tracking and collecting data and therefore have a certain overlap. However, they are in many ways complementary in their respective evolution. First, they have different origins. As the core of xAPI is to enable any type of experience and evidence tracking, both online and offline for learning to be performed within the SCORM context (Torrance & Houck, 2017) the Caliper instead aims to present quantitative metrics for learning to provide details in certain learning activities. Second, Caliper is a result of a closed process in a membership organization and therefore it primarily focuses on use cases obtained from different IMS member organizations while providing provisions for extensions. xAPI instead has appeared from an open process and provides an open framework that doesn't support specific vocabularies from the specification itself and can be implemented in any internet-ready device. (Haag, 2016)

Even though both xAPI and Caliper are generally perceived as "solving the same problem" this is not unambiguous. The advantage of xAPI is the practice of how an individual application can log freeform statements and how that data can be stored to be retrievable by the logging entity. Caliper instead aims to provide a framework for aggregating agreed-upon events across a set of applications to enable processing across the aggregation of data. As the learning analytics field can currently be identified as quite a variable and changing concept, the comparison between the functionalities of these standards is not a clear 'one-or-the-other' but depends on multiple issues such as analytics needs, use cases, scenarios, and motivations.

The third research question was utilized to define *what kind of factors must be considered in the development of the xAPI specification as a means of transmitting learning data.* The flexibility of xAPI provides a dynamic but loose structure that doesn't support specific vocabularies from the specification itself. This gives a lot of control for adopters to define statement structures and vocabularies but on the other hand, requires defining unified rules and practices to guarantee interoperability. Furthermore, while interoperability is critical for the expansion of use, the national level may not be sufficient. Several educational institutions globally have taken interest in implementing xAPI as a part of their learning infrastructure. To improve collaboration and ensure interoperability between systems these rules and practices should be considered on top of the national level at a global scale.

xAPI enables tracking a wide range of data with high volume and variety. As data itself is however merely a collection of values such as numbers, characters, etc. it is not valuable unless it has a meaning. Even though modern technologies and learning forms can provide more data to be tracked and collected, it isn't the volume that's interesting, but the granularity and the ability to build detailed analytics based on this data. To provide valuable information for education and utilize the full potential of xAPI educational institutions and organizations implementing xAPI should consider having unified practices and strategies on what data is needed to track and what are objectives with this data.

Certain security and privacy issues as well as system capabilities should be considered in the development of xAPI. Even though xAPI provides various controls to improve information assurance the transparency and flexibility of xAPI enable communities and institutions to control their own implementations, including security and privacy issues. Different implementers are therefore rather free to use any architecture, technology, or security controls desired. Furthermore, while security and privacy issues still remain ongoing research topics, different security and privacy issues should be paid careful attention to in the development of xAPI. Therefore, the implementation of the full setup of an xAPI and LRS system can require a significant investment of time, dedication, and technical expertise from the adapters.

In chapter 1, the main research question was set for the study as *How ca*n *xAPI support the learning* industry *to meet future e-learning expectations?* With the increasing digitalization, the modern learning environment is becoming a combination of more versatile learning forms and technologies to better respond to the demands of society. This is reflected in the objectives and expectations for the e-learning industry to improve the development of digital competency, understand learners more comprehensively, and improve the quality of information. With the learning environment undergoing digital changes and becoming a more diverse and complex system, the functionalities of xAPI provide a capability for effective tracking of a wider range of learning activities and more diverse experiences to improve the analytics capabilities and therefore support achieving the national e-learning objectives.

xAPI provides a standardized interface that considers many limitations of previous standards. By enabling efficient tracking of both traditional and modern learning forms, data sources, and activities, xAPI provides a way to collect data to understand learners on a more personal basis and instead of merely results and scores to have valuable information about the development of competence related to these outcomes. In addition to diverse tracking capabilities, xAPI provides flexibility and interoperability properties to integrate systems, extract siloed data, unify data models and integration practices, and support global integration and collaboration. While still under a continuous development process, xAPI has already been largely adopted by the global e-learning industry, especially in Europe, and provides a framework for a nationally significant standard to emerge from it. This could provide education sector opportunities to deliver comprehensive solutions to schools and other educational institutions to respond the future needs and expectations and avoid laborious and expensive alternative one-on-one integrations.

8.3 Research evaluation

Evaluation is a standard part of research work. The research is typically evaluated utilizing predefined evaluation criteria. A comprehensive evaluation covers the reliability and applicability of the research as well as the achievement of the research objectives. (Saaranen-Kauppinen & Puusniekka, 2009) There can be identified different methods and techniques to evaluate research. Qualitative case studies can be for example evaluated by the fourfold method (Guba, 1981, pp.75-91), which is a generally recognized method for evaluating qualitative research. (Guba & Lincoln 1994; Thomas & Magilvy, 2011, pp.151-155) According to the fourfold method, the research is evaluated from our different perspectives called credibility, generalizability and applicability, certainty, and confirmability (Guba & Lincoln 1994).

The research credibility can be examined through the correctness and non-contradiction of the research methodology and results. Credibility can be improved by implementing the research process and describing it unambiguously. Furthermore, all methodological choices must be rationalized, and different interpretations made from the data must be justified and written as openly as possible (Hirsjärvi et al., 2009; Saaranen-Kauppinen & Puusniekka, 2009). According to chapter 1.3, a qualitative case study was chosen as the research strategy because it was suitable for understanding and describing the research object in the research context. Using the theme interview as a data collection method was justified to express the opinions of the interviewees and create a deeper understanding of the research topic. In an interview situation, the credibility of the research can be improved by recording the interviews (Saaranen-Kauppinen & Puusniekka, 2009). According to chapter 5.2., the conducted interviews were recorded and transcribed for a deeper analysis of the results.

The generalizability and applicability of the research are evaluated by how well the research results can be generalized and transferred to other situations. A case study prefers to examine the research phenomenon profoundly in a chosen context, and therefore it doesn't pursue generalizing the results. It is however possible for a case study in some situations to provide information that transcends the context and provides opportunities to apply the results to other contexts. (Saaranen-Kauppinen & Puusniekka, 2009) The research explored the functionality of xAPI-specification, especially towards the expectations of future e-learning and analytics expectations and needs in the context of a project creating a national digital service platform. The empirical data was primarily limited to the opinions of the project experts and expanded by interviewing experts from different stakeholder groups who have experience in e-learning and learning ecosystems at the national level. The results of the empirical material supported the results obtained in the literature review and therefore also endorsed the assessment of xAPI-specification as a suitable solution for the project.

The generalizability of the research can furthermore be assessed by collecting appropriate material (Saaranen-Kauppinen & Puusniekka, 2009). The material can be identified to be sufficient when it is saturated, i.e., when saturation is reached. Interview material gets saturated when it starts to repeat itself and collecting it no longer produces new information in terms of the research questions. (Eskola & Suoranta, 1998) In this research, saturation was achieved quite well as the answers received in the interviews began to resemble each other as the interviews progressed. It is possible that by increasing the number of interviewees, some new answers to the research questions could have been achieved. However, it is generally typical for theme interviews to have a preferably small sample size, and with a larger sample, analyzing the material and making observations could have been more difficult.

The assessment of the research certainty includes examining the presuppositions of both the research and the researcher. In a qualitative case study, the researcher's subjectivity is identified as research affecting factor. (Saaranen-Kauppinen & Puusniekka, 2009) The research aims to describe the research object without considering the researcher's personal preconceptions, and therefore the researcher must recognize his own biases toward the research topic and act as if they have no effect on the research outcome. In this regard, the objective was to keep the researcher's presuppositions separate from the interpretation of the data and results. The nature of a case study is however subjective, which makes it possible for another researcher to possibly interpret the results in some respects differently in conducting corresponding research. (Guba & Lincoln, 1994, pp.105-117).

The confirmability of the research is evaluated based on whether the results receive support from previous research studies (Guba & Lincoln, 1994, pp. 105-117). In this research, the results obtained from the empirical data were compared with the theory to draw conclusions. This is presented in chapter 7. The confirmability of the research is supported by the fact that the results achieved based on empirical data mainly supported the previous studies on the topic presented in the theory section.

One of the research objectives was to produce sufficient e-learning- and learning analytics-related information for the target project, which can be used to assess the suitability of xAPI as a part of the digital service platform. The results of this research are therefore best suited for the use of the target project and other corresponding projects with similar expectations and needs. The research provided an answer to the research questions with the support of a literature review and a case study, and the knowledge related to e-learning, analytics, and e-learning standardization concepts was increased. Considering the research results and the conclusions drawn from them, it can be stated that the research has achieved its objective.

8.4 Research limitations and further research topics

The research was limited to the context of the target project and the empirical material of the research was limited to expert interviews obtained from the research target project experts and stakeholder experts working in different consulting roles. However, there can be identified companies with needs that are very different from the needs of the target project, and therefore it would be interesting to examine how the different e-learning, analytics, and business needs affect standard selection in different environments.

The research was limited to the context of the target project and largely dealt with comparing the functionalities of xAPI with certain pre-selected standards and specifications. Further research could therefore concern the utilization of the new specifications established to emphasize a set of practices providing all xAPI and SCORM competencies while making use of the IMS Caliper and CMI-5 for a large-scale data architecture for an exchange of compliant content between learning applications.

Due to the time span and scope, the research was limited to creating a model of functionalities of xAPI specification based on theory and testing the suitability of these functionalities with interviews. The functionality of the xAPI could not be tested in a real environment, and therefore it remained at the theoretical level. In further research, the functionality of the xAPI specification could be tested in practice by implementing it as a part of information system architecture and collecting feedback on its functionality, as well as whether it achieves and meets the actual business needs.

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APPENDIX A: INTERVIEW BODY

Background questions (common to all groups)

1. Your job description/role in the organization
2. Your knowledge/experience with e-learning standardization and xAPI

Question body 1: DigiOne

1. What possibilities do the current systems and technologies provide for tracking and collecting learning data?
    a. What kind of learner/learning-related data is currently being collected and analyzed?
    b. Does the data give enough information to understand learners and learning behavior comprehensively?
2. How do you see the role of tracking and collecting learning data in the future?
    a. How do you consider the objectives of DigiOne, especially in the field of learning analytics?
    b. Do you consider the current e-learning technologies and standards setting any shortcomings or challenges for tracking and collecting learning data?
3. What are the main reasons to consider a new specification?
    a. What expectations do you have towards a new specification/standardization?
4. Which factors should be considered to successfully design and implement new standardization technology as a part of the DigiOne platform?

Question body 2: Stakeholder Groups

1. How do you see the current state and future of digitalization of learning?
    a. What is the role of e-learning in the learning ecosystem?
    b. How do you think e-learning is going to evolve in the future?
2. What kind of expectations do you have towards e-learning and learning analytics, especially in the future?
    a. What kind of data is needed to analyze learning more comprehensively?
    b. What kind of technologies are needed?
3. Do you consider there is a demand for more advanced e-learning standardization technology in the future?

a. Do you consider the current e-learning technologies and standards possibly setting any shortcomings or challenges for tracking and collecting learning data, especially in the future?
b. Which factors should be considered to successfully design and implement new e-learning standardization technology?