

Architecture for a Large Scale Learning Ecosystem

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Abstract. This paper presents a concept for an integral learning ecosystem for the Netherlands armed forces consisting of six components: learning content, didactics, people, technology, data, and policy and governance. The ecosystem is designed to enhance personalized learning and development by improving both effectiveness and efficiency. To facilitate the design of learning ecosystems, we propose a reference architecture tailored to the Netherlands armed forces. This paper also explores the implications of this architecture for Automated Instructional Systems (AIS), emphasizing the need for adaptability, standardization, and seamless integration with learning analytics. The continuous development of this learning ecosystem in The Netherlands may serve as a testcase for AIS platforms, providing further research and evaluation of their effectiveness in large-scale learning ecosystems.

Keywords: Learning Ecosystem, Adaptive Instructional System, Personalized Learning.

1 Introduction

Adaptive Instructional Systems (AIS) are data-driven tools that support learning within a single lesson or, to some extent across multiple lessons. As an example of Learning Analytics, this makes AIS rather unique. Other applications of Learning Analytics generally do not focus on the learning process, but support design or managerial decisions about lessons, modules or courses [1]. Recently, large (training) organizations have shown increased interest in integrating both perspectives into an integral learning ecosystem. Barret proposed a concept of such a system for the K-12 education system in de United States [2].

AIS also emphasizes automated real-time personalized instruction without instructor interventions. While this approach is common and often feasible in e-learning, it is less accepted - and sometimes impractical - for complex skills training. In scenarios with many contextual factors influencing the dynamic actions of the student or the team, such as air combat tactics training for fighter pilots, strict automation may not be possible. However, instructors may benefit from real time performance analytics using data to extend their observational capabilities. These analytics may provide warnings or recommendations during the exercise. Recommendations may also be provided based on analyzing trends in students' progress over a range of exercises. Such instructional support systems may be partly automated, but for complex situations mediated by

instructors. This may be more acceptable and more feasible than fully automatic AIS. Also, an integrated system of a variety of adaptive and conventional learning resources, which may include instructor guidance and interventions, presented as a hybrid tutor [3], appeared to be accepted [4]. An integral learning ecosystem of AIS, hybrid tutors and data driven decision support on all levels of an educational and training organization may support the ever-growing need for more efficient and effective training. This is particularly relevant for organizations experiencing rapid changes in technology, operations, and personnel. This perspective reinforces that AIS, on its own, does not constitute a full learning ecosystem. AISs typically have a smaller scope, focusing on a individual lessons or modules within a broader curriculum. They do not cover all aspects and processes of an educational and training organization as learning ecosystems intend to.

Not only formal education may benefit from an integral learning ecosystem. Measuring, analyzing and predicting proficiencies is also a Human Resource Development instrument in achieving a more flexible and supporting organization. Personal capabilities, development, and needs may be monitored and acknowledged sooner to guide (formal, informal or experiential) learning and career choices more effectively and more fulfilling to personnel.

Hybrid tutors and managerial support systems require data, data analysis, a technological infrastructure and organizational processes in a well-coordinated system. We explored what this implies for Netherlands armed forces. In this paper we present the main concepts and a reference architecture that enables development of large scale learning ecosystems consisting of a variety of ICT tools that support the work processes of Learning and Development (L&D) organizations. The architecture is a first step to guidelines for the integration of AIS, measuring systems and other analytics tooling in learning ecosystems. We recommend to consider and integrate the specific tooling on multiple levels (micro: the learning process of individuals, meso: Learning and Development tracks, and macro: the strategy and policy level) to ensure smooth acceptance and involvement of all actors in the large scale learning ecosystem. We conclude the paper with a discussion on the implications for AIS as part of such a larger ecosystem.

2 A learning ecosystem perspective for the Netherlands armed forces

Building on Walcutt and Schatz [5], we recognize that a learning ecosystem extends beyond the tooling and technological backbone that supports it. The following six components of a learning ecosystem need to be considered and carefully aligned: learning content, didactics, people, technology, data, and policy and governance. Together, these elements collectively define a learning ecosystem for the Netherlands (NL) armed forces:

a learning ecosystem is a dynamic and versatile system of carefully aligned [aforementioned] components that continuously supports and guides NL armed forces personnel

(as part of this system) in a flexible and personalized way in their learning and development.

Figure 1 illustrates the six components that comprise a customized learning ecosystem. The components must be optimally aligned to enable learners to learn efficiently and effectively. The components must be developed at three levels: micro, meso, and macro. At the micro level, learning takes place among individual learners. At the meso level, an L&D organization accommodates these learning processes. At the macro level the necessary frameworks (overarching and policy processes) are provided. A central element (at the meso level) is the L&D track, which encompasses all learning activities that a NL armed forces employee carries out in order to be able to perform one or more core tasks at the required level of proficiency. The key principle of L&D tracks is *information-driven personalized learning and development*. This ultimately leads to qualified and deployable personnel, in faster response to operational needs.

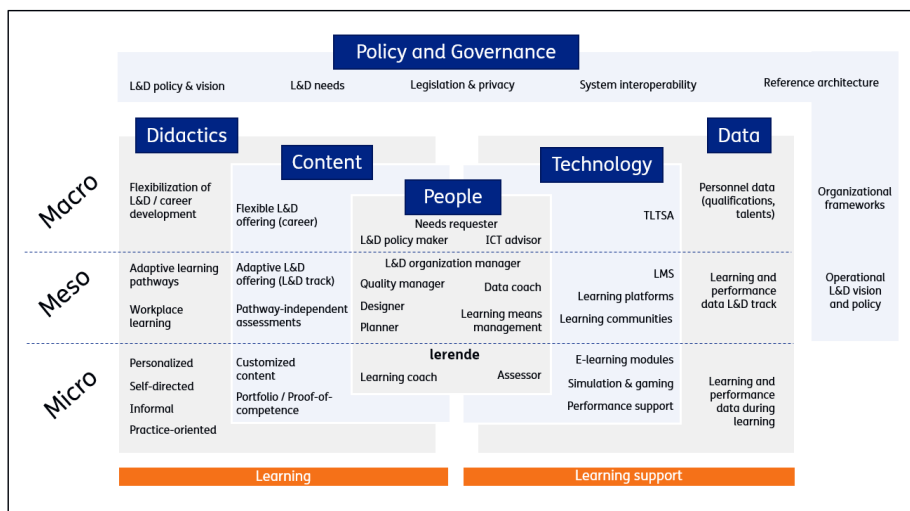


Fig. 1. Concept for the customized learning ecosystem for the Netherlands armed forces

Policy & Governance. This component provides a framework of recommendations, rules and guidelines for stakeholders and tools within the learning ecosystem with the primary goal of contributing to (rapid) operational readiness. Central bodies of the NL armed forces develop strategy and policy for education and individual training at the highest level. Military units and schools, as well as operational units or other workplaces in which learning takes place, then translate this high-level vision into specific guidelines tailored to their contexts.

Didactics. The learning ecosystem extends and changes the way the NL armed forces learn and develop. This starts with the design of learning. New teaching methods, forms of work, theories and practices are available, which often need to be further developed in order to properly and fully exploit the potential of a learning ecosystem [6, 5]. Teaching methods and educational principles should be scientifically based, so that evidence-based methods are used to convey information and knowledge to learners. At the NL armed forces, didactic methods such as personalized, self-directed, collaborative and informal learning have been introduced [7]. A learning ecosystem facilitates these methods by providing a platform for learners to collaborate and share ideas, resources and feedback. It also provides space for online learning communities and facilitates other important didactic principles applied in NL armed forces: any time, any place and 'just as needed'. Within a learning ecosystem, NL armed forces personnel can learn tailor-made, at a distance and at a moment's notice. Additionally, technological, data-driven applications incorporating didactic principles can optimize the learning experience by tailoring content, timing and the environment of the learning experience. Traditional education and training methods can also be enhanced and personalized, leading to faster and more effective deployment of NL Armed Forces personnel.

Learning content. The learning content provided by a L&D organization (such as a training institution or school) to the learning ecosystem encompasses a wide range of resources, including instructional materials, courses, and information. This content supports both formal learning, such as online and classroom instruction, and informal learning within learning communities or at the workplace. This may include asynchronous courses, videos, articles, podcasts, on-the-job tools, guides, e-books and webcasts. Learning by using simulations/simulators, Virtual/Augmented/Mixed Reality devices, serious gaming, training ranges etc. requires the organization and development of training scenarios and practice material. Performance support in the workplace may be provided to support NL armed forces personnel in carrying out tasks. Effective management of the learning content is essential to ensure that it aligns with the learning needs and preferences of NL armed forces personnel. A learning ecosystem enables the seamless integration of this learning content, supporting individualized learning pathways across different military domains (or units). Learning content can be offered more integrally across military units. It is also important to align courses, modules and training scenarios with military careers. This approach can facilitate staff exchange and contribute to faster, more effective personnel readiness.

People. A learning ecosystem provides NL armed forces personnel with the tools and resources they need to continue to acquire new knowledge and skills throughout their career, i.e. to continue to learn and develop. There are several stakeholders involved in a learning ecosystem. First of all, it concerns the learners, in our case, the NL armed forces personnel who are on a learning or development path. A learning ecosystem also encompasses various other stakeholders, such as principals of the various schools or operational units, instructors, content developers, support staff such as planners, policymakers and other stakeholders within NL armed forces who interact with learners throughout their learning journey. Learners should not learn in isolation but in

interaction with each other, for example in learning communities [8]. A community of practice (CoP) is an example of a group in which individuals work and reflect together in order to learn and develop together. Lave and Wenger [9] point out that learning is often situational, that is, people learn through social interactions. Lave and Wenger define a community of practice as "a set of relations among persons activity and world over time and in relation with other tangential and overlapping CoPs" (p.98). Finally, it is important that participants feel comfortable within the learning ecosystem. NL armed forces personnel must recognize its potential and understand how to use it effectively to navigate their personal learning paths.

Technology. Information technology is an important building block of the future learning ecosystem. Instruction systems, interoperability standards, cross-platform data integration and centralized software services allow the integration and facilitation of learning experiences, provided that the technology is properly embedded in the organization. This also includes the change process that individuals involved must undergo. Within this framework, the NL armed forces is working on the Technological Learning, Training and Simulation Architecture (TLTSA). This is a technological infrastructure that is based on the Total Learning Architecture of the Advanced Distributed Learning (ADL) initiative [10]. TLTSA that will enable links between all types of learning environments as well as data-driven information to be deployed throughout the NL armed forces. Data schemes, technical standards, management conventions and (generative) AI techniques allow for far-reaching automation of the recording, aggregation, analysis and production of various learning activities. This provides new options for substantial personalization and possible data-driven adaptations of the learning organization at throughout the NL armed forces. This enables truly ubiquitous learning making is accessible anytime, anywhere, in various formats and for diverse functions. As result, learning can be tailored for maximum effectiveness. Learning experiences acquired in various learning environments, training or workplaces can be combined and monitored, ultimately contributing to formal qualifications or less formally acquired learning outcomes of NL armed forces personnel, all of which can be centrally monitored.

A modern technology used to support and promote a learning ecosystem – also applied by the NL armed forces - within the TLTSA - is a Learning Experience Platform (LXP), which is increasingly coming alongside the familiar Learning Management System (LMS). Generally accepted standards based on xAPI (experience API) are used to link all types of NL armed forces personnel data collected from various learning systems. Recently, content can also be produced using generative AI, which brings a new dimension to the LXP concept. In the defense industry, changes and technological developments follow each other in rapid succession. Lifelong learning is therefore essential for NL armed forces to remain competitive and adapt to new challenges [11].

Data. Data is essential to a learning ecosystem as it supports understanding and optimization of the learning behaviour, progress and outcomes of NL armed forces personnel. For example, data provides insights into the functioning of the underlying ecosystem technology platform, identifies trends and reveals how, when and where employees

engage in learning. Measuring and monitoring learning data, using standard data protocols such as xAPI, enables the learning behaviour of NL armed forces personnel to be analysed, interpreted, evaluated and reported. Not only the learners themselves, but also coaches, developers, educators and management benefit from such Learning Analytics, for example, to be able to follow the activities, progress and performance of large groups of learners. In addition to information for and about learners' choices, time spent and progression, insights can be gained into preferences for types of content or modality for learners on the basis of which personalised advice can be given or generated. Data about courses and sessions (e.g. occupancy rate or dropout rate) or about learners' (preferences) and learning effectiveness can be used to make decisions about which learning resources should be retained, extended or removed. The conclusions and recommendations that follow from data analyses are in line with the quality of the data. Without adequate quantitative and qualitative data (objective, reliable, valid, usable formats), good conclusions and decisions are not possible. The same applies to advice and decision support as well as to the generation of teaching material, lesson plans and training scenarios. This may relate to the completeness and reliability of the data, the method of linking, etc. The same applies to applications based on Artificial Intelligence (AI). These applications also rely on the collection and use of large amounts of data. By leveraging this technology in combination with learning analytics, a learning ecosystem can realize diverse learning opportunities. Beyond data analysis, it also provides in substantive support for learning itself, such as acting as a sparring partner, evaluation and feedback, scenario generation and simulation, and the delivery and structuring of information.

A key aspect of our definition of a large scale learning ecosystem is the recognition that different schools and training providers will have unique training needs and approaches often requiring highly specialized tooling, data management systems, and processes. A learning ecosystem should be able to accommodate these special needs and therefore a learning ecosystem itself needs to be adaptive. The need for standardization as well as the need for adaptability to specific needs of L&D providers are recognized and may provide some challenges. We aim to ease the design of a learning ecosystem by providing a reference architecture.

3 An architecture to guide development and implementation of a large scale learning ecosystem for the Netherlands armed forces

To support both harmonization, commonalities, as well as adaptability of learning ecosystems, we develop a framework containing the organizational principles, terminology, and stakeholders of a learning ecosystem as well as a blueprint for the design of the (organizational) information processes within that system. The framework forms a reference architecture for the learning ecosystem within the NL armed forces.

A reference architecture is a standardized model or framework that describes the principles for designing and implementing the information provision within a domain

or organization. The architecture aims to facilitate a shared understanding among different parties as well as to help achieve consistency, interoperability, and reusability of information systems and their components. A reference architecture typically includes 1) a vocabulary with definitions of all concepts within the considered domain, such as actors and (business) processes, 2) a set of general design principles and standards to be applied, and 3) a description of the components of the information systems, their functionalities, relationships, and interactions.

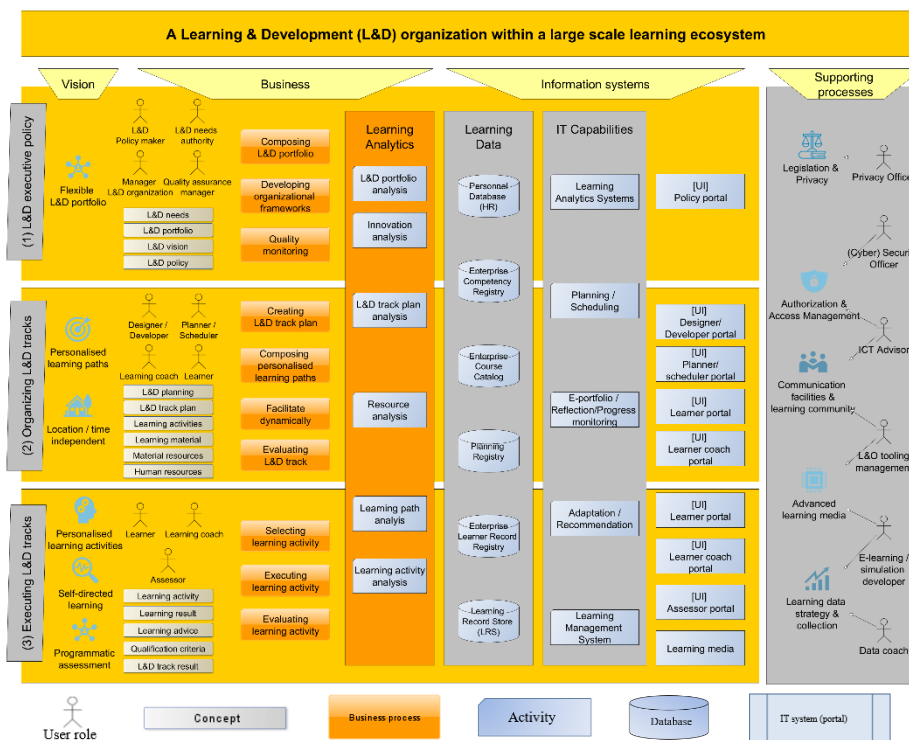


Fig. 2. Architecture overview for a large scale learning ecosystem for the Netherlands armed forces (L&D organization scope).

The reference architecture is still under development. Figure 2 shows the latest version of the architecture, that focuses on learning at the micro level, organized at the meso level by an L&D organization. The business processes of the macro-level of the learning ecosystem are not yet modelled. An L&D organization refers to a school, operational unit, or other entity where learning and development take place. This can include various types of L&D tracks, ranging from specific training programs for military personnel to career development programs for both military and civilian personnel, and learning-on-the-job. An L&D organization can, for example, be 1) a specific school within the NL armed forces (such as a Manoeuvre School), 2) an organisation unit of the NL armed forces that combines multiple schools, 3) an operational unit that

facilitates learning-on-the-job, or 4) an external organization (such as a civil school or a civil training agency) that provides or facilitates an L&D track on behalf of NL armed forces.

The central principle for the design and organization of L&D tracks, *information-driven personalized learning and development*, is considered to be the main policy principle for L&D within the NL armed forces. Other key (didactical) policy principles are provided in the first column of Figure 2. Together they form the conceptual framework for the learning ecosystem.

Three main business processes to support the mentioned central principle on meso and micro levels are: 1) design and evaluation of L&D executive policy, 2) organizing L&D tracks, 3) executing L&D tracks. These main processes are represented by the three horizontal layers in the architecture overview.

The three main business processes are carried out on the basis of learning data which is collected, analysed, presented and secured at all levels within the L&D organizations for the purpose of personalized learning. The aim is to vastly increase the efficiency and effectiveness of learning and development. Learning analytics could be considered as the fourth main business process within the learning ecosystem. However, in view of its close interrelationship with the other three main business processes, learning analytics is not described as a separate main business process but as an integral part of the three main business processes. Within that core business process, analyses of learning data are performed from different perspectives (e.g. learning activity analysis, learning track analysis). The results of these analyses are used to support the business processes falling within the three main business processes mentioned above.

The architecture highlights the implementation of these main business processes from two perspectives (the middle two columns in Figure 2): the Business perspective and the Information Systems perspective. The architecture also highlights a number of Facilitating processes (the right column in Figure 2).

The Business perspective includes, on each layer, the business processes that are performed there and the user roles and concepts that play a role in them. The Learning Analytics column provides an overview of the different types of learning analytics used in the business processes. The Information Systems perspective includes a set of (learning) data sources, ICT functionalities, and user portals. The ICT functionalities represent the required functionality for achieving the information flows.

A user role (e.g. a learning coach or a designer) is not necessarily connected to a single person. A user role may be performed by a person, a team, a human-machine team, or an (AI) automated system. This is not yet worked out in the architecture and is expected to change over time within the life cycle of a learning eco-system. Also, not worked out are the various learning analytics processes and associated user roles that relate to the steps between data collection and interpretation/decision making.

4 Implications for Adaptive Instructional Systems

AIS has the potential to become a key tool at the micro level of a learning ecosystem. This perspective is promising, as it could enhance both the applicability and acceptance

of AISs. However, integration of AIS within such ecosystems may introduce more requirements, constraints and opportunities that have not been previously considered by developers and researchers.. For example, an AIS may need to use learning task meta tags in a direct link with a L&D track design tool. Additionally, learning trajectory analytics design tools may require data from an AIS beyond its internal analytics model, For example, data such as the number of trials that a learner needed to perform before meeting a performance criterion. Also, results from other training courses may need to be serve as automatic input for another AIS module. A critical aspect of AIS integration concerns data standards, security, and privacy measures, which can no longer be dealt with in a stand-alone set up. Beyond these technical considerations, macro-level policies may impose onset constraints to AIS functionalities. For example, a personalization policy may require that there is always human instructor involvement in major decision making processes. Consequently, future AIS implementations may need to adapt to broader learning and development systems.

At least two initiatives propose approaches towards modularization of AIS which allow integration to broader eco-systems: i.e., GIFT [12] and STATS (SoarTech Adaptive Training Services) [13]. These service-oriented frameworks are based on general assumptions of interoperability and efficiency, rather than specific requirements of large scale ecosystems. While these generic principles may prove sufficient, the full range of ecosystem-level requirements remains uncertain. Furthermore, how AIS (frameworks) may benefit from processing data from organizational learning analytics and dynamic models of personal learning is not yet well understood. Future research should explore these effects. The ongoing development and implementation of the NL armed forces learning ecosystem may serve as a valuable testcase for evaluating AIS platforms within a large-scale, real-world setting.

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