Development of Learning Analysis Framework on Metaverse

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Research studies in various educational fields related to metaverse are increasing, raising the possibility as an online education integration platform. In this study, prior studies were systematically analyzed based on Activity Theory to develop a learning analysis framework that can be used in the metaverse. Conceptual Framework Development Model was applied to the framework conceptualization. In the first step of data collection and selection, 30 papers were selected through a systematic literature review model, PRISMA. In the second step, literature analysis was conducted using Activity Theory-based system. In the third stage, an initial model of the theoretical framework was derived based on previous step's result. In the step 4, expert validation for model evaluation was carried out, and a modified theoretical framework was formed. In step 5, we develop a conceptual framework that extends the theoretical framework based on expert opinions and finally present a learning analysis framework applicable in the metaverse learning environment.

Key words: Metaverse Learning Analysis, Learning Analysis, Learning Analysis Framework, Metaverse Framework, Learning Analytics, Activity Theory

INTRODUCTION

As non-face-to-face education spreads, studies are being conducted for future education such as artificial intelligence, advanced science and technology, and metaverse. In particular, metaverse, in which reality is expanded to a virtual space, is attracting attention as a new paradigm as it can interact through combination of the physical world and the virtual world, and can carry out social, economic, educational, and cultural activities as an extension of reality (Go et al, 2021; Lee, 2021).

When Metaverse is expanded to an online education platform, various problems and issues have been raised, including learners' learning activities, students' educational concentration, frustration and stress, and the absence of learning tutors. As a solution to this, learning analytics has been proposed (Oliveira et al., 2016; Sukon et al., 2012; Wojciechowski & Cellary, 2013; Xi et al., 2022).

Learning Analytics is defined as 'the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs' (LAK, 2011), and academic approach to controlling learning outcomes by applying teaching and learning prescriptions using learning analysis results (Elias, 2011; Siemens & Long, 2011).

On the other hand, applying Learning Analytics requires a framework to guide this. It is necessary to collect data that can be used in the metaverse, a digital virtual space (VR), and synthesize measurable variables and related factors.

Existing metaverse learning analysis-related frameworks has some limits. Some focus on hardware elements in fragments, or do not go deep in explaining concepts. In addition, procedural elements or the level of categorization is rather simple for application (Christopoulos et al., 2020; Fernández-Gallego et al., 2013; Park & Kim, 2022; Rosa et al., 2020).

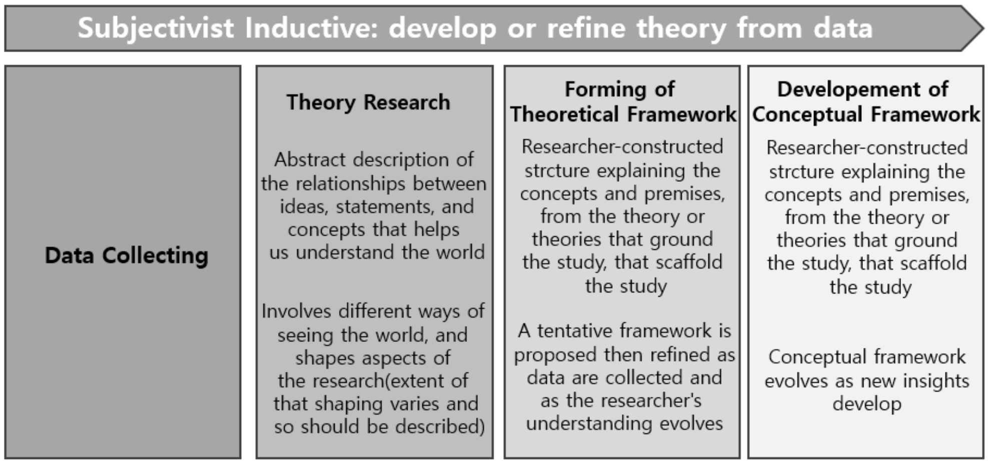
The framework is expressed in various ways according to necessity and purpose, and in this study, the 'conceptual framework development model' was applied as a step-by-step approach to develop metaverse learning analysis framework (Varpio et al., 2020). This is a model that logically sets the overall direction and association of the subject to be dealt with, and finally presents it, including the researcher's systematic perspective.

RESEARCH DESIGN & METHODS

Framework Modeling

In this study, we progressed based on the 'Conceptual framework development model' to develop the metaverse learning analysis framework, and based on a bottom-up approach that starts with data related to a specific phenomenon through inductive methods and move to general or abstract conceptualization of the phenomenon. Figure 1 shows the specific process of conceptual framework development modeling used in this study.

Figure 1.
Subjectivist Inductive Approaches to Research (Varpio et al., 2020)



Research Process & Methods

The specific research process for the development of the conceptual framework of this study is as follows. Phase 1 Data Collection: Literature was collected and selected by applying PRISM (Page MJ et al., 2021). Phase 2 Theory Exploration: Collected literature was analyzed using Engeström (1987)'s second-generation activity system based on Activity Theory. Phase 3 Theoretical Framework Formation: Learning analysis theoretical framework was derived by eliminating duplicate data, categorization, and sequencing. Phase 4 Expert Validation and Opinion Collection: Expert validation of the theoretical framework and collection of expert opinion for the conceptual framework were administered. Phase 5 Conceptual Framework Development: A metaverse learning analysis framework model was developed based on the collected expert opinions. The research procedure of this study is shown in Table 1.

Table 1.
Research Process

Phase	Process	Description

Phase 1	Data Collecting	-Data collecting & selection based on PRISMA -Process: Identification > Screening > Eligibility > Included
Phase 2	Theory Research	- Literature review based on Activity Theory - Using Activity System reconfigured (Engeström, 1987)
Phase 3	Forming of Theoretical Framework	Result-based (Phase 2) Forming of theoretical framework
Phase 4	Expert Validation Collecting Opinions	- Expert validation of theoretical framework - Expert opinions for conceptual framework development
Phase 5	Development of Conceptual Framework	- Suggestion for Metaverse Learning Analysis Framework

Research Tools

In this study, Engeström (1987)'s second-generation activity system was adapted for research purposes, and the components were divided into behavioral and contextual areas (Florian et al., 2011). Subjects, objects, and tools were analyzed as behavioral area which is the center of the research. Community, rules, and role were analyzed as the context area which is peripheral of the study. The activity system used in this study is shown in Table 2.

Table 2.
Activity System Reconfigured (Engeström, 1987)

Activity System		Contents	Description
Contents of Activity System	Activity Area	Subject	Learning activity subjects, Learners' characteristics
		Object	Domains of learning, Learning activity, Learning activity data
		Tools	Systems, Interaction tools, Analysis tools/methods
	Context Area	Community	Stakeholders related to learning analysis
		Rules	Learning conditions/limitation, Assessment criteria, Teaching methods
		Roles	The roles of stakeholders
Results of Activity System		Outcome	Purpose and type of learning analysis

To verify the development of the metaverse learning analysis framework, 10 experts with more than 10 years of experience in related fields were surveyed. The validation tool consists of items such as validity, explanatory power, usefulness, universality, understanding, acceptability, and testability, and consists of optional questions on the Likert 4-point scale and open questions. Table 3 shows the validation tools used in this study.

Table 3.
Expert Validation

Section	Definition
Validity	This framework is valid for use in learning analysis in metaverse.
Explanation	This framework explains the elements and their relationships step by step.
Usability	Elements, relationships, and structures of this framework are useful.
Applicability	This framework can be universally applied to learning analysis.
Comprehension	This framework is understandable for language and visual representations.
Acceptability	This framework is familiar and acceptable to the person concerned.
Testability	This framework presents an empirical and reproducible hypothesis.

In this study, the theoretical framework was expanded by collecting opinions from experts widely, and a conceptual framework was developed for metaverse learning analysis. The format of questions is partially semi-structured open questions with a range, and the expert questionnaire is shown in Table 4.

Table 4.
A Survey Tool for Development of Conceptual Framework

Section	Description
Category	1. What are the additional categories? ※ Category, Range, Series, Array, Placement
Elements	2. What are the additional elements in categories? ※ Elements, Content, Variables
Procedure	3. What are the additional procedures? ※ Flow, Association, Direction
Characteristics	4. What are the metaverse features? ※ Space, Realism, Non-verbal Communication, Affordance, Avatars, and etc.
Addition	5. What are the additional comprehensive comments?

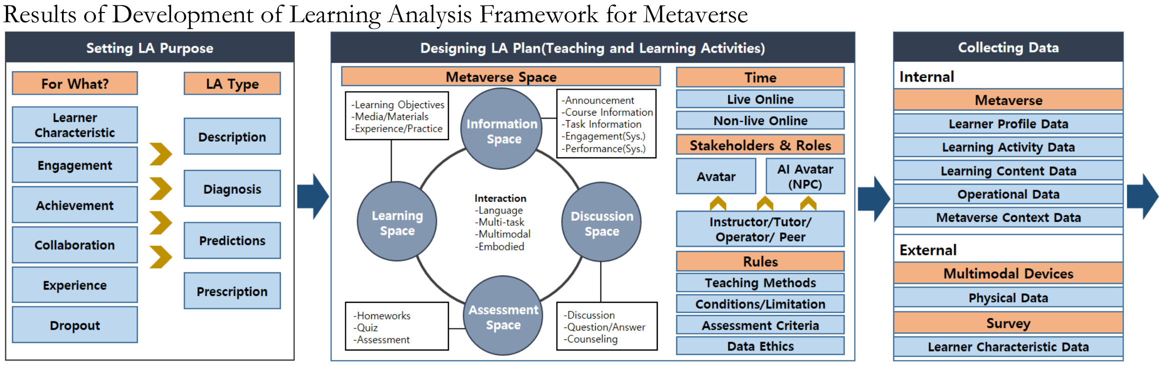
RESULTS

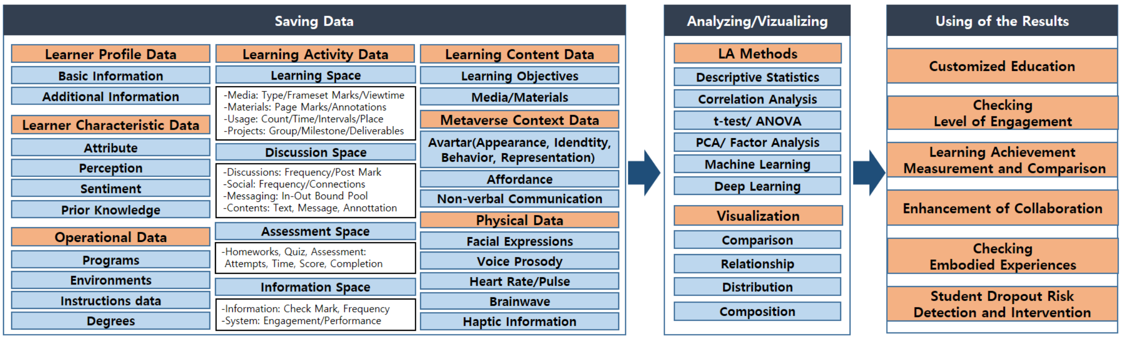
Studies to be analyzed were selected according to the guidelines of the PRISMA method. After four stages of the PRISMA method (Identification, Screening, Eligibility, and Included), the final 30 documents were selected for analysis. A literature analysis process was conducted based on the activity system model for 30 selected papers, and a learning analysis theoretical framework was derived based on the analyzed contents. The theoretical framework was used as a role of scaffolding to expand the concept of existing LMS-centered learning analysis research and achieve the purpose of the study. The CVRs results on the theoretical framework were validity (0.8), usefulness (1.0), understanding (0.8), and acceptability (0.8). However, explanatory power (0.4), applicability (0.4), and testability (0.2) were low (Ayre & Scally, 2014).

The main opinions of experts on deficiencies of the framework were complementary design of structures and procedures for practical use, absence of categories considering user aspects, consideration of item selection, and lack of reflection of elements of the activity system model. The results are to be combined with the next stage of expert opinion collection and reflect them as much as possible in the development of a conceptual framework. In addition to expert validity, experts' opinions were collected to expand the concept of the theoretical framework for metaverse. As the main opinions of experts, space, avatar, presence, multimodal information, affordance, and non-verbal communication were presented as contents about the discriminatory characteristics of the metaverse. Through this, a conceptual framework expanded by supplementing the theoretical framework was developed, as shown in Figure 2.

Figure 2.

Results of Development of Learning Analysis Framework for Metaverse





The suggested learning analysis framework on the metaverse has six stages. In the first step, the responsible variable of learning analysis and the type of data analysis were presented to establish the purpose of learning analysis. The instructor can specify the purpose of the learning analysis by selecting and combining the suggested response variable of the learning analysis and the type of data analysis.
In stage 2, it is to establish a plan for collecting data related to the explanatory variable of learning analysis, and contents that need to be considered focusing on teaching and learning were presented. In this stage, the contents are divided into virtual space, time, stakeholders and roles, and rules, reflecting the characteristics of the metaverse.

In the third stage, data based on the second stage learner activities and the surrounding context were largely divided into the inside and outside of the metaverse and presented. In stage 4, related elements of the collected data are summarized. Specifically, the 'learner profile data' stores basic information and additional information of the students. In 'learner characteristic data', learner attitudes, perceptions, emotions, and prior knowledge collected through survey tools are stored. The 'operational data' includes curriculum-related information and systematic environmental factors. The 'learning activity data' collects data based on learning activities by dividing the extraction area into four main areas (learning space, discussion space, information space, and assessment space). Here, the learning activity trace data is digitized or stored in the form of text. In addition, the appearance, behavior, representation and affordance, and non-verbal communication of avatars, which are characterized by major functions in the metaverse, are stored as 'metaverse context data'. Elements of 'physical data' include facial expression, voice, heart rate/pulse, brain waves, and haptic related information. In stage 5, the data analysis method and visualization method are presented in the analysis and visualization process.
In the stage 6, a way for instructors to utilize the results through all stages of learning analysis is presented. For example, it can be used to check the level of learning participation through the learning analysis framework on the metaverse, measure and compare learning outcomes, provide customized education, detect and intervene dropouts, promote cooperative activities, and confirm Embodied Experiences.
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