Immersive Learning Explored: Subjective and Objective Factors Influencing Learning Outcomes in Immersive Educational Virtual Environments

Andreas Dengel
Mathematics and Informatics Education Unit
University of Passau
Passau, Germany
andreas.dengel@uni-passau.de

Jutta Mägdefrau
Chair of Educational Science
University of Passau
Passau, Germany
jutta.maegdefrau@uni-passau.de

***Abstract*—Recent studies in Immersive Learning show that different factors influence the learning outcomes in Educational Virtual Environments (EVEs). An underlying theory about learning in EVEs from an educational perspective is yet lacking. To enhance immersive learning research, a systematic framework of immersive learning processes as a theoretic foundation is required in order to appropriately discuss these processes. This paper summarizes the factors influencing learning in EVEs and introduces their localization in the Helmkes' pedagogical supply-use-model. Presence as the subjective feeling of "being there" is emphasized as the central criterion influencing immersive learning. Presence is influenced by objective and subjective factors. The objective factors which are provided by the technology are summarized under the term immersion; the subjective factors consist of the motivational, cognitive, and the emotional factors. They are summarized as (immersive) learning potential. The localization of these predictor variables of learning outcome in Helmke's supply-use-model results in the educational framework for immersive learning (EFiL), which provides an educational understanding of immersive learning as "learning activities initiated by a mediated or medially enriched environment that evokes a sense of presence". It constitutes a first educational reflection of immersive learning processes which has to be pursued and evaluated by empirical research.**

Keywords—immersive learning, supply use model, presence, immersion, learning outcome

I. Introduction

Research in terms of the use of virtual and mixed reality technology in education has been around for a while now: Bricken named Virtual Reality (VR) as a paradigm shift in education in the early 90s. Several technology aspects of VR will change education as we know it: *Symbol processing* becomes *reality generation*; *viewing a monitor* becomes *wearing a computer*; *symbolic* becomes *experiential*; the *observer* becomes a *participant;* an *interface* becomes an *inclusion*; *physical* experiences are now *programmable*; *visual* perception becomes *multimodal* in VR; a *metaphor* becomes a *virtuality* [1]. Even though Bricken states that the generation of VR applications for education is easy ("Just substitute the virtual for the actual, then get rid of the constraints of the actual" [1]), he is well aware of the fact that different factors that might influence the learning process in an educational virtual reality by separating the concepts *Programmable Participation* (creating/programming environments for a specific curriculum in which students can participate), *Natural Semantics* (creating natural VR input possibilities), *Constructivism* (explaining abstraction through interaction), *Cognitive Presence* (bringing the learners perspective within the same context as the learning object) and *Multiple Participants* (social interaction in virtual worlds) [1].

Due to the lack of VR applications at the time, Bricken stays at a theoretical level. But it becomes clear that a learning experience in an educational virtual environment (EVE) which immerses the user into a virtual or mixed reality is influenced by many different individual (subjective) and technological (objective) factors. As an EVE pursues one or more educational objectives by using pedagogical metaphors and provides experiences which users would otherwise not be able to experience in the physical world [2], an examination of these factors is necessary for an explanation of how these objectives can be fulfilled. In order to provide a solid basis for discussions and research from a pedagogical perspective in terms of immersive learning, a subsumption and a classification of these factors is needed. This paper aims to provide a theoretical localization of factors which were disclosed through empirical research in a pedagogical framework for explaining learning outcomes.

An appropriate educational framework can be of use for future research as well as for practitioners aiming to increase the learning performance of their students by using EVEs. Therefore, the use of an already established educational framework seems appropriate in order to explore immersive learning and to localize the factors influencing the learning outcome during the learning process.

II. Factors Influencing Learning Outcomes

On the basis of Brickens' work, many researchers conducted studies on immersive learning. In order to develop an understanding of immersive learning, this part presents an excerpt of the factors immersion, presence, motivation, cognition, and emotion, which have been disclosed to influence the learning outcome in EVEs.

A. Immersion

In this paper, we follow Slater's definition of *immersion*: "Let's reserve the term 'immersion' to stand simply for what the technology delivers from an objective point of view" [3]. This understanding of *immersion* enables a quantifiable perspective of technology: Steuer separates *vividness* and *interactivity* as central components of a technology which is capable of immersing a user into a virtual or mixed reality. *Vividness* is defined as "the representational richness of a mediated environment as defined by its formal features, that is, the way in which an environment presents information to the senses" [4]. *Vividness* consists of the factors *sensory breadth* (the total number of sensory dimensions which are simultaneously presented to the user) and *sensory depth* (the resolution within the respective perception channels). *Interactivity* can be defined "as the extent to which users can participate in modifying the form and content of a mediated environment in real time". As the three factors contributing to *interactivity*, Steuer names *speed* (the assimilation rate of the input into the mediated environment), *range* (the total number of action possibilities at any given time), and *mapping* (the systems' ability to map its controls to modifications in the mediated environment regarding a natural and predictable manner) [4].

Research on the effect of different immersive settings on learning outcome mostly resulted in the comparison of apparently different levels of immersion like a desktop computer and a head-mounted-display (HMD), where all of Steuers' factors were either higher or equal from the one to the other setting. Until today, this procedure is inevitable as there is still a lack of methods to distinctly (or numerically) quantify the immersion level (in the understanding of Slater) of a technological device. Wan, Fang, and Neufeld emphasize the importance of technological features in the learning process [5]. The effect of different aspects of immersion on learning has been examined by several researchers: Most comparisons of desktop computer settings and HMD settings have shown that a more immersive setting has a positive effect on learning success [2][6]. This has also been confirmed for physical learning activities [7]. Mikropoulos examined differences between egocentric and exocentric perspectives [2]. Bailenson et al. investigated the effect of the field of view on the attention of the user [8]. Lee, Wong, and Fung investigated the effect of *immersion* in a similar understanding of Steuers' *mapping* factor, but with a subjective judgment of the genuineness of the interaction on learning outcome. They found positive effects of the latent variables *usability* (consisting of *perceived ease of use* and *perceived usefulness*) and *VR features* (consisting of *Presentational fidelity* and *immediacy of control*) on *presence, motivation*, *cognitive benefits*, *control & active*, and *reflective thinking*, which were the determining variable for *learning outcomes* [9].

It becomes clear that immersion has a strong influence on learning activities. Empirical research indicates that this effect may not be a predictive but a moderating one. As an objectively quantifiable factor, the components of immersion (provided hardware and software) can be directly manipulated by the teacher in order to enhance the students learning processes in immersive virtual environments.

B. Presence

The counterpart of our understanding of *immersion* is *presence*: *Presence* can be described as the feeling of being there [10]–[12]. As a subjective feeling, the user of a virtual or mixed reality feels present, when his "perceptual, vestibular, proprioceptive, and autonomic nervous systems are activated in a way similar to that of real life in similar situations" [3]. As an experience of a physical environment, it does not refer to one's surroundings as they actually exist in the physical world, but to the users' perception of those surroundings as mediated [4]. The process of mediation may result from both automatic and controlled mental processes. Doing so, *immersion* (given through *vividness* and *interactivity*) as technology influences (tele-) *presence* as human experience [4]. This effect has been experimentally verified [6]. Mikropoulos states that *presence* is a unique characteristic in EVEs which derives from different immersive settings (differences in hard- and software) [2]. Some research models distinguish different types of *presence*. A common categorization separates *physical presence*, *social presence* and *self-presence* [11][13]. As *presence* poses an individual psychological, situational variable, it is not directly assessable. Therefore, the most common assessment methods are subjective measures (most popular are post-test questionnaires, but also continuous assessment methods or several qualitative measures are possible) [14].

The effect of *presence* on learning outcome has been investigated in several studies: While early research from Bailey et al. investigating the effect of *presence* on recall could not find positive correlations [15], Lin et al. could verify a positive effect of *presence* on memory ($r=0.484$). The study also discovered positive correlations between *presence* and simulator sickness. Furthermore, a combined score of engagement, enjoyment, and immersion (with an understanding of *presence* as we use it in this paper) had an even higher effect on learning than *presence* alone ($r=0.530$) [7]. Roy and Schlemminger could verify a better improvement in terms of language competence correlating with a higher sense of *presence* (three points of measurement) [16]. In the mentioned study of Lee, Wong, and Fung, *presence* was one of the main factors predicting learning outcomes ($\beta=0.20$). In total, most divergences ($R^2=0.97$) in learning outcomes could be explained through the subjective measures *motivation*, *cognitive benefits*, *control & active learning*, and *reflective thinking*, and *presence* [9].

Presence as a subjective perception of the non-mediation of mediated (or real) contents seems to pose the central factor to influence learning outcome. The different kinds of measurement and theoretical understandings of *presence* are a challenge for the comparison of existing studies. Further, most studies about *presence* integrate different *immersion* levels without addressing the question whether differences in learning outcome correlating with *presence* derive from the perceived *presence* itself (moderated through the *immersion* level) or rather from a mediating effect of the *immersion* level on both, *presence* and learning outcome. Beyond the revealed effect of *presence* on learning outcome, more subjective factors (together with immersion as an objective factor) like cognitive aspects, motivational aspects, and emotional aspects seem to have an influence as well on learning outcome as on *presence*.

C. Motivational Factors

Motivation is an important predictor of scholastic learning in general. It can be seen as the underlying "why" of behavior. Following this approach, behavior can be intrinsically motivated, extrinsically motivated, or amotivated [17]. *Intrinsic motivation* "refers to the fact of doing an activity for itself, and the pleasure and satisfaction derived from participation" [18]. A tripartite taxonomy by Vallerand et al. distinguishes intrinsic motivation into *intrinsic motivation to know* (pleasure and satisfaction through learning, exploring, or trying to understand something new), *intrinsic motivation toward accomplishments* (pleasure and satisfaction through attempting to accomplish or create something), and *intrinsic motivation to experience stimulation* (pleasure and satisfaction through experiencing stimulating sensations). *Extrinsic motivation* "pertains to a wide variety of behaviors that are engaged in as a means to an end and not for their own sake" [18]. The theory of self-determination of Deci and Ryan separates three types of *extrinsic motivation*: *external regulation* (regulation through external means like rewards and constraints), *introjected regulation* (internalization of past external contingencies), and *identification* (perception of extrinsic motives as chosen by oneself). *Amotivation* refers to a motivational state where an individual does not perceive contingencies between outcomes and his or her actions [18].

Regarding immersive learning environments, motivation has been identified as a central criterion for designing virtual learning environments [19]. On the basis of Bartles' player type distinction (which separates players into *Achievers, Explorers, Socialisers,* and *Killers*), Pirker suggests the *Player Type Design* in order to meet different types of extrinsic and intrinsic motivation regarding different types of players and learners [20]. In a conceptual model for creating motivational environments, Pirker identifies *engagement* and *immersion* (with an understanding of *immersion* as a subjective criterion, including *presence*) as central factors influencing learning. Qualitative and quantitative evaluations of the immersive physics laboratory *Maroon Room-Scale VR* and *Maroon Mobile VR* showed that more immersive settings are capable of meeting motivational objectives better than less or non-immersive settings and may hereby enhance *presence* [19]. Dede highlights the impact of the use of interactive and immersive learning environments on *intrinsic motivation* and *attention*: "Discovering new capabilities to shape one's environment is highly motivating and sharply focuses attention" [21]. As the research of Lee, Wong, and Fung indicates, *motivation* seems to be an impact factor (β=0.16) influencing learning outcomes. Furthermore, high correlations between the indicators of learning outcomes (*presence*, *motivation*, *cognitive benefits*, *control & active learning*, and *reflective thinking*) were expected in the research model [9].

Motivation seems to play two important roles regarding immersive learning: On the one hand, it influences learning through *intrinsic* and *extrinsic motivation*, as well as *amotivation* towards the learning content; on the other hand, the design of the EVE meets different motivational objectives which affect presence.

D. Cognitive Factors

The study from Lee, Wong, and Fung indicates that this is also true in virtual learning environments. They measured the effects of the cognitive factors *cognitive benefits*, *control & active learning,* and *reflective thinking* on *learning outcomes* [9]. According to Antonietti, Rasi, Imperio, and Sacco, *cognitive benefits* refer to a better memorization and a better understanding, as well as to a better application and overall view of learning contents in VR [22]. Students can adapt a presentation's pace and sequence to their own cognitive needs and skills through interactive and dynamic visualizations in VR in order to get a better comprehension and assimilation of the knowledge learned [23]. *Control & active learning* as a psychological state is experienced as a consequence when an individual focuses his or her attention on a coherent set of related activities and stimuli [24]. Hereby, "instructional designs where learners make their own decisions concerning the learning path, flow, or events of instruction" [25] evoke learner control in order to learn how to learn by making one's own instructional decisions [26]. This leads to an active involvement in the learning process resulting in higher feelings of being competent and self-determined as well as a higher interest in learning [27]. Dewey defines *reflective thinking* as the "active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends" [28]. It is needed for resolving cognitive discrepancies which evoke from the learner's new experiences and his or her previous knowledge. This puzzlement can be seen as a catalyst for meaning making: "By reflecting on the puzzling experience, learners integrate new experiences with their prior knowledge, or they establish goals for what they need to learn in order to make sense out of what they observe" [29]. For learning objectives closely aligned to assessment tasks, *reflective thinking* can be seen as a predictor of learning outcomes [30]. Lee, Wong, and Fung found that all cognitive factors (*cognitive benefits* with β=0.14, *control & active learning* with β=0.33, and *reflective thinking* with β=0.36) were strong antecedents to *learning outcomes* [9].

Cognitive skills have also been identified as a determinant for presence [31]–[33]. Schubert, Friedmann, and Regenbrecht argue that presence in a virtual environment derives from the construction of its spatial-functional mental model. This model involves two cognitive processes: construction as the representation of one's own bodily actions as possible actions in the virtual world, and the suppression of incompatible sensory input [34]. This argumentation corresponds to the presented definitions of presence from Slater [3] and Steuer [4] as well as to Biocca's understanding of presence as an unstable experience oscillating between the physical (non-mediated), the virtual (mediated), and the imaginal (mental) environment [13].

Cognitive factors have always played an important role in learning processes and activities. Immersive learning seems to benefit from cognitive factors in multiple ways: They enhance presence and learning outcomes and can be affected by providing EVEs which support instructional decisions and active learning.

E. *Emotional Factors*

For many years, educational research on learning activities mainly focused on cognitive, motivational, and behavioral constructs, neglecting the role of emotions in learning processes. But in recent years, research efforts in terms of the influence of academic emotions on learning outcomes has been fostered [35]. Following the control-value theory of emotions by Pekrun et al., assuming a connection between emotions and achievement motives, activities, and outcomes, academic emotions shape key learning processes [36]. Positive academic emotions like *enjoyment* and *pride* can have a positive effect on learning outcomes [37]. Negative academic emotions like boredom lead to lower levels of achievement [38]. However, varying combinations of emotions may lead to distinct outcomes. Ganotice Jr, Datu, and King, therefore, pursue these variable-centered approaches and suggest a person-centered approach for investigating associations between academic emotion profiles and academic outcomes [39]. Pekrun classified academic emotions into *positive activating emotions* (enjoyment, hope, pride), *positive deactivating emotions* (relief), *negative activating emotions* (anger, anxiety, shame), and *negative deactivating emotions* (hopelessness, boredom) [40]. These academic emotions were used to investigate the effects of different academic emotion profiles on the factors learning outcome in Mathematics (represented through the previous grades) and engagement (represented through *university intention*, *school valuing*, intention to *leave school*, and *affect to school*). Ganotice Jr, Datu, and King found intercorrelations between most of the factors and their variables. A cluster analysis could show that individuals with high levels of positive academic emotions and low levels of negative academic emotions exhibit the best educational outcomes [39].

In terms of technology-assisted learning, Fraser et al. found that the emotions *tranquility* and *invigoration* affected learning in virtual simulation training. Increased *invigoration* and reduced *tranquility* were associated with an increased *cognitive load* which led to a worse learning performance [41]. While an early study of Lin et al. could not verify a positive relation between *enjoyment* and *presence* [7], research in emotional psychol. in immersive virtual environments depict strong associations between *presence* and emotions like *anxiety* and *fear* [42]. *Presence* can be regarded as a necessary mediator for activating real emotions through the use of virtual environments [43][44]. Another study of Ganotice Jr, Datu, and King showed associations between different types of motivation and academic emotions. A composite score of *intrinsic motivation* and *identified motivation* as the more *autonomous* forms of motivation was associated with academic emotions [39].

Academic emotions like enjoyment, hope, pride, relief, anger anxiety, shame, hopelessness, and boredom seem to be a crucial factor influencing learning outcomes and are therefore important for explaining learning activities. Other emotions like fear, tranquility, and invigoration can also influence learning and presence. Possible associations between emotions, presence and motivation have to be considered in further research.

F. *Learning Outcomes*

Another important factor in immersive learning is the learning outcome itself. Many studies regarding EVEs suffer from a lack of understanding about what should be learned, whether the outcome should be a memorization of the virtual world and its objects, a transfer from a metaphorical visualization or the acquirement of new skills and competencies.

The problem of measuring learning outcomes derives from the implicit construction of knowledge in the mind of the learner. As knowledge cannot be directly measured, measurements of learning outcome observe actions and performance resulting from learning activities [45]. A possible classification of learning outcomes separated the three domains *cognitive outcomes*, *affective outcomes*, and *psychomotor outcomes*. A common taxonomy for the *cognitive* domain, which currently poses the most relevant domain for immersive learning, is presented by Bloom: He introduces the six major classes *knowledge*, *comprehension*, *application*, *analysis*, *synthesis*, and *evaluation* [46]. The objective *knowledge* most emphasizes the psychological processes of remembering, but may also involve relating and judging. *Comprehension* may pose the largest general class of intellectual abilities and skills which are emphasized in the educational context. *Comprehension* includes "those objectives, behaviors, or responses which represent an understanding of the literal message contained in a communication" [46]. The a*pplication* of knowledge for a presented problem requires a solution process: The problem can either immediately have familiar aspects to guide actions in which case the student would do some restructuring in order to make the resemblance to the familiar model complete, or the problem is initially unfamiliar, in which case the student searches for familiar elements in order to restructure the problem in a familiar context. After classifying the problem as familiar in type, the student selects an abstraction which is suitable to the problem type. Finally, the use of the abstraction to solve the problem leads to the solution to the problem [46]. *Analysis* emphasizes the breakdown of a given material into its constituent parts. The learner detects the relationships of the parts and the way in which they are organized. *Analysis* can also be directed at the techniques and devices which are used to convey the meaning of a communication or to establish its conclusion. The *synthesis* is defined "as the putting together of elements and parts so as to form a whole" [46]. In order to constitute a pattern or a structure which is not clearly there before, the learner works with elements, parts, etc. and combines them. The *synthesis* category provides the most creative behavior on the part of the learner. Bloom defines *evaluation* as "the making of judgments about the value, for some purpose, of ideas, works, solutions, methods, material, etc. This involves the use of criteria as well as standards for appraising the extent to which particulars are accurate, effective, economical, or satisfying" [46].

Bloom's initial taxonomy has been discussed and was revised later by Anderson and Krathwohl [47]. Still, the basic categories of the taxonomy provide an easy and solid method for describing the intentional learning outcomes of immersive learning. By the use of the taxonomy for EVEs, learning objectives can be distinguished and explained.

III. SUPPLY-USE-MODELS FOR THE EXPLANATION OF SCHOLASTIC LEARNING

The idea of gathering several factors influencing learning comes along with the endeavor of putting these factors in relations using a theoretical framework. Weinert states that scholastic learning cannot be explained by the observation of isolated variables as there are many context dependencies between educational characteristics [48]. In recent years, pedagogical research has replaced simple cause-and-effect relationships with more comprehensive frameworks integrating multiple pedagogical actors and influences, as well as individual psychological factors.

Supply-use-models describe these relations by separating the three domains *supply structures*, *use of learning opportunities*, and *learning outcomes*. Learning opportunities are specified through certain *supply structures*, consisting of teacher characteristics, teaching competencies, and teaching processes, as well as the context of the classroom. The *use of learning opportunities* describes the individual learning activities, which depend on a number of individual characteristics as well as on contexts like the classroom composition. Hereby, learning activities are separated into external (visible) learning activities and internal (mental) learning activities. Internal learning activities are considered as being the decisive factors which lead to learning outcomes. These cognitive and meta-cognitive processes are influenced by motivational-affective processes. The multi-criterial *learning outcomes* consist of cognitive learning outcomes and non-cognitive aspects like attitudes and interests towards a subject or generic competencies [49].

A popular supply-use-model has been developed by Helmke [50]. His multi-level framework, shown in Fig. 1, consists of the characteristics of the *teacher*, the *context(s)*, the *instruction*, *the family* of the learner, the *individual learning potential*, the *mediation processes*, the *learning activities of the learner,* and the *effects*. Helmke regards the *supply of learning opportunities* from a constructivist view of teaching and learning processes: The *instructional supply* does not directly and inevitably lead to its learning effects (intended or non-intended) but has to be actively *used* by the learner. The perception and interpretation, the instructional supply, but also the expectations of the teacher influence the *learning activities* together with the *context* variables and the *learning potential*. The factor *learning potential* includes the cognitive, motivational and volitional conditions which influence learning. Helmke names the factors intelligence, previous knowledge, learning strategies, self-concept towards competencies, performance anxiety, learning motivation, and learning emotion as central influences of the *learning potential*. It is influenced by the *family* conditions and by *effects* resulting from previous learning activities. The different *contexts* (e.g. a cultural context) of the educational setting influence the *teacher*, the *instruction* itself, the *learning activities*, and the *effects*. Helmke notes that the *teacher* may as well be another student as the model sees the *teacher* as the provider of the *learning opportunity* as *supply*. The content of the instructional material as a central part of the *instruction* factor may differ in terms of its didactical quality and its stimulating effects [50]. By integrating multiple determinants in an understanding of learning, Helmke's model is an appropriate framework for explaining learning processes and outcomes. An understanding of immersive learning will benefit from a localization of the factors influencing learning processes, activities, and outcomes in such a supply-use-model for the explanation of scholastic learning. As Helmke's model separates subjective and objective factors, the use of this framework seems appropriate.

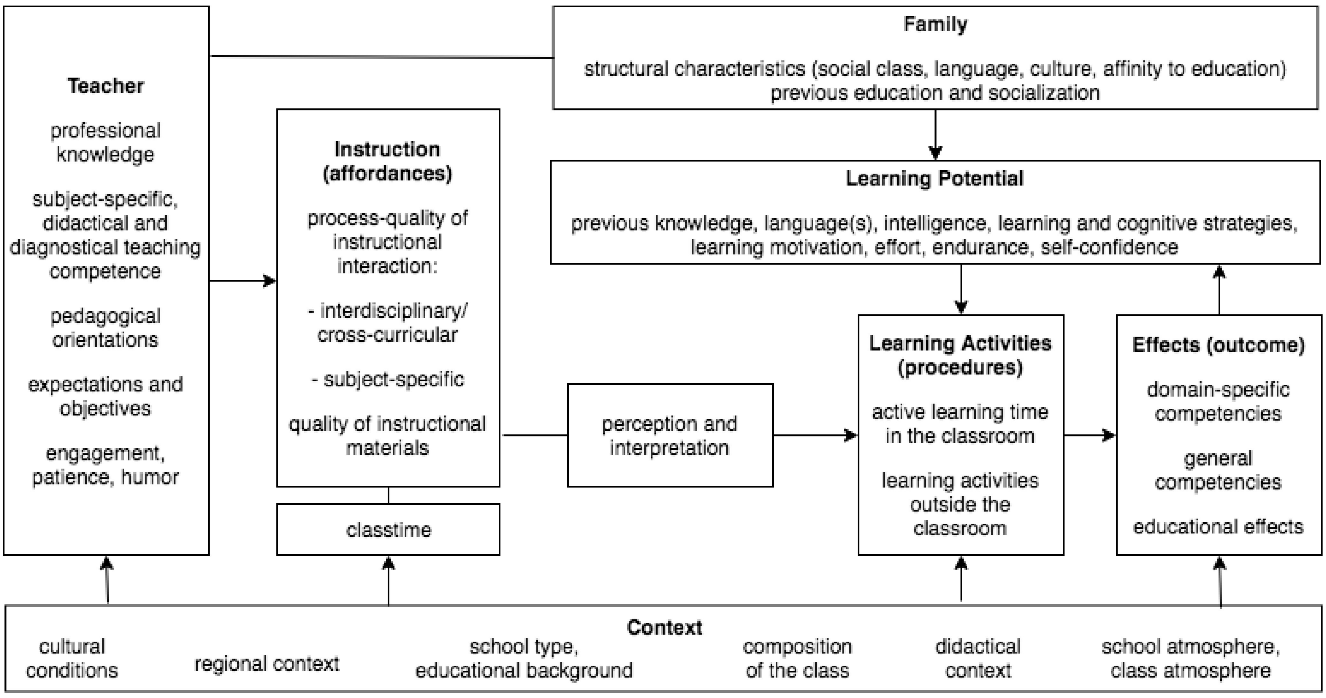

Fig. 1. Helmke's Supply-Use-Model (translated from German).

IV. Developing the Educational Framework for Immersive Learning

In Chapter II, we investigated which factors influence learning activities in immersive learning environments. We discovered that *immersion* and *presence*, as well as *motivational factors*, *cognitive factors*, and *emotional factors*, play a crucial role in the process of immersive learning. Previous research indicates causal relations between the level of *immersion* and *presence*, and between the level of *immersion* and *motivational factors*. The design of the immersive EVE can strengthen the positive effect of *cognitive factors* on *learning activities*. Further, associations between the *motivational factors* and *presence*, between the *cognitive factors* and *presence*, and between the *emotional factors* and *presence* have to be considered. Also, an association between *emotion* and *motivation* has been revealed. The effects of the *motivational*, *cognitive*, and *emotional factors* on *learning outcomes* postulated in Helmke's model could be verified in the presented immersive learning studies. A localization of the factors influencing learning activities in immersive learning environments leads to the proposal of an educational framework for immersive learning (EFiL), shown in Fig. 2.

We identified *immersion* as a quantifiable description of technology which suppresses stimuli from the physical reality and simulates stimuli of an artificial environment. This includes as well the hardware used to display the educational content given through technology (e.g. a textbook, a desktop computer, a VR-setting) as the software (the educational content itself). Therefore, the objective process of *immersion* is a part of the *instructional supply* which provides learning material with a certain didactical, immersive, and content quality. A *teacher* provides the immersive learning opportunity with certain educational objectives. The content and the available *immersion time* are influenced by several *context* conditions.

Presence, as the subjective feeling of "being there", poses the central factor of *perception and interpretation* for immersive learning. The immersive content itself does not invoke *learning activities* directly as it has to be perceived by the learner first. A higher feeling of presence in terms of actually being in the immersive EVE enhances the *learning activities*. *Presence* can be influenced through the level of *immersion* of the *instructional material*, as well as through *motivational factors*, *cognitive factors*, and *emotional factors*.

As the *motivational factors* influence the *learning activities* and *presence* intraindividually, a localization in the *(immersive) learning potential* follows Helmke's initial proposition placing learning motivation in the *learning potential*. Following Vallerands hierarchical model [18], we separate *extrinsic motivation*, *intrinsic motivation*, and *amotivation.* These motivation types occur as *global motivation*, *contextual motivation* or *situational motivation*. While *global motivation* and *contextual motivation* (e.g. academic motivation towards learning in general/in a specific subject) are stable individual characteristics that can only slowly be changed, *situational motivation* refers to a current activity [18]. *Situational motivation* can be influenced for example through the provided immersive EVE or other situational (state) characteristics of the individual (e.g. *emotional factors*).

The *cognitive factors* summarize all intraindividual cognitive characteristics and skills that influence *learning activities*, including *intelligence*, *learning strategies*, and the ability of *reflective thinking*. They are localized in the *(immersive) learning potential* which follows the original classification of Helmke who assigned intelligence, previous knowledge, learning strategies, and self-concept towards competencies as cognitive determinants to the *learning potential*. The activation of *cognitive factors* can be influenced by the didactical and methodical design of the immersive learning content. As the cognitive processes are closely related to perception processes, the *cognitive factors* influence the sense of *presence*.

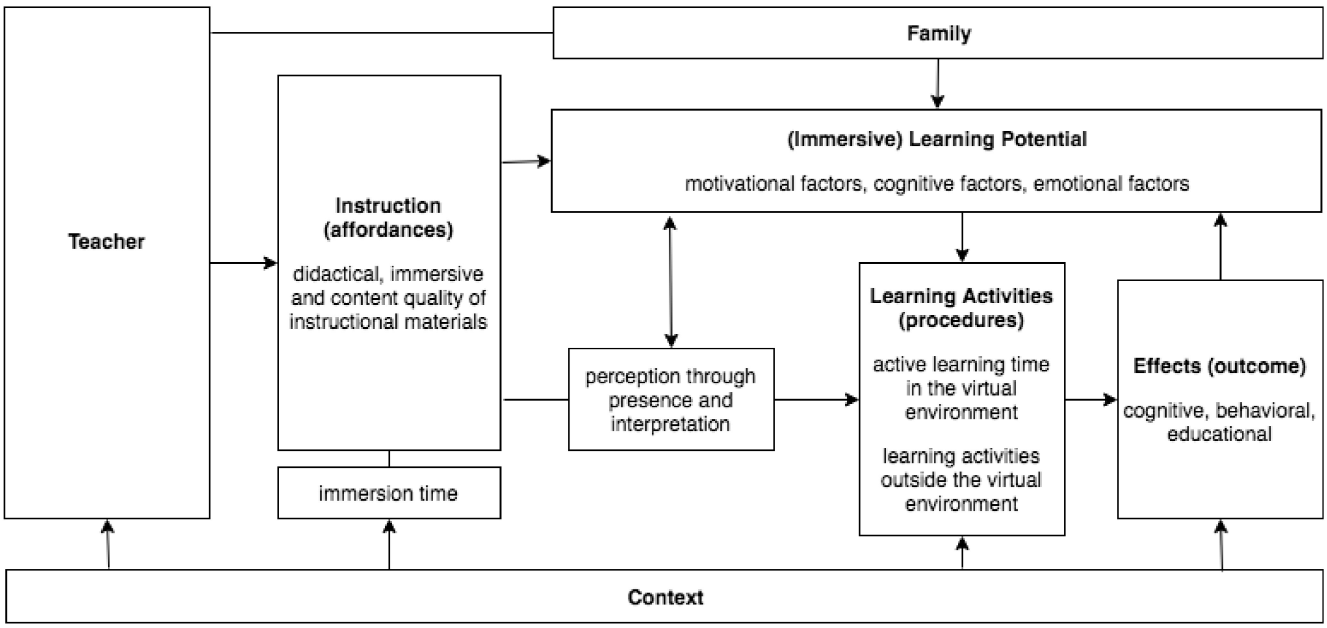

Fig. 2. An educational framework for immersive learning (EFiL): The localization of the influencing factors in Helmke's supply-use-model.

Emotional factors contribute to *learning activities* and to *presence*. In terms of learning, especially *academic emotions* towards the learning content are interesting. *Positive activating emotions* (enjoyment, hope, pride), *positive deactivating emotions* (relief), *negative activating emotions* (anger, anxiety, shame), and *negative deactivating emotions* (hopelessness, boredom) can influence learning activities. Certain emotions can influence presence (e.g. enjoyment and fear). The content quality of the immersive material can influence *emotional factors.* The *effects* of the learning activities are the intended and non-intended cognitive, behavioral and educational *learning outcomes* resulting from the *learning activities*. The active learning time in the virtual environment and the learning activities outside the virtual environment (e.g. reflection about the learning content displayed in the virtual environment) define the *learning activities* (*procedures*). The cognitive *learning outcomes* can be categorized in terms of the cognitive processes involved in and resulting from the *learning activities*.

With regards to the localization of the factors of learning in immersive EVEs in the EFiL, immersive learning is defined as *learning activities* initiated by a mediated or medially enriched environment that evokes a sense of presence. Immersive learning activities are determined through the *(immersive) learning potential*, the *context* of the learner, the *perception* of the didactical, immersive and content quality of the instructional materials at a certain level of *presence* and the *interpretation* of these materials. The factors influencing immersive learning are related among each other and (especially in scholastic environments) affected by the *family* and the *teacher* of the learner.

V. Discussion and Conclusion

The presented localization of subjective and objective factors influencing learning processes in immersive environments (especially EVEs) in a supply-use-model provides a new perspective on immersive learning. By utilizing a pedagogical framework for the explanation of immersive learning, we receive a theoretical model which can be used for formulating and testing hypotheses. For example, according to the EFiL, immersion does not have a direct effect on learning activities but influences them through the *perception through presence and interpretation* on the side of the learner what makes *presence* the decisive factor in terms of learning. This could to be considered when developing immersive EVEs. Note that the presented EFiL is no more than a localization of factors determining immersive learning in an appropriate educational framework. Therefore, it is not an adaption of Helmke's existing model but more of a specification in terms of immersive learning. Each factor named by Helmke which is (due to clarity) not displayed in detail in the EFiL still retains its importance for learning processes. The characteristics of the *teacher* and the *family* remain crucial factors for the learning process in general (e.g. the *teacher* who embeds the immersive learning opportunity into a teaching sequence or into a scholastic curriculum). One may ask why the framework does not use more specific or advanced theories for the *motivational*, *cognitive* or *emotional factors*, as well as for the cognitive levels of the intended *learning outcome*. This also applies to the use of Helmke's supply-use-model. The model is just one of many possible frameworks, but the successful localization of the determining factors for immersive learning proves its adequacy. Still, it would be interesting to see perspectives on immersive learning out of other educational approaches. The theories underlying the EFiL have been pursued, adapted and revised by several researchers. But until today, they constitute the fundamentals of the research fields included in the framework and therefore built a solid basis for argumentation. Still, detailed research about the several factors including modern approaches and theories is definitely needed: What type of motivation towards which objective influences presence? How can immersive settings be quantified? Which emotional constructs are responsible for learning activities in immersive EVEs and how can they be evoked by technology? The EFiL leaves a ton of questions unanswered. But this also means that the use of the EFiL allows discussions about immersive learning with an identical educational basis: The EFiL provides a theoretical framework for a fundamental educational understanding of immersive learning, its influencing factors, conditions, and relations, while current and upcoming research in immersive learning fill the gaps. Another challenge poses the heterogeneous use of terms and definitions: It is difficult to compare studies and theories when the same name is used for different constructs or vice versa. For example, the different use of the terms *immersion* and *presence* complicates scientific discussions in the field of immersive learning. By integrating both concepts with a sharp distinction (internal subjective and external objective), argumentations relating to the EFiL can benefit from its theoretical clarity. Here too, the use of general theories is conducive. There may be more factors that may play a role in immersive learning. This may be, for example, additional factors influencing *presence* or other intraindividual factors that are influenced by the immersive material. When new factors are discovered, the EFiL can be a useful tool to identify the character of the factor and to explain its role in the learning process. Therefore, the framework is not final but a constant work-in-progress in which researchers from the field of immersive learning may contribute in. Even though the EFiL builds upon existing research, it is still a theoretical framework. Empirical research including all postulated factors, causal relationships, and associations with the objective to prove (or disprove) the claimed relations between the factors is needed in further work.

References

[1] W. Bricken, *Learning in Virtual Reality*, Seattle WA: University of Washington, 1990.

[2] T. A. Mikropoulos, "Presence. A unique characteristic in educational virtual environments," *Virtual Reality*, vol. 10, no. 3–4, pp. 197–206, Sep. 2006.

[3] M. Slater, "A note on presence terminology," *Presence Connect*, vol. 3, pp. 1–5, Jan. 2003.

[4] J. Steuer, "Defining virtual reality. Dimensions determining telepresence," *J. Communication*, vol. 42, no. 4, pp.73–93, Dec. 1992.

[5] Z. Wan and Y. Fang, "The role of information technology in technology-mediated learning: A review of the past for the future," *J. Inform. Syst. Educ.*, vol. 18, no. 2, pp. 183–192, 2007.

[6] K. Mania and A. Chalmers, "The effects of levels of immersion on memory and presence in virtual environments. A reality centered approach," *Cyberpsychol. & Behavior*, vol. 4, no. 2, pp. 247–264, Apr. 2001.

[7] J.-W. Lin, H. Duh, D. E. Parker, H. Abi-Rached, and T. A. Furness, "Effects of field of view on presence, enjoyment, memory, and simulator sickness in a virtual environment," in *Proc. IEEE Virtual Reality* 2002, Los Alamitos, California, USA, pp. 164–171.

[8] J. N. Bailenson, A. C. Beall, J. Blascovich, J. Loomis, and M. Turk, "Transformed social interaction, augmented gaze, and social influence in immersive virtual environments," *Human Communication Research*, vol. 31, pp. 511–537, Jan. 2005.

[9] E. A.-L. Lee, K. W. Wong, and C. C. Fung, "How does desktop virtual reality enhance learning outcomes? A structural equation modeling approach," *Comput. & Educ.*, vol. 55, no. 4, pp. 1424–1442, Dec. 2010.

[10] K. L. Nowak and F. Biocca, "The effect of the agency and anthropomorphism on users' sense of telepresence, copresence, and social presence in virtual environments," *Presence*, vol. 12, no. 5, pp. 481–494, Oct. 2003.

[11] K. M. Lee, "Presence, explicated," *Communication Theory*, vol. 14, no. 1, pp. 27–50, Jan. 2006.

[12] J. N. Bailenson and N. Yee, "Virtual interpersonal touch. Haptic interaction and copresence in collaborative virtual environments," *Multimedia Tools and Applications*, vol. 37, no. 1, pp. 5–14, Sept. 2007.

[13] F. Biocca, "The cyborg's dilemma progressive embodiment in virtual environments," in *Humane Interfaces: Questions of Method and Practice in Cognitive Technology* (Human Factors in Information Technology, vol. 13), Amsterdam, 1999, pp. 113–144.

[14] J. V. Baren and W. Ijsselsteijn, *Measuring Presence: A Guide to Current Measurement Approaches*, Eindhoven University of Technology, 2004.

[15] J. Bailey, J. N. Bailenson, A. S. Won, and J. Flora, "Presence and memory: Immersive virtual reality effects on cued recall," in *Proc. Int. Society for Presence Research Annu. Conf.*, Philadelphia, PA, 2012.

[16] M. Roy and G. Schlemminger, "Immersion und Interaktion in virtuellen Realitäten: Der Faktor Präsenz zur Optimierung des geleiteten Sprachenlernens," *Zeitschrift für interkulturellen Fremdsprachen-unterricht. Didaktik und Methodik im Bereich Deutsch als Fremdsprache*, vol. 19, no. 2, pp. 187–201, Oct. 2014.

[17] E. L. Deci and R. M. Ryan, *Intrinsic Motivation and Self-Determination in Human Behavior*, New York: Plenum Press, 1985.

[18] R. J. Vallerand, L. G. Pelletier, M. R. Blais, N. M. Brière, C. Senécal, and E. F. Vallières, "The academic motivation scale: a measure of intrinsic, extrinsic, and amotivation in education," *Educ. & Psychological Measurement*, vol. 52, pp. 1003–1017, Dec. 1992.

[19] J. Pirker, *Immersive and Engaging Forms of Virtual Learning*, Graz, Austria, 2017.

[20] R. Bartle, "Hearts, clubs, diamonds, spades: players who suit muds," *J. MUD Research*, vol. 1, no. 1, 1996.

[21] C. J. Dede, "The evolution of constructivist learning environments: Immersion in distributed, virtual worlds," *Educ. Technol.*, vol. 35, pp. 46–52, Sept.-Oct. 1995.

[22] A. Antonietti, C. Rasi, E. Imperio, and M. Sacco, "The representation of virtual reality in education," *Educ. & Inform. Technol.*, vol. 5, no. 4, pp. 317–327, 2000.

[23] S. Schwan and R. Riempp, "The cognitive benefits of interactive videos: Learning to tie nautical knots," *Learning & Instruction*, vol. 14, pp. 293–305, June 2004.

[24] M. J. Schuemie, P. Van Der Straaten, M. Krijin, and C. A. Van Der Mast, "Research on presence in virtual reality: A survey," in *Cyberpsychol. & Behavior*, vol. 4, 2001, pp. 183–210.

[25] M. D. Williams, "Learner-control and instructional technologies," in *Handbook of Research and Educational Communications and Technology*, D. H. Jonassen, Ed. Simon and Schuster Macmillan, New York, 1996, pp. 957–983.

[26] M. D. Merrill, "Learner control: Beyond aptitude-treatment interactions," *Educ. Technol. Research & Develop.*, vol. 23, no. 2, pp. 217–226, June 1975.

[27] R. F. Lepper, "Microcomputers in education: Motivational and social issues," *Amer. Psychologist*, vol. 40, pp. 1–18, Jan. 1985.

[28] J. Dewey, "What is thought?" in *How We Think.* Lexington, Mass: D.C. Heath, 1910, pp. 1–13.

[29] D. H. Jonassen, K. L. Peck, and B. G. Wilson, *Learning with Technology: A Constructivist Persperctive*, Prentice Hall, Upper Saddle River, NJ, 1999.

[30] H. P. Phan, "An examination of reflective thinking, learning approaches, and self-efficacy," *Educ. Psychol.*, vol. 27, no. 6, pp. 789–806, Dec. 2007.

[31] M. Slater, M. Usoh, and A. Steed, "Depth of presence in virtual environments," *Presence*, vol. 3, no. 2, pp. 130–144, 1994.

[32] B. G. Witmer and M. J. Singer, "Measuring presence in virtual environments. A presence questionnaire," *Presence*, vol. 7, no. 3, pp. 225–240, June 1998.

[33] J. Lessiter, J. Freeman, E. Keogh, and J. Davidoff, "A cross-media presence questionnaire: The ITC-sense of presence inventory," *Presence*, vol. 10, no. 3, pp. 282–297, June 2001.

[34] T. Schubert, F. Friedmann, and H. Regenbrecht, "The experience of presence: factor analytic insights," *Presence*, vol. 10, no. 3, pp. 266–281, June 2001.

[35] R. Pekrun and L. Linnenbrink-Garcia, "Academic emotions and student engagement," in *Handbook of Research on Student Engagement* (vol. 343), S. L. Christenson et al., Eds. 2012, pp. 259–281.

[36] R. Pekrun, T. Goetz, W. Titz, and R. P. Perry, "Academic emotions in students' selfregulated learning and achievement: A program of qualitative and quantitative research," *Educ. Psychologist*, vol. 37, pp. 91–105, 2002.

[37] F. T. Villavicencio and A. B. I. Bernardo, "Positive academic emotions moderate the relationship between self-regulation and achievement," *British J. Educ. Psychol.*, vol. 83, pp. 329–340, June 2013.

[38] R. Pekrun, N. C. Hall, T. Goetz, and R. P. Perry, "Boredom and academic achievement: Testing a model of reciprocal causation," *J. Educ. Psychol.*, vol. 106, pp. 696–710, Feb. 2014.

[39] F. Ganotice, J. A. Datu, and R. King, "Which emotional profiles exhibit the best learning outcomes? A person-centered analysis of students' academic emotions," *School Psychol. Int.*, vol. 37, pp. 498–518, July 2016.

[40] R. Pekrun, "A social-cognitive, control-value theory of achievement emotions," *Motivational Psychol. of Human Develop.*, J. Heckhausen, Ed. Oxford: Elsevier, pp. 143–163, Dec. 2000.

[41] K. Fraser, E. Teteris, H. Baxter, B. Wright, and K. McLaughlin, "Emotion, cognitive load and learning outcomes during simulation training," *Med. Educ.*, vol. 46, no. 1, pp. 1055–1062, Nov. 2012.

[42] J. Diemer, G. W. Alpers, H. M. Peperkorn, Y. Shiban, and A. Mühlberger, "The impact of perception and presence on emotional reactions: a review of research in virtual reality," *Frontiers in Psychol.*, vol. 6, no. 26, pp. 1–9, Jan. 2015.

[43] T. D. Parsons and A. A. Rizzo, "Affective outcomes of virtual reality exposure therapy for anxiety and specific phobias: A meta-analysis," *J. Behav. Ther. Exp. Psychiatry*, vol. 39, no. 3, pp. 250–261, Sept. 2008.

[44] M. Price and P. Anderson, "The role of presence in virtual reality exposure therapy," *J. Anxiety Disorders*, vol. 21, pp. 742–751, Dec. 2007.

[45] M. Alavi and D. E. Leidner, "Review: Knowledge management and knowledge management systems: conceptual foundations and research issues," *MIS Quarterly*, vol. 25, 1, pp. 107–136, Mar. 2001.

[46] B. S. Bloom, M. D. Engelhart, E. J. Furst, W. H. Hill, and D. R. Krathwohl, *Taxonomy of Educational Objectives: The Classification of Educational Goals. Handbook I: Cognitive Domain.* New York: David McKay Company, 1956.

[47] L. W. Anderson and D. R. Krathwohl, et al., Eds., *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*. Allyn & Bacon. Boston, 2001.

[48] F. E. Weinert, "Psychologische Orientierungen in der Pädagogik," in *Richtungsstreit in der Erziehungswissenschaft und pädagogische Verständigung*, Röhrs, H., Hg. Frankfurt am Main, 1989, pp. 203–214.

[49] T. Seidel, *Performance Assessment and Professional Development in University Teaching*, 2014.

[50] A. Helmke and F. Weinert, *Bedingungsfaktoren schulischer Leistungen.* Max-Planck-Inst. für Psychologische Forschung, 1997.