A Conceptual Basis for Educational Applications of Virtual Reality

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I. Introduction.

Virtual Reality (VR) has caught the imagination of many people. Frequent reports in the popular and technical press describe the hardware and software that permit people to "enter" a computer-created "world" and give accounts of what the VR experience is like. Invariably, these reports end with claims for the applicability of VR to all manner of activities, including education.

This paper discusses the potential value of VR to education. It does so in the light of research conducted at the Human Interface Technology Laboratory at the University of Washington and on the basis of recent developments in cognitive theory that are relevant to human learning. The case is made that immersive VR offers very different kinds of experience than those students normally encounter in school. The psychological processes that become active in immersive VR are very similar to the psychological processes that operate when people construct knowledge through interaction with objects and events in the real world. Such a convergence of learning processes with experiences permitted by technology is relatively rare and requires that we rigorously examine both the psychological and the technological sides of the equation. This paper therefore starts with a description and analysis of VR. It then describes recent psychological theories of knowledge construction. Finally it examines the nature of the confluence of VR and constructivist learning theory -- the "goodness of fit" between the two, concluding that constructivism is the best basis for building a theory of learning in virtual environments.

II. Virtual reality.

As a new technology seeks its identity, there is bound to be ambiguity in early attempts to define it. The roots of the field, at least in its popular conception, can be traced to the development of head-mounted devices (HMD's) for use by fighter pilots (Furness, 1989) and for computed-aided design (Sutherland, 1965). The point of these early projects was to place participants in environments that provided them with just the information they needed and with which they could interact as naturally as they could with the real world. This required: 1) HMD's with a wide field of view so that objects in the world could be detected by peripheral and well as foveal vision, ideally subtending a visual angle of 200 degrees horizontally and 120 degrees vertically (Furness, 1989); 2) tracking the position and attitude of the participant's body; 3) transducers that interpreted participants' natural behaviors, such as looking and pointing, as commands to the computer; and 4) negligible delays in the rate at which the virtual environment was updated in response to participants' movements and actions. These four conditions are necessary for immersive VR. As a result of total immersion in a virtual world, participants report a very real sense of being in another place -- a phenomenon known as "cognitive presence" (Bricken, 1990) -- as well as a conviction that a virtual world is a valid, though different, form of reality.

Recently, the term "Virtual reality" has been applied more widely (Heim, 1993) to include graphics applications that allow users to walk through a simulated environment and, possibly, to interact with objects in it. However, "desktop VR" (e.g. Lavroff, 1992) does not meet the four necessary conditions for immersion mentioned in the previous paragraph and therefore does not engender presence. The user interacts with it, as with any other computer program, by a mouse or keyboard or joystick rather than by looking or pointing. HMD's and position-tracking are usually not used. Although this kind of non-immersive VR has a great many potential uses in education, and costs but a fraction of immersive systems, it offers no more than a few modest extensions of computer graphics programs. The following discussion is concerned only with immersive VR.

III. Immersion.

The VR systems that Furness (1986) developed for the Air Force were designed to simplify the interface through which pilots interacted with the airplane. The "Super Cockpit" was one in which the pilot could access the data he needed and could operate some of the aircraft's controls by performing natural actions, such as looking, pointing, and touching. The interface was simplified to the point where it became totally unobtrusive. In fact, for immersive VR, the interface has ceased to exist altogether (M. Bricken, 1991a).

The removal of the interface between computer and user is a necessary condition for immersion in VR. The participant "wears the computer" (W. Bricken, 1991), is inside the data. As a result, participants can interact with the virtual world, which might be a simulation of some aspect of the real world, an instantiation of some abstraction that would otherwise only be accessible as numerical data, or a creation entirely of whim or fancy, as naturally as they do with the real world. It is largely on the advantages of the natural interactions that occur when the interface disappears that many writers have based their endorsements of VR.

Two other less obvious but more profound changes occur as a result of immersion which are particularly important for education. First, the subject-object distinction that exists between people and information in computers, or between students and much of what they learn in school, disappears (W. Bricken, 1991). Second, immersion permits entirely non-symbolic interaction with the world. Both of these deserve comment.

First-person experience in virtual worlds.

We know the world in two ways. First, we know the world as a result of our everyday interactions with it. This knowledge is direct, personal, subjective and often tacit in the sense that we often do not know that we know something (Polanyi, 1958). Second, we know the world as it is described to us by someone else. This knowledge is vicarious, communal, objective and explicit. We always know when we have acquired this kind of knowledge, because it has been taught to us.

The experiences that lead to the first, subjective, kind of knowledge are called "first-person" experiences, experiences and knowledge of the second kind "third-person" (Clancey, 1993; Searle, 1992). Here is an example. A first-person account of my listening to a piece of music would express in some way my enjoyment of the melody and harmony. A third-person account would include an explanation of how vibrations in the musical instruments cause sound waves to form in the air, which create sympathetic vibration of my eardrum, which causes small amounts of electrical current to flow through my auditory nerve to my brain. I could, of course, give a third-person account of my first-person enjoyment of the music by describing it to a friend. However, that account would be qualitatively very different from my personal experience.

The experiences and actions that arise from first-person knowledge are normally characterised by an absence of deliberate reflection. This means that action flows directly out of perception of the world without the intervention of conscious thought. In fact, most of what we accomplish in our daily lives is achieved without our deliberately thinking about it. Heidegger (1962) refers to this phenomenon as "throwness". We are "thrown along" the busy course of our lives with no time to reflect on what we do until after the event, if at all. Lave (1988) and Suchman (1987) present extensive evidence that thinking in the real world about real-world problems, such as using a Xerox machine or making a recipe, is non-reflective in this way. People do not usually plan ahead about how they will solve day-to-day problems. They simply use what is on hand at the time and attempt to perform the task. A recipe problem involving liquid measures is therefore solved very differently from one requiring the measurement of solid quantities. Even professionals only reflect when a dilemma confronts them, and even then the reflective act is not dissociable from action (Schon, 1983, 1987). Winograd and Flores (1986) go further and imply that, until things go wrong and we are forced to attend to a problem, reflection gets in the way of action. And Varela, Thompson and Rosch (1991) propose that all cognition is based on real-time action in the world, going so far as to claim that perception itself is not possible without action.

Recently, neuroanatomical evidence has been cited as grounds for removing reflection from the perception-action loop (Clancey, 1993; Edelman, 1989, 1992). The idea is that connections among perceptual and motor groups of neurons are "re-entrant". This means that they are connected bi-directionally and can interact with each other and simultaneously with new information from the senses, without the intervention of what Edelman (1992, p. 89) calls a "supervisor" that summarizes and interprets the information the neural groups send back and forth. The higher areas of the brain that are implicated in active thought do not appear to be involved at all.

First-person experiences are therefore natural, non-reflective, private, and predominate in our everyday interactions with the world. On this view, interacting with a computer through an interface is a third-person experience. Even though we may master the keyboard or mouse to a level of skill where we use them automatically, the information the machine presents always requires reflection before we respond to it, is always objective, usually comes from someone other than ourselves, and precludes interactivity on the basis of natural behavior. We experience the computer as an object "out there" in the world. The information it gives us is contained in it and is not directly accessible. It is for this reason that software designers are frequently concerned, first and foremost, about our mental model of the system projected by the interface (Norman, 1986), and only then with the functionality of the program. The interface creates a boundary around the computer and its information, and establishes the distinction between us -- "subject" -- and it -- "object". In short, it defies first-person experiences.

As we have seen, however, immersion in a virtual world effectively removes the interface allowing us to cross the subject-object boundary that exists between us and the machine (W. Bricken, 1991). Once this has happened, our experiences in the virtual world can be of exactly the same quality as our experiences in the real world. The knowledge they engender is direct, personal, subjective and often tacit, in other words first-person. Immersive VR allows us to create from our experiences the kind of knowledge that has hitherto been accessible only through direct experience of the world, never through computer interfaces, desktop VR, or any of the third-person experiences that predominate in school.

Non-symbolic interaction.

From my description of first-person and third-person experiences, it is clear that the latter are symbolic and the former usually are not. Any medium, like the computer, has its own symbol system (Salomon, 1979) without which it can convey no information at all. We read text symbols and pictorial icons from the screen. We are shown data as charts and graphs. We hear earcons which tell us something about the state of the system or direct the next step in our interaction with it. All of these are conventional and have to be learned at some time or other. In fact, in many school subjects learning the symbol system of a knowledge domain is a prerequisite to learning its content, as in mathematics or music. Unfortunately, mastery of the symbol system is often mistaken for mastery of the content, and teaching stops before students really "get into" the material. They learn a lot about Mathematics without really learning Mathematics at all.

If mastery of a symbol system is a necessary, though not sufficient, condition for learning through third-person experiences, it is not so for learning through the first-person experiences of immersive VR. Immersive VR allows students to interact with the world using what W. Bricken (1991) calls the "natural semantics" of the world. It is perfectly possible, for example, for students to learn the conceptual basis of Algebra without learning its conventional symbols (Winn & Bricken, 1992) provided that the learning experience is direct, personal and implicit. If students learning Algebra in immersive VR are forced to symbolize their experiences so that they can be communicated in the third person -- to a teacher or in a test, perhaps -- the reflection this requirement imposes gets in the way of the natural course of learning, just as any unbidden reflection destroys first-person experience. (Heidegger [1962] calls this "breakdown".) It is therefore the case that immersive VR can allow students to learn concepts and to solve problems non-symbolically. Indeed, the symbol system can be learned subsequently once the concepts have been mastered. However, knowing the symbol system is neither a precondition nor a catalyst for learning, an eventuality that is certain to be beneficial to students who have particular predispositions to learn that are not supported in third-person symbol-based classroom activities.

These observations anticipate a more extensive examination of educational uses of VR in section V below. Before dealing with that issue, we first turn to a review of relevant aspects of psychological theory underlying learning and instruction.

IV. Learning by Constructing Knowledge.

The chances are that VR would be little more than another educational gimmick were it not for the fact that the theory that directs the design and use of technology-based educational systems is currently undergoing a radical revision. In fact, educational computing has gone through three generations and, coinciding with the advent of VR, is entering a fourth.

The first generation was shaped by the same enthusiasm for behavioral theory that gave rise to traditional approaches to instructional design (e.g. Gagne, Briggs & Wager, 199?; Dick & Carey, 19??). The assumptions underlying this "first generation" of computer-based education were: 1) Student behavior is reasonably predictable if enough is known about the intended outcomes of instruction, the methods it employs and the conditions under which it occurs (Reigeluth, 1983); 2) The knowledge and skills students are to master can be reduced, using appropriate analytical techniques, to "atomic" components (Landa, 1983), the mastery of which will, in aggregate, produce the intended behavior; 3) Prescriptive instructional theory is sufficiently reliable for the procedures of instructional design to ensure that instruction developed by their systematic application will work effectively without further intervention from designers or teachers (Gagne & Dick, 1983). Arguments that these assumptions are seriously flawed have been made on a variety of grounds (Streibel, 1991; Winn, 1990, 1993). Nonetheless, a great deal of computer-based education still goes on that follows this content-oriented approach based on the traditional procedures of instructional design.

The "second generation" of computer-based education saw something of a shift from the instructional designer's emphasis on content to the message designer's emphasis on how information is presented to students (see Fleming & Levie, 1993). This emphasis arose from the realization that how students process information has a greater impact on what they learn than the accuracy of task reduction and the prescription of instructional strategies on the basis of content. The focus on the design of instructional messages arose from psychologists' realization that behavioral theory provides an incomplete account of human learning, leads to inadequate prescriptions for instructional strategies, and that cognitive theories of learning and instruction are more satisfactory sources for instructional designers to draw upon for guidance (Bonner, 1988; Champagne, Klopfer & Gunstone, 1982; DiVesta & Rieber, 1987; Tennyson & Rasch, 1988; Winn, 1990). The emergence of the second generation got a considerable boost from the realization that no two students are alike in their psychological make-up (see Gardner, 1983, 1993) and that sometimes these differences among individual students are sufficiently important to require the prescription of instructional methods matched to their aptitude (Cronbach & Snow, 1977) and their ability (Tobias, 1976, 1989).

The "third generation" of computer-based education arose from the belief that the nature of the interaction between the student and instruction is a determinant of learning of equal if not greater importance than content or how information is presented. This orientation is also strongly grounded in cognitive science. Indeed cognitive theories, such as Anderson's ACT* (Anderson, 1983), have formed the basis of just about all attempts to develop highly interactive "intelligent" computer-based tutors (Wenger, 1987). The strongest and one of the most recent expressions of this approach is Merrill's (1991, 1993) "Instructional Transaction Theory" which is based on the idea that all learning results from an interaction ("transaction") between student and program.

From an approach to computer-based education that relies on an understanding of how students interact with courseware, it seems, at first sight, to be but a short step to the assumptions of the "fourth generation", that knowledge is constructed by the students themselves, not delivered by the courseware. The idea of knowledge construction is by no means new to cognitive science. Bartlett (1932) was among the first to propose that learning occurred as people constructed "schemata" that represented the world for them. Neisser (1976) extended this idea to suggest that schemata guide the way people search the environment for information, causing them to anticipate what they might find there. Today, most textbooks on teaching and learning describe the tenets of cognitive science in some detail. And many of the recent theories that deal specifically with knowledge construction are soundly based in cognitive theory, for example Spiro et al's (1991) "Cognitive Complexity Theory", and Bransford et al's (1990) theory of "Anchored Instruction".

However, many "constructivists" are taking the more radical tack of rejecting cognitive science as a basis for instructional design and technology (Allen, 1992; Bednar, Cunningham, Duffy & Perry, 1992; Cunningham, 1993; Streibel, 1991). The emergence of this fourth constructivist "generation" is driven by a vigorous criticism of the assumptions of cognitive science. It is in this criticism, and in the theories that are promoted as the hiers of cognitivism, that the confluence of educational theory and VR technology is becoming apparent.

The accounts of learning provided by cognitive science are built around the ideas that the mind works like a computer, and that cognition consists of the mental manipulation of symbols (Boden, 1988; Jackendoff, 1987; Johnson-Laird, 1988; Pylyshyn, 1984). For example, Marr's (1982) seminal work on vision is based on the premises that the brain is too complex to understand and that therefore we must explain cognition by means of computations based on mathematical functions that purport to model cognitive processes. (Marr was extremely successful in explaining low-level vision in this way. The question is whether a computational approach is appropriate for higher-level processes.) As a second example, Larkin and Simon's (1987) account of how people process the information in diagrams desribes a production-system model of how people store and inspect nodes in an internal information network.

The criticism of cognitive science is aimed particularly at its computer metaphor for mind and at the inevitable consequence of this assumption, that cognition is essentially symbol manipulation. You will recognize that these two grounds for criticism are exactly those that we saw above to be the reasons why the presence of a computer interface limits students' experiences in computer-based education to the "third person". The corollary, of course, is that non-symbolic, non-reflective, first-person psychological activity that occurs when people interact directly with worlds, whether real or virtual, has no place in the theories of cognitive science. This is a fatal omission according to the constructivists and to critics of cognitive science generally (Dreyfus, 1972; Edelman, 1992; Searle, 1992).

Criticism of the dominant paradigm cannot be taken seriously unless those making it propose a valid alternative. The constructivists offer a variety of accounts of how knowledge is constructed and learning occurs. While these accounts have not yet been drawn together into a unified theory, the following three assumptions about knowledge construction provide a basis for guiding the design of learning experiences and for implementing VR.

<u>Humans are informationally closed systems</u>.

The work of the biologist Maturana (Maturana & Varela, 1987; Varela Thompson & Rosch, 1991) has been particularly influential with some constructivists (e.g. Cunningham, 1993). Maturana proposed that living organisms, including humans, do not take information in from the outside, but rather react to "perturbations" in the environment through the adaptation of existing structures within them. Interaction with the environment therefore does not add "ingredients" to an organism's physical structure or symbols to its mental structure, but causes qualititative and quantitative changes in the structures that already exist. The ability to detect perturbations and the kind of structural change that they bring about is determined by the phylogeny of the species and the history of the individual's previous adaptations. The world as each of us understands it is therefore the product of structural adaptation to perturbations.

<u>There is no "standard" objective world</u>.

It follows that the world each organism constructs is unique. To give an extreme example, a bat is equipped to adapt to very different perturbations in its environment than humans. A world constructed primarily from ultrasonic reflections from objects in the environment will be very different from one built from information limited to the visible portion of the electromagnetic spectrum. As Nagel (1974) has pointed out, even though we may be able to construct a third-person description of the bat's sensory and information-processing apparatus, we can never know first-hand what it is like to be a bat.

The same is true among humans. Although we can communicate with each other, we usually do so symbolically. This means that my experience of someone else's world can only be my experience of a <u>description</u> of that world. It is inevitably a third-person experience. I can never really know the true nature of someone else's world. This conclusion has been the basis of claims by constructivists that instructional designers are wrong to assume that they can base instructional strategies on the analysis of an objective, standard world (Duffy & Jonassen, 1992) and that evaluation of learning can only tell us what students appear, or pretend to know (Winn, 1993), not what they really know.

<u>Meaning is negotiated socially</u>.

The previous two assumptions bring constructivism dangerously close to solipsism. If we are informationally closed and if there is no standard objective world, then it is tempting to conclude that we cannot ever communicate with each other. However, we know this is not the case. Communication is made possible by what Maturana and Varela (1987) call "structural coupling". Organisms of the same species have basically the same apparatus for detecting and adapting to perturbations. Also, they inhabit similar environments and are likely to encounter the same perturbations. As a result, the history of their structural adaptations will be similar. Their structures are "coupled", which is why we can communicate with other humans but not with bats.

Communication between people separated in time or space occurs when we place symbols into the environment that act as perturbations of other people who share the environment through structural coupling. However, in spite of structural coupling, each person's construction of the world is unique with the result that the symbols I place in the environment will mean different things to different people in the group. In order to make communication possible, we therefore have to come to an agreement about what the symbols mean (Vygotsky, 1978). The negotiation among members of the group over meaning may lead to compromises and may result in only temporary agreements. Nonetheless, in practice constructivists frequently insist on providing opportunities for learning that require students to work in groups and arrive at a consensus about meaning (McMahon & O'Neil, 1993).

These three assumptions tempt one to conclude that instruction cannot be designed -- that prespecifying content, or message format, or the kind of interaction students have with an instructional system is to no avail because learning takes place entirely within the student who is impervious to the influence of instructional strategies. However, the environments within which students construct knowledge still have to be provided. These environments may be natural environments. For example, proponents of situated learning recommend apprenticeships (Brown, Collins & Duguid, 1989; Brown & Duguid, 1993; Lave & Wenger, 1991) and reflective practica (Schon, 1987) as means for allowing students to construct knowledge from "authentic" activites. These environments may also be artificial environments that simulate aspects of the real world which may not be accessible through direct experience. Zucchermaglia (1993) describes such artificial environments as "empty technologies", or shells, within which students, teachers and designers can construct anything they want. ("Full" technologies are content specific, like computer-based tutors.) Kozma (1991) makes the point that technologies can create learning environments that cannot be created using traditional strategies, and that it is this quality that makes them superior to other kinds of pedagogical method.

The emerging "fourth generation" of computer-based education is therefore founded on constructivist theories of learning. With it, the focus shifts from the design of prescribed interactions, or "transactions" (Merrill, 1993) with the learning environment to the design of environments that permit students any kind of interaction the system is capable of. Such environments are characterized by a potential for interaction rather than by prespecified instructional transactions. This is precisely what VR affords.

V. VR Applications in Education.

With some exceptions (among them M. Bricken, 1991b; Bricken & Byrne, 1993; W. Bricken, 1990; Winn & Bricken, 1992), educators have not made the connection between constructivist theories of learning and VR, thereby missing the opportunity to provide a theoretical basis for applying VR in education. In this section, I make the case that the characteristics of immersive VR and the axioms of constructivist learning theory are entirely compatible and claim that constructivist theory provides a valid and reliable basis for a theory of learning in virtual environments.

The key to the compatibility of VR with constructivism lies in the notion of immersion. We have seen that first-person experiences account for a great deal of our activity in the world and our learning about it. We have also seen that first-person experiences occur when our interaction with the world does not involve conscious reflection or the use of symbols. According to constructivist theory, knowledge construction arises from first-person experiences that can never be entirely shared. Immersive VR allows first-person experiences by removing the interface that acts as a boundary between the participant and the computer. In this, VR technology is unique. It alone allows a synthetic experience to capture the essence of what it really means for a person to come to know the world.

Immersion in a virtual world allows us to construct knowledge from direct experience, not from descriptions of experience. Any learning that is mediated by a symbol system, whether text, spoken language, or computer, is inevitably a reflection of someone else's experience not our own. Any requirement that we use a symbol system to communicate about the world we have constructed to someone else can never permit that other person to know our world as we know it. Constructivist theory describes how first-person worlds come into being, and argues that the imposition of symbolic representations for the sake of communication require negotiation about meaning leading to compromise. However, multi-participant VR, in which a group of participants inhabit the same world at the same time, allows the negotiation of meaning to take place should communication among participants be required.

Immersion in a virtual world allows the same kind of natural interaction with objects that participants engage in in the real world. If cognition is non-symbolic and learning intimately tied to action, then it is through interaction with the virtual world that knowledge is constructed. Papert and his colleagues (Papert, 1991) use the word "constructionism" to describe knowledge construction that arises from physical interaction with objects in the world. Immersive VR permits both physical and perceptual interactions to occur.

To the extent that VR can simulate the real world, it allows students to learn while they are situated in the context where what they learn is to be applied. As we have seen, the case has been made that situated learning is both more relevant and successful than learning out of context (Brown, Collins & Duguid, 1989; Lave & Wenger, 1991).

Because a virtual environment is computed from data, it allows the participant three kinds of knowledge-building experience that are not available in the real world, but which ahve invaluable potential for ecuation. These concern what I call "size", "transduction" and "reification".

Size.

Immersion in virtual environments permits radical changes in the relative sizes of the participant and virtual objects. In the real world, an object appears to become larger as I approach it and smaller as I move away. However, there are limits to both extremes. There is a point at which I can get no closer to a physical object and this point sets the object's maximum apparent size. Likewise, there is a point where an object disappears as I move away from it. In a virtual world, on the other hand, I can get infinitely close to and far from objects allowing extremely large changes in size. For example, rather than bumping into a virtual wall, I can keep getting closer to it so that smaller and smaller details of the material from which it is made are revealed. I can see the cellular structure of the wood panelling, and can even enter the molecules and atoms of which it is ultimately composed. At the other extreme, I can "zoom out" from the wall, out of the house, the city, the country and the planet if I want, while still not violating any of the four conditions for immersion. (Some readers may be familiar with the film Cosmic Zoom, produced by the National Film Board of Canada, which conveys this idea far better than any written description.)

The advantages of such changes of size for education are significant. On the one hand, it is possible for students to enter an atom, inspect and replace the electrons in their orbitals, thereby altering the atom's valence and its ability to combine to form molecules (a project that is currently under development at HITL). At the other extreme, it is possible for students to get a sense of the relative sizes of and distances between the planets of the solar system by flying from one the other.

Transduction.

Transducers such as eyephones and earphones are used in VR hardware to present information to participants, and to convert participants' behavior into commands to the rendering software. The notion of transduction discussed here is concerned with the first of these functions.

Transducers are devices that convert information that is not available to our senses into forms that are. A depth sounder on a ship bounces sounds that we cannot hear off the bottom of the ocean that we cannot sea and converts the echos into digital or analog displays for us to read. HMD's convert data into images on CRT's and sounds in earphones. But the data from which these transducers construct visual and auditory displays need not be originally obtained through the human senses. It is perfectly possible to construct a world from data that represent the spread of the Mediterranean fruit fly and to move around a virtual population distribution superimposed over a virtual California. It is possible to convert the ultrasonic echolocation data from a bat into lower-frequency sounds or into visual displays so that we may indeed experience the world of the bat, albeit in the third person.

What is important for education is that as soon as students put on HMD's, they put on an infinite array of transducers. They can see the world as if through infrared or ultraviolet light. They can lay trails of pheromones and watch the behavior of the moths that they attract. They can journey to the center of the sun and observe or alter the convection currents that move material from the core to the surface. They can slow down the speed of an atom and, like Rutherford, watch what happens when it hits a sheet of gold foil (another project that is under development at HITL). And all the time, they are enjoying first-person experiences and constructing first-person knowledge about objects and events that are accessible to them in the real world only as third-person descriptions.

Reification.

Changes in size and transduction give first-person access to experiences that students could not otherwise have. Some of these experiences arise from simulations of aspects of real objects and events, such as atoms or bats. Others arise from representations in perceptible forms, through transduction, of objects and events that have no physical form, such as algebraic equations or population dynamics. "Reification" is the process of creating these perceptible representations.

Reification stands in contrast to simulation. In simulations, virtual worlds contain facsimiles of real objects and their behavior. Their advantage is that students can interact with them safely and that often virtual simulations are cheaper to build than full-blown physical simulators. However, it is often the case that the power of VR is wasted when it is used for simulation. For example, if you enter a virtual world in which there is a virtual microscope through which you can look at a virtual drop of water, you gain nothing. Learning about the microscopic life-forms that live in the droplet is accomplished far more effectively by using a real microscope in the biology laboratory. The microscope in the virtual world is a transducer (revealing to the eyes what would not otherwise be revealed), and the participant is on the wrong side of it! VR comes into its own when, through a massive change of size, the participant jumps through the virtual microscope's eyepiece and into the drop of water, attaining the same relative size as the microorganisms that live there. At this scx1ale, the experience is first-person. But then you do not need the microscope at all. As a general principle, the construction of virtual transducers with which participants can interact gains you nothing. VR is not used wisely when it used to create simulations that can be realized by traditional simulators.

VI. Summary and Conclusion.

This paper has made the following points: 1) Immersive VR furnishes first-person non-symbolic experiences that are specifically designed to help students learn material. 2) These experiences cannot be obtained in any other way in formal education. 3) This kind of experience makes up the bulk of our daily interaction with the world, though schools tend to promote third-person symbolic experiences. 4) Constructivism provides the best theory on which to develop educational applications of VR. 5) The convergence of theories of knowledge construction with VR technology permits learning to be boosted by the manipulation of the relative size of objects in virtual worlds, by the transduction of otherwise imperceptible sources of information, and by the reification of abstract ideas that have so far defied representation.

This leads to the conclusion that VR promotes the best and probably only strategy that allows students to learn from non-symbolic first-person experience. Since a great many students fail in school because they do not master the symbol systems of the disciplines they study, although they are perfectly capable of mastering the concepts that lie at the heart of the disciplines, it can be concluded that VR provides a route to success for children who might otherwise fail in our education system as it is currently construed.

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Abstract Virtual reality represents simulated three-dimensional environment created by hardware and software, which providing realistic experience and possibility of interaction to the end-user. Benefits provided by immersive virtual reality in educational setting were recognised in the past decades, however mass application was left out due to the lack of development and high price. Intensive development of new platforms and virtual reality devices in the last few years started up with Oculus Rift, and subsequently accelerated in the year 2014 by occurrence of Google Cardboard.Â A conceptual basis for educational applications of virtual reality. Human Interface Technology Laboratory Report TR-93-9. Seattle: University of Washington. Virtual Reality (VR) has caught the imagination of many people. Frequent reports in the popular and technical press describe the hardware and software that permit people to "enter" a computer-created "world" and give accounts of what the VR experience is like. Invariably, these reports end with claims for the applicability of VR to all manner of activities, including education. This paper discusses the potential value of VR to education.Â It is perfectly possible, for example, for students to learn the conceptual basis of Algebra without learning its conventional symbols (Winn & Bricken, 1992) provided that the learning experience is direct, personal and implicit. Assessing Virtual Reality for Education. Syracuse University. Johnson, A., Moher, T., Ohlsson, S., & Gillingham, M. (1999). The Round Earth Project: Collaborative VR for Conceptual Learning. IEEE Computer Graphics and Applications19(6), 60-69. McCloskey, M. (1983). Intuitive physics.Â A Conceptual Basis for Educational Applications of Virtual Reality.Technical Report TR-93-9, Human Interface Technology Laboratory - University of Washington. Appendix. CAVE is a projection based virtual reality system developed at the Electronic Visualization Lab (http://www.evl.uic.edu/home.html).

Computer Basis is one of public obligatory courses in university. According to its characteristic and the different computer skills of undergraduates, network teaching has become the priority of educational reform for this course. It mostly focuses on theoretical knowledge, while very little on interactivity.Â [3] He Kun: The Research on the Creation and Application Effect of the Shot-put Courseware Applied Virtual Reality, submitted to Wu Han Institute of Physical Education for master degree (2007). [4] Li Changshan: Virtual Reality Technology and Applications, Oil Industry Publishing (2006). [5] Information on http: /www. vrp3d. com. Cited by. Virtual Reality, Cyberspace and Living Organisms: Towards a New Understanding of Perception and Cognition? Karl Edlinger. This contribution deals with virtual reality and cyberspace and their implications for human perception and the mind. It can be shown, that concepts and elaboration of virtual reality and cyberspace must be based on well founded and consistent concepts of the latter, although these concepts are not considered explicitly in most cases.Â In order to find answers to these questions conceptual studies as well as technologies dealing with virtuality have to be reviewed and analyzed. In this contribution virtuality is elaborated, as introduced and used in computer science, both, at the conceptual, and technology level.