CRITICAL FACTORS IN THE DESIGN OF PLAYFUL LEARNING ENVIRONMENTS: REFLECTIONS ON "THE RETURN OF THE INCREDIBLE MACHINE: CONTRAPTIONS"Ô

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SUMMARY

This paper analyzes "The Return of The Incredible Machine: Contraptions" from two complementary perspectives–educational software engineering, and theories of learning through play and games. One goal of the analysis is to identify the specific design features that make edutainment software successful, and, in doing so, to assist creators, evaluators and consumers in making more informed decisions. [*]

INTRODUCTION

It is not an assignment–it is an absolutely free activity that kids, teenagers, and even adults who have access to any of the versions of **TIM**™[†], **The Incredible Machine**, love to do: solve and create puzzles dealing with the behavior of devices that embed the cause-and-effect principle, and where logical integration of these devices results in machines that work!. They find this software exciting, challenging, worth playing one, two,…. many, many times. I have seen this over the years with my kids and their friends, as well as with educators and parents: they spend hours and hours trying to solve or create functional puzzles. They apply their own intuitive knowledge about the physical behavior of things. They have fun while learning by experience, inquiry, trial and error, cooperation, or even by simple observation.

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[*] This document was prepared for "PLAYSPACE: An examination of learning in multicultural, digital play spaces". This project is sponsored by a Cilt seed grant. Further details on the project are available at http://concepts.concord.org/playspace

[†] *The Incredible Machine*, by Sierra Online. Its version 3.0, 1995, runs on Windows 3.1, Windows 95 or Macintosh. In this article I will refer to this as TIM™.
The Return of The Incredible Machine: Contraptions, by Sierra Online. Version 1.0, 2000, it runs on Windows 95/98/2000 or Macintosh. In this article I will refer to this as CONTRAPTIONS™

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Many questions arise from this phenomenon: Why is playing this game so exciting for such a varied group of people? Why is it educational? How can we distinguish good edutainment from bad? This paper will try to provide answers to some of these questions, drawing upon the research literature and findings from the fields of educational software engineering and the theory of play.

UNCOVERING THE DESIGN OF CONTRAPTIONSÔ

I invite the reader to find a copy of CONTRAPTIONS™ and play with it–even better, invite a kid or a group of them to play with it. If that is not possible, at least go to http://www.nowthisisfun.com/contraptions/ and read what is written there about this software. There is no doubt: The Incredible Machine™, or TIM™ (in any of its versions) is exciting for kids, for teenagers and even for adults. Professional evaluators of CONTRAPTIONS™, the newest version, report an 84% overall rating on their online rating system! The evaluator Mike McDermott, says "The legacy of the Incredible Machine continues with The Return of the Incredible Machine: Contraptions. This is easily the best puzzle game to come along in years and fans of the genre will not want to miss it. The multiplayer options could use a little tuning, but the improvement on the Contraption Builder as well as the 250 pre-set puzzles is sure to provide hours of fun for gamers of all ages" [1].

The important thing now is to identify *why* TIM™ is so exciting for such a varied audience. The enticing quality of this game is not just a matter of 3D graphics, sound, action, and such "fancy stuff." A sound design and implementation are also essential to capture such a varied audience time and again. Let us explore, then, what is behind this phenomenally successful software.

EDUCATIONAL DESIGN OF THE SOFTWARE

There are many ways to design educational software. At The University of Los Andes we have developed and documented a systematic way of approaching this design process [2, 3 4, 5]. This approach has enabled us to create highly interactive (as opposed to expository) educational software, and to describe and assess it[‡].

The methodology we have developed [2] takes into account three dimensions of the design: educational, communicational and computational. For the purpose of this paper, only the educational perspective is considered. In conceptualizing the educational aspects of a piece of software, we deal with the scenarios and microworlds that users interact with. Specifically, we explore different:

- arguments and challenges that drive the action;

[‡]   For instance, see in http://lidie.uniandes.edu.co/ludomatica/ciudadfantastica/menu.html the html presentation of the components of "Fantastic City", a highly interactive software for the kids to develop creativity and problem solving.

- characters and tools (intervening and control variables) that can be used to change the status of the microworlds;
- contextual variables that can be used to change the settings of the system.

Scenarios[§] / microworlds[**] in TIMÔ

The action takes places in a playful environment, Contraptions. This is the place where *The Professor* lives.

When you start the program you are given a demo of the kind of things you can do there, such as create a machine that is started by a mouse when he sees a piece of cheese, and that loads all of the artifacts that you will be able to use.

Posted at the entrance of Contraptions are different iconic signs, giving you a graphic menu that will allow you to decide what you want to do. Clicking on any of the signs is associated with an action.

There is also a button with the message "press to hear" that will play an audio clip with a greeting from the Professor and will give you the basic thesis of the story line.

Fig. 1 Entrance to Contraptions

The first choice that you make will take you to the game console, where you are required to sign in. This console can also be accessed at any moment during game play, in order to change the user. There are different types of activities, depending on the sign that you choose. If you press '**Play contraptions"** you will either be taken to the puzzle you were solving the last time you played with the system, or to the first one if you are just beginning.

[§]   *Scenarios* are the different virtual spaces where the user can interact. They are interconnected by logical gates that open depending on the choices that the users make. Each scenario has one or more communication zones that make possible a coherent interaction [2, 3].

[**]   *Microworlds* are subsets of the scenarios where it is possible to model and simulate the behavior of given worlds, real or imaginary, usually simplifying their functioning. Microworlds contain arguments, challenges, characters, tools. A microworld offers the user the possibility of observing the performance of the modeled system when it is started, as well as to edit the model behind the world. *Intervention variables* (tools) are under control of the user, in the sense that s/he can decide if they are active and what their behavior should be. *Output variables* are tied to the expected results, usually have a graphic display showing the status of the system, but their values can also be displayed, depending on the wishes of the user. *Context variables* condition the performance of the microworld or its appearance to the user [2, 3].

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The first 50 puzzles are designed to help you learn about the characteristics of the different types of tools and options available in the system. To solve them you have to find out (by trial and error or by asking The Professor for help) about each available tool, what can be done with it, and how to use it. Besides this set of 50 puzzles you have a battery of 200 puzzles to be solved, ordered by increasing level of difficulty. You can customize the human-computer interface (sound, color, graphics) as well as the physical conditions that affect the puzzle (gravity and air pressure).

The following figure illustrates the three communication zones available at this level.

Fig. 2 Communication zones

Zone 1, Control, allows you to start/ play your solution, to hear/see the goal, to change the activity, to play with/without hints, to call *The Professor* and get help about the objects you want. It also shows/hides the options below zone 3.

Zone 2, Microworld, is the zone where the action takes place when you press START. It contains the puzzle to be solved.

Zone 3, Tools, is the zone where objects and tools are available to be used to solve the puzzle.

If you press "**Build contraptions**" at the entrance of Contraptions, a workbench and tools are provided for you to build new machines. These can be tested, edited, saved, and recovered.

The structure and functionality of this level are identical to those in "Play contraptions". You are given a workbench with which you can define the title, goal, microworld, and tools to be used in creating and posting a new puzzle.

You can test the puzzle you are creating, by means of START. Pressing OPTIONS enables you to change the context of the puzzle (sound, music, graphics, color, gravity, air pressure and to save your new puzzle.

Fig 3. Build contraptions interface

If you do not know how to build puzzles, you can learn by pressing "**How to build contraptions**" in the central scene. This will give you a step-by-step tutorial on how to do it, using *The Professor* as your guide.

Fig 4. Tutorial on demand

The tutorial supposes you already know how to play Contraptions and know the purpose of each of its tools and options.

Now you must learn how to define challenges and how to build microworlds using tools and contexts. Solutions are defined in the context of the behavior of different objects in the microworld. You can define hints, as well as test the system and save it with a name. By the end of the tutorial you will have created a puzzle.

You can use the system on your own or with a partner, in which case you can press "**Two players**" in the main menu and enter the participants' names, number of games to play, and length of turns. When pairs are playing the game, the system will manage the turns and their lengths.

For a complete description of what Contraptions is, you may press the arrow sign "**Website**" and it will take you to http://www.nowthisisfun.com/contraptions/ where a menu-driven text and graphic description of the system is given, providing details of the different tools available. This website could be used as a handbook describing the system, its requirements, opinions, tips. You can download new puzzles and releases of the program from it. For general help, outside the context of a specific puzzle, you may press the hypertext "**Help**" and get the information you want using a text menu.

When you are done with the system, you click on the "**Exit**" traffic sign. The program will ask you to confirm, save the status of your games, and quit.

Argument and Challenge

When you press the door bell in the entrance of Contraptions, the loud speaker says:

> "Welcome to The Return of The Incredible Machine, Contraptions. Hi! I'm The Professor. I am speaking to you through this loud speaker because one of my experiments went wrong. I'm currently radioactive and I do not want to contaminate you. I've assembled dozens of contraptions for you to complete. If you can solve them all, I'll will know you are the one who has what it takes to beat my friends."

When you click on HELP in the entrance of Contraptions, this is what you get:

"Welcome to the Return of The Incredible Machine: Contraptions. Your host, The Professor is a world famous scientist. His inventions have made him extravagantly wealthy. For years he has worked behind closed doors, laboring away in solitude, deep within his top-secret complex.

Now, he needs an apprentice…

To assist him in picking a suitable apprentice, the Professor has invited you, and a select group of other scientists and inventors, to take part in a little contest. The rules of the contest are simple.

A number of the Professor's favorite contraptions have been left unattended in his complex. Your objective, besides having fun of course, is to solve all the contraptions that the Professor has left behind. If you manage to do this, you'll be guaranteed a life of fame and fortune as the Professor's trusted apprentice."

Characters

The Professor and the active user (one of the two possible participants) are the only two characters involved in the scenarios. Neither of them is visible. You listen to the professor but you cannot see him. The user is able to "see" what is going on, s/he can move objects, click on them or on the variables available, but s/he is not represented by a character: the user IS the character behind the action.

Tools – Intervening and control variables

Available tools include over 100 different parts to mix and match. They belong to one of the following categories: scenery, gear, rope, balls, walls, electric, fire, laser, critter, programmable parts, miscellaneous.

Using tools

Dragging a component from the tools zone to the microworld zone allows you to place the part where you want, while it is not interfering with other parts.

Moving the cursor to a given part in the microworld zone, allows the user to explore it (pressing on the magnifying glass sign), to flip it horizontally (pressing on the red arrows sign), to define if the part is an output variable and what is its expected status (pressing on the flag), to lock the part in a given place of the microworld zone (pressing on the lock sign) or to return it to the tool's zone (pressing on the garbage can sign).

Fig. 5 Exploring parts

Understanding and defining desired status of tools

A given part can be explored by trying it out (trial and error), by getting an explanation of its function (magnifying glass) and/or by a demonstration of the different status (flag). The left figure below shows the window that appears when the magnifying glass is selected. The right figure below shows the window that appears when the flag is pressed. This Flag window is used also to define the final status of the part, when it is in the solution of the puzzle.

Fig. 6 Magnifying a part
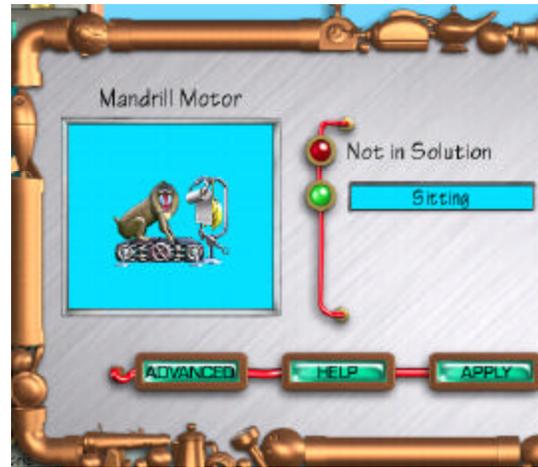
Fig. 7 Defining initial and final stages

Contextual variables

There are two types of contextual variables: those that are in the context of the microworld and those that are in the context of the user, that is the human-computer interface.

Fig. 8 Options

Fig. 9. Preferences

The above two figures show the windows that appear when you press the OPTIONS "Environment" (left side) and "preferences" (right side). You can play a puzzle in a "normal" environment, from the physical point of view (gravity and air pressure on the earth surface, an open space), or change it to another planet and pressure conditions. You can also customize the appearance of the screen, the music, sounds and graphics to be displayed, in order to feel comfortable with the context of the game.

LEARNING FROM THE DESIGN

Examining the structure of the game has helped us to get a better understanding of two different groups of concepts: those specific to Contraptions™, its parts and functioning, and those more general, related to overall design and/or evaluation of this kind of edutainment software. We have partially reengineered the educational design behind this kind of software that combines play, modeling and simulation in the frame of reference of a general microworld (in this case the planet in which we live) and using many building tools (physical components with behavior) to define and to solve exciting puzzles under the control of the user.

Let's now go deeper, trying to learn from the above example what should be considered critical design principles for playful learning environment. I will comment on two general categories of principles: those related to "playful" digital environments and those that deal with "educational" digital environments.

CREATING PLAYFUL DIGITAL ENVIRONMENTS

The following concepts about play, taken from Huizinga and Rieber will help illuminate the essence of the first challenge behind the design of a playful learning environment: making it playful.

> Play is a free action, executed as such and experienced as something situated outside of normal life, but in spite of that, something that can completely absorb the player even without a material interest and without obtaining any benefit, which is executed within a determined time and place, which is developed within order and subject to rules and which gives birth to associations that tend to surround themselves with mystery or costumes for detaching oneself from the actual world. [6, p.26]

> Play is generally defined as having the following four attributes: 1) it is usually voluntary; 2) it is intrinsically motivating, that is, it is pleasurable for its own sake and is not dependent on external rewards; 3) it involves some level of active, often physical, engagement; and 4) it is distinct from other behavior by having a make-believe quality [7, p.43]

In the design of an interactive learning environment the following aspects should be considered in order to make it playful:

- control of the microworld by the user;

- contextual, constructive, and non-controlling feedback;

- adaptive and robust interface design;

- flexible, history-based sequencing;

- seductive induction;

- illuminating help on request; and last but not least important,

- fantastic tools and arguments.

Control of the microworld by the user

When playing computer and electronic games, simulators or "sintonic[††] microworlds, many kids enjoy the *sensation of control of the microworld* [8, 9, 10] – the pleasure of being able to think and make the ideas reality. This is something that people do not often experience, especially in a formal educational setting. The design of the microworld (see the definition of the term in the [**] footnote) is critical to creating this sense of pleasurable control.

Contraptions™ uses an *intrinsic microworld* – a metaphor, argument, and objects, that are directly related to the concepts the designer wants the user to deal with. Our living planet (or another planet with different gravity and pressure) is the frame of reference within which the contraptions function, both those that the Professor has prepared and those that the user has built. This planet is also the environment where the challenges are to be solved. Intuitive physics and problem solving arise naturally within this microworld. The user is in *control of the microworld*, as long as s/he can select or define the goal, keep or change the context variables, select and make discretionary use of the intervention variables (tools), use trial-and-error and reflection to pursue the goal, or use his/her imagination to define new goals and the tools to be used for achieving them.

However, not all the domains of knowledge offer the same potential for building environments where one can have direct experiences related to the content to be learned. Because of this, *extrinsic microworlds* are superimposed on the concepts and skills to be learned, in order to make the process exciting. This layering of the fantasy structure is also common in some drill and practice programs, where the

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[††] Sintonic microworlds according to Papert [8] do not need to be learned, their metaphors are in the vital field of the learner, i.e., his/her previous experiences and expectations.

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microworld is used as an external motivator and reinforcer of the action. For example, in hangman- or hall-of-fame-based games, solving the exercises is the way to prevent your character from being hanged or to get to first base, but the knowledge behind these exercises is completely independent of the behavior of the microworld. The mental models one develops to solve the problems are not reflected in the microworld. Extrinsic microworlds do not provide users with the sensation of control over action; they simply provide rewards or punishments for achieving or failing to achieve an externally imposed task.

Contextualized, constructive and non-controlled feedback

Intrinsic feedback, which is just information about the task being performed [11], is essential in building playful, interactive learning environments. The sensation of control the kids talk about relates to this component. When users use tools in the microworld to make changes, they must see these changes actually reflected in the microworld–sometimes in real time, sometimes when the user requests it.

Contraptions™ allows the user to explore each of the tools, getting intrinsic immediate feedback as they are used (you know right away if the tool fits somewhere, if the direction is appropriate, if it can be joined or linked with others). It also allows users to assemble machines and, upon request (by pressing the START button), get intrinsic feedback about what works and what does not.

The feedback can be extrinsic also, becoming a reward that is external to the task at hand [11]. Extrinsic feedback is usually linked to achievement of the goal. In order to provide this kind of feedback, the system needs to know what the goal is, what variables reflect the desired status of the system, and the expected levels of performance. When the goal is achieved, the program confirms to the user that his/her solution corresponds to the expected one, and/or provides the prize that was announced when the puzzle or set of problems was launched.

Contraptions™ also makes use of external feedback. For example, when you solve a puzzle, the system tells you that you achieved the goal, and allows you to see the Professor's solution, which is not necessarily the best. Similarly, when you define a puzzle, the system asks you to define the variables that signal that the goal has been achieved and their expected values, and requests you to test that the system works. When you do so, you get a reward message. Just try it and you will see this in action!

In using external feedback related to puzzles with multiple solutions the system can assess the achievement of the goal, but it cannot determine whether a given solution is the best. So the external feedback, to be constructive, needs to encourage the user to find out if there is a better, simpler, or more efficient solution, instead of simply reinforcing the result obtained. Also, it is good to invite the user to explain his/her solution to others and to contrast it with someone else's solution.

Another critical point concerning feedback when you are playing games or solving puzzles deals with the "I give up" or "I got it" behaviors of the users. When the user decides to give up, the system should certainly not provide the expected answer. The system's answer should only be provided to the user when s/he has gotten his/her own answer, and only for the purpose of contrasting and testing other solutions to the puzzle, not as a means of giving

the best answer. Providing answers when the users "give up" fosters dependency on the system and favors mental laziness. This is what happens in systems where after two or three trials the program gives the solution.

A final critical issue concerning feedback is what Bos [11] calls "controlling feedback." This type of feedback inhibits reflection and does not promote thinking. An example of this occurs in arcade games, where users simply react to the event; they do not plan a solution or evaluate the status of the system and possible alternate solutions. Though the sensation of control one feels when playing these arcade games may be very high, to be constructively educational these games should allow reflection and not only reaction.

Adaptive and powerful interfaces

The human-computer interface is not just the communication system between the computer and the user [12]. The human-computer interface is also the way of making the user's interaction with the program easy/difficult, boring/fun, attractive/disgusting, etc.. Providing the ability for users to customize many of the features so that they might feel better while working in the program is not an easy task. "Perception is relative" is a well-stated Gestalt principle [13], "there is not disputing about tastes and colors" is a popular saying, and features such as adjustable color, sound, music, background objects, are important. Users feel comfortable and they appreciate the adaptability of the system when they are given control of some of these variables.

Prensky suggests that [14, p.46] that members of the Game Generation are native speakers of the digital language of computers, video games and the Internet. But these are not the only users of a playful learning environment. There are also digital "immigrants" whose accent betrays itself in such behaviors as turning to the Internet for information second rather than first, or reading the manual for the program rather than relying on the program itself to teach how to use it. Both types of users should find the interface powerful, and it should allow them to approach the system in their own preferred way: from direct experience, trial and error, reflection, or being taught beforehand how to use each of the different functions available. Finally, different users' abilities or disabilities should not be an obstacle for using a playful learning environment. If you are hearing impaired, you should be able to read what is otherwise spoken, but if you are illiterate, listening to the messages should also be possible.

Contraptions™ is a masterpiece in these aspects. Part of the fun of using the game is that you can adjust the interface and the way you use the system to your own preferences or needs.

Flexible history-based sequence

It is not just a matter of having control over the sequence of the action that leads the designer to keep track of past performance. Controlling the sequence of the action can be used, in effect, to help the user follow a suggested path of learning experiences. However, when the sequence is flexible, when the user is allowed to follow suggestions or to make his/her own decisions concerning what to do next, without penalty or warning, this becomes a powerful feature. Combining menu-driven with history-driven sequences gives the user control over the sequence of learning activities without losing the knowledge derived from past experience [2].

In the case of Contraptions flexible, history-based sequencing is fully implemented, and it allows different users to approach different types of puzzles in their own ways, based on their level of problem solving skills, topic preferences, the nature of the arguments, or the type of activity (e.g., create or solve puzzles) they want to perform). This is fun.

Seductive induction

Demos are good ways to capture attention. When you know from the very beginning the kind of excitement that the system can provide, your internal motivation grows and your expectations are raised very easily. If you also find that trying things out, taking risks and making mistakes is not a punishable activity but a very natural way of behaving, then you will find it fun to explore each one of the new devices or tools that are available. But if you want to be sure before trying, it is also fun to be able to ask for an interactive demo where you can see what you want without losing the control of the device being explored.

This kind of seductive induction is an exciting way of learning about each one of the components of the system, as it allows you to learn by experience but also by demonstration. In Contraptions™ the user has the means of learning about each one of the devices just by trying it or by pressing the magnifying glass and getting an interactive demo. Cool, isn't it?

Illuminating help on request

Illuminating with indirect light [15] is a wonderful principle for helping people learn without imposing the instructor's mental model about the content to be learned. In problem solving this is a particularly difficult teaching challenge: One does not want the user to be discouraged because of the level of difficulty or obscure nature of the problem (to be relevant, problems ought be in the proximity zone of the learner, according to Vigotsky [16]). At the same time, one does not want to be so helpful that asking for help becomes the solution. It is good to give the user control of the kind of help he wants (hints or no hints, leading but not giving the solution; demos about the functioning of the parts of the system, guided interactive tours). This places the possibility of learning in the hands of the learner. Contraptions™ is a wonderful example of this.

Imaginative tools and situations

What makes an environment creative and fun is not the power of the tools available within it. Have you realized the power behind a productivity tool such as a word processor or a spreadsheet? But are they fun by themselves? Nope!!!!! And have you realized how powerful and fun the tools are in Contraptions™? Each element is curious by itself, it has properties that you can explore and use to change its behavior depending on the circumstances. On the other hand, all of the tools are surrounded by fantastic situations and exciting challenges (when you are solving problems) or the means for building new fantasies and challenges (when you are creating new puzzles).

If you provide the user with provocative tools and arguments for building or solving exciting challenges, you are opening a gate towards creativity, awakening curiosity and internal motivation, as well as giving powerful tools to build and test new mental models.

CREATING EDUCATIONAL DIGITAL ENVIRONMENTS

Educational digital environments are not synonymous with boring lecture-type digital presentations. What kids and adults associate with good computer software and Internet services are highly interactive environments where multimedia information is flowing and where the user is having a dialog with a piece of software, information service or other people who are on the net. How do we make such an experience educational? Even better, how can we make playful digital environments educational?

Well, there is no single recipe, since there are many ways to educate and different learners have different educational needs. I will explore the following points as an opening: educational approach, characteristics and needs of the audience, educational intention, motivation and reinforcement, learning activities, integration of learning means, and integration with existing curricula.

Educational approach

When you look at a software application like Contraptions™ you realize that it is more that entertainment. It is also educational, and has an educational philosophy behind it. Definitely the authors of Contraptions™ had in mind a mostly constructionist way of helping people get the essential knowledge. In the game, this constructionist approach is to create and solve problems in the context of a given microworld. But the environment also directly teaches some essential things, such as the functioning of the different parts and the functioning of the system, such as when you ask for help in order to learn about the intrinsic properties of the different objects through the first 50 puzzles and when you decide to go to the component "How to build contraptions", you get a tutorial by default.

Both algorithmic and heuristic approaches for learning [15] are encouraged in Contraptions™. The latter is predominant, since most of the activities are under the control of the user who decides what to do (solve which puzzle, build what contraption?) and how to do it (with which tools, with/without hints, with/without contrasting his/her solution with the Professor's solution). This variety of treatments reflects an eclectic educational philosophy where different types of goals (e.g., "reproductive"/low-level objectives concerning the appropriation of the means of the system vs. "productive"/high-level objectives concerning the final goals of the system) and different styles of learning (field-dependent learners who need external locus of control, vs. field-independent learners who follow their own internal locus of control) are supported through different kinds of learning activities. The literature on Aptitude by Treatment Interaction suggests [17]combining treatments, most of them under the control of the user and some under the control of the system.

The critical point in the above eclectic combination of educational treatments is that it has to be both selective and consistent. One cannot be blamed by being directive or permissive in helping others to learn, by being a transmitter of knowledge or a facilitator of learning. It is most important to know why and when to use which educational approach, with what purposes and with whom.

Characteristics and needs of the audience

Understanding the characteristics and needs of the audience greatly affects the kind of stimuli you provide, the arguments you use, and the motivators and reinforcers that drive the action.

In the case of Contraptions, there is not an explicit definition of the audience, neither in the software, nor in the printed or web documents. However, looking at the interface, there is a clear evidence that kids and young people were taken into account in its design and production: Color, sound, voice, graphics and animations have a touch of young people used to playing with video games with high performance and adjustable interfaces. However, looking at the different sets of puzzles, which are organized in five sets of 50 puzzles each, you realize that the intended audience may be groups of kids or teenagers, either working collaboratively among themselves or with their parents as facilitators. The more you advance in the solution of puzzles, the more complex contexts you need to understand in order to find out what is going on, what the challenge is and how to solve it with the given tools. This may require cooperation between kids or interaction with adults.

I do not mean to imply that the software was not also designed for adults, and it is interesting to find that many adults find this game exciting and worth using not only for their kids but also for themselves. Adjustable interfaces and selective puzzles help the different users of the system feel excited while using it.

Educational intention

The educational intent of the software is what drives the action. You may be very constructivist but if you intend to help people memorize a poem, this is not going to be the most effective way of doing so. On the contrary, you may be very behaviorist but if you want people to create their own solutions to puzzles, such an approach will not work. Usually your intention and educational approach are coherent, and you can be coherent. If not, you need to decide how to make your goals and educational approaches compatible. Being clear about the goals and subgoals is critical.

In the case of Contraptions™, this software is definitely designed for developing creativity, in its two complementary dimensions [18, 19, 20]: "being creative[‡‡] (inventing new puzzles) and "having creativity" (solving given puzzles). Intuitive physics is the domain in which this creativity is to be developed, but with the clear expectation that it will transfer across knowledge domains.

In both modes of using the system (posting or solving contraptions) the user is totally in control. If you are solving existing problems, you can decide which problem to solve, or to drop and change it. You decide how to solve it, using selected tools and combining them the way you want. Time is not a restriction, nor is the number of trials. You can test your solution as many times as you want, but you never get the system's solution before you

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[‡‡] According to Jaime Parra [18 cited in 19, p.179] *having creativity* is having the capacity to establish unusual relationships and associations, to solve problems, to identify diverse alternatives, development of analogical thinking, fluency, originality, etc. *Being creative* has to do with the sources of inspiration, the brilliancy of ideas, spontaneity, freedom of spirit, psychological security, motivation, familiar environments, humor, etc.

have found at least one of your own. If you are building contraptions, you have total freedom to select and combine parts.

A subgoal within the system is to discover how different machines or parts function under different physical conditions. This can be done playing with the machines when they are explored. The system also demonstrates the different functions or each part when the user sets the appropriate conditions.

Motivation and reinforcement

What moves the audience to interact with the software is a critical educational aspect. The challenge is not only that kids decide to use the system (this can be internally or externally motivated), but that they keep doing it because they want to, (internal motivation). Contraptions™ uses a highly intrinsic motivation system, as well as implicit reinforcement. Though the system initially declares that the professor is seeking an assistant and will select a person who has solved all of the puzzles, this is not generally what motivates repeated participation. Users agree that the satisfaction of building interesting and challenging machines (implicit motivation) and/or of solving a given puzzle (implicit reinforcement) is what drives the action.

The other critical motivational factor is that the puzzles to be solved should be relevant challenges in the zone of proximal development [16] and vital field [21] of the learners: Not interesting, too easy, or too difficult challenges may not motivate the learners to try. In Contraptions™ puzzles can be selected to accommodate the level of difficulty that the user wishes ,as well as the significant and relevant arguments and goals to be achieved.

The possibility of playing with the adjustable background, sound and colors, makes this a friendly and exciting system, but by themselves, these are not the key motivational factors. Nevertheless, if they were absent they might discourage certain audiences from playing repeatedly.

Learning activities

The core of the interaction between the user and the software occurs through specific learning activities. Each of these has an intention and an approach. Each responds to a need (motivation) and has a way of knowing whether that need has been successfully met. It is evident that each of the scenarios has a different educational intention, with particular ways of helping learners to be successful. If the system were to be used with a different intent, a facilitator would have to create supplementary learning activities For instance, someone interested in using Contraptions™ to help teach general problem-solving principles would need to include activities focused on finding and generalizing meta-knowledge based on the experience [22, 23, 24].

Integration with existing resources

What does it mean to "integrate with existing resources?" I ask myself whether the reader has the answer, but let me share my point. Depending on the educational intent of the person selecting the software, it will be necessary to make use not only of the software, but also of other learning devices. And this must be done in the right way.

Contraptions™ was apparently not designed to be used in formal education settings, but rather in informal settings. Teachers find this a very exciting program that has educational value; it can be used just for having fun and to help kids develop some kind of exciting mental activity. But I have realized in working with educators and kids of the project Ludomatica[§§], a Colombian project focused on playful learning environments for kids, that if one wishes to go beyond the immediate goal, one cannot limit the learning experience to the computer. Educators are required to functionally integrate different resources so that students can learn how to learn from different means and to make the best possible use of each of them.

For instance, in Ludomatica, where classroom size varies from 20 to 40 students, where heterogeneous knowledge and level of development is a pattern, where there are only one or two computers per classroom, teachers need to find a way to help all of the students obtain knowledge, build knowledge, and share knowledge concerning the topics of interest. This can be done by having them work simultaneously in small groups, all of them searching for answers to relevant problems. They can make use of manipulatives, software, Internet, magazines, books, encyclopedias, physical activities, artistic activities, etc. in an integrated way, in the sense that the same intention drives all of the different uses of media and the same pedagogy is behind their use.

If you do not know what you are looking for and how to help the learners to achieve it, the use of a playful digital learning environments will never be more than a way of keeping the kids focused on the task because of the fun they are having. Integration of playful digital learning environments is not an easy task; it is even more difficult if you intend to use them in a coherent playful pedagogy!!!. However, there is research that can support you in this regard [20, 25, 26].

Integration with existing curricula

Both informal and formal education settings are important, since both contribute to lifelong learning, which is in essence the great challenge of education: to help learners become permanent and increasingly independent learners, able to contribute and participate in society. We know that edutainment software can be effective in informal education settings and all of us wonder if it can be properly and successfully used in formal education. I believe that it can.

I have had the opportunity to work with non-conventional educators who combine constructivist and problemic [***] [27] pedagogy. I wonder if this combination may make the difference in the integration of edutainment with existing curricula. If the curricular approach is centered on problems, these are the focus of edutainment. Learning units could be focused on problems to be solved; in this case, both edutainment software and many other media can be articulated under playful learning environments, all of them helping to build the desired knowledge and skills. The fun of learning would be combined with the fun of playing!!!! What a dream!!!

[§§]   See http://lidie.uniandes.edu.co/ludomatica
[***]   Problemic pedagogy is focused on exploring, analyzing, building knowledge, verifying knowledge related to problems. It is problem focused rather that content centered.,

FINAL REMARKS

This document has been a very exciting adventure for me. I hope that this becomes contagious. If you have not played with TIM™ or with Contraptions™, please do it! And then reflect on these things that may help you decide if other edutainment software can be analyzed and evaluated using a similar structure. Also consider if the ideas derived from these playspaces are worth implementing in your educational setting. I would be very happy if that were the case.

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