# Multimedia Support for Learning Advanced Packaging Manufacturing Practices

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**Abstract**

We propose to develop a Manufacturing Research Training System (MRTS) that is focused on the domain of advanced packaging prototype manufacture. Our approach takes into account the unique features of such a manufacturing environment where a diverse group of students need to acquire knowledge at various levels of detail about a rapidly changing process and environment. We will use PML, a new procedural markup language, to develop the knowledge organization and media separately and couple them by cognitive media roles. This enables the separation of the content organization from the presentation. This separation has several advantages over a coupled approach, the most important of which is the ability to customize the presentation to the user in a dynamic fashion. Our approach is well founded on current theories of how learning takes place in real world environments. The result of this project will be a new tool to support learning that will have been tested in the context of the Packaging Research Center at Georgia Tech, but which will be generic enough to support prototype manufacturing environments at other locations and other parts of the electronics manufacturing chain.

**Introduction and Objectives**

Manufacturing Research Training System (MRTS) is a proposed system for helping a diverse group of students communicate, learn and record information acquired in the in a prototype facility such as the one at the Packaging Research Center (PRC) at Georgia Tech. Its ultimate goal is to facilitate learning in this environment by mediating and supporting the actual manufacturing activities, helping the students record their interactions with the environment, facilitating communication between the students about their experiences and ultimately author parts of the system.

The complex manufacturing environment at the PRC creates some interesting issues that have to be considered during system design. In this environment, the prototyping of products is the norm, rather than large scale production. The complexity arises from a number of factors including:

- The multi-step nature of the process with significant re-entrant structure. This means the same basic process is applied to a product several times during its production. A process on the same equipment may need subtle variations when applied at different stages of the production process.
- The highly dynamic nature of manufacturing processes where improvements to the process must be carried out during production in order to increase manufacturing yield and test new processes or materials and where new equipment is constantly being introduced.
- The potential for reasonable turnover in personnel staffing the prototype line. This could be due to the special circumstances surrounding the Packaging Research Center at Georgia Tech where graduate students and industrial interns are cycling through the line, or because staff will use the prototype line and then move with the product into full-scale production.

It is our assertion that in these environments:

- a static manual on how to use equipment or materials will rapidly become out of date,
- the personnel are actively developing new knowledge that needs to be captured for subsequent generations of researchers, or for those seeking to adopt the process at other locations,
- the presentation of material will need to be customized for different groups of users, undergraduate, graduate and professional. These diverse users will have different levels of background knowledge and, depending on the situation, different requirements on the level of detail and style of presentation of the material.

To address these problems, a learning support system needs to:

- support different levels of expertise
- support different tasks with the same equipment
- support constructivist learning by allowing the student to interact with the system while using the equipment in the center
- allow students to author and edit the information within it
- support the communication and recording of ideas and expertise

Thus, we intend to provide a structured computer environment in which new procedures can be recorded and existing ones modified. This environment will explicitly separate the knowledge of electronic pacakaging manufacture from the structure of the multimedia presentation by using the Procedural Markup Language (PML) developed by several of the co-authors.

The theory of learning behind MRTS is based on constructivism and situated learning, the idea that knowledge

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is actively constructed by the learner based on previously acquired knowledge and that this knowledge is situated within the context in which it was learned and used. The other important learning theory is that of distributed cognition, which holds that cognition is distributed and shared among one's tools, community and environment.

The system will promote cognition, not only in the individual system, but within the entire environment, by facilitating the sharing and development of the tools, community and environment within the individual's learning environment. Processes, practices, artifacts and groups can be understood at a number of levels: the historical, theoretical and procedural levels. In a hypertext system training system, student-authored information can be tied to past projects, procedures and objects, as well as those being developed. If the system makes authoring easy and presents information at the appropriate level and in the appropriate context for the user, then students can have a rich space to develop an understanding of the manufacturing research going on at the PRC, as well as a "how-to" when they need help.

**Procedural Markup Language (PML)**

PML has two basic elements. Information about a domain is encoded in *knowledge nodes* which are interconnected using *knowledge links*. Using the basic ontological principles established in AI and Cognitive Science, the knowldege nodes are things, states and procedures and the knowledge links are Is-a, Has-a, Connects-to etc. The content of the knowledge nodes is physical media. A media node is the actual information about a knowledge node that can be displayed by the system. This can be of any physical type such as text, sound or video. The unique feature of PML is that the media nodes are organized using cognitive media roles (example, justification, description etc.) rather than the physical type of the media (text, sound, video etc.) that comprises them. This organization is shown in

Figure 1.

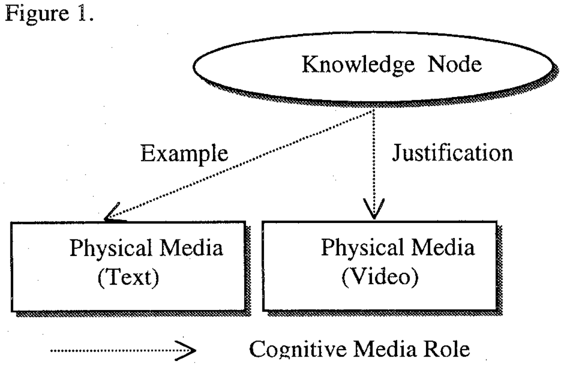


**Figure 1**

This organization has three immediate benefits. First, it enables the content provider, essentially the engineer, to focus on authoring the content without regard to how that information will utimately be displayed: PML separates the content from the presentation. Second, it is possible to design different presentations for the same piece of information based on the user's level of expertise. Third, since the connections between media and knowledge are explicitly represented, the systems can create appropriate presentations on the fly based on the current interactions and context.

The language has a graphical version tkPML, that as its name suggests, is built in the tcl/tk language. We will provide an initial set of examples and pre-constructed templates based on the manufacturing processes under development at the PRC. These will be useful cases to enable engineers to understand the sorts of information that it is useful to record. The PML representation is not the ultimate end-product that is needed to achieve our objectives. We need to compile the PML code into hyperlinked web pages. A simple version of this compiler already exists, we plan to extend the compiler to enable the generation of different presentations depending on the requirements of the user.

The key areas where we see the need to differentiate the presentation are the level of detail and the scope. For undergraduate interns approaching the manufacture of packaging for the first time, the detail in the presentation of the processes will need to be high and the background information easily accessible. For graduate students we envision a similarly detailed description of the processes but the background can be suppressed. For industrial interns we expect a spectruum of knowledge, but in general we would be able to lower the level of detail in the description of the processes. The scope of the presentation will be determined by the interests of the user. We expect to support queries that enable focusing of the presentation on certain subsections of the process. For example, a materials engineer researching a new dielectric material for a substrate might be interested in the processes surrounding polymer deposition, patterning and methods for assessing adhesion but not the deposition of copper. On the other hand, an undergraduate in his/her first packaging course might be interested in the whole manufacturing process from substrate through assembly and test.

**Description of Learning Activity**

MRTS is a tool within a learning context, rather than the learning context or environment itself. Its use is just one part of the activity of learning about or doing manufacturing research. Thus, the focus of this proposal to build MRTS is on using the tool in the context of the learning activity, instead of on learning from the tool. As Jonassen, Campbell and Davidson state, the "debate should focus ... on the role of media in supporting, not controlling the learning process."

**Subject**

The typical user of MRTS will probably be someone who has had limited exposure to the manufacturing processes for advanced packaging, but may understand the theories behind it or may have developed similar processes. It will be someone who might understand the big picture, but needs to get information about the details of the process. Users will have different levels of understanding about the process, and the system provides support to accommodate people with different understanding and skill levels. The user-directed scaffolding in the system helps the user rely on the system less as she learns more about the process and how to use the external environment for clues on how to diagnose and solve problems.

### Goal

One begins using the MRTS once one has the goal of transfering a research idea into a prototype or acquiring the idea or manufacturing process embodied in the prototype. The learning goals are self-generated, not external to the learner or the manufacturing problem she is facing. The MRTS is a way of bringing them into those process, communities and tools, both socially, through the reports generated by other students, and physically, through the procedural and practical knowledge it gives about operating equipment in the environment.

### Object

The object, which is the product being developed in the prototype facility, a board or substrate for example, is what drives the learning process. Creating or manipulating the object is what is driving the student to participate in the prototyping activity. The student learns about the object by understanding thoroughly the process behind creating it.

The MRTS facilitates the learning process by having students learn about creating the object while actually working on creating it. The system isn't separated from the making of the object, it facilitates it. The system supports experimentation and manipulation of the object, through flexible organization of the necessary information. The system tailors the presentation of information to both the task and knowledge level of the individual using it.

### Community

The community also plays a large role in the learning activity. When one cannot solve the problem using the tools, including the MRTS and the traditional tool set, one can turn to this community. The community can involve fellow students in the environment, support people and the virtual community online using the MRTS. The system emphasizes the communication of ideas and processes that are occuring or have occured in the environment. The system will enhance communication within that community. Links to personal web pages with information about the student's projects and identity will help facilitate communication and understanding within that community.

### Environment

The environment of the learning activity is important for the design of the MRTS. The system needs to be a part of the environment where the learning is occurring. The system will be on the Internet, so that it can be accessed from the computers in the lab as well as other locations students might be operating in. The system then can be accessed while in the actual environment or outside of it.

A cleanroom environment imposes some constraints on what kind of learning materials can be brought into it. Cellulose materials will be forbidden, hence a networked electronic system on the computers already in the lab would be ideal. It can be easily integrated into the environment, rather than requiring the students to leave the context to get information.

### Manufacturing Research Training System – Next Steps

MRTS will accommodate four main types of activity: exploration; operating equipment and problem diagnosis and solving; and communication. The learner is expected to use the system to explore the PRC and manufacturing research that is going on there, to operate the equipment in the PRC, to diagnose and solve any problems arising while operating the equipment and then to communicate what they have been doing in the environment. Through this communication, record keeping for the center can be done, and the system can be enhanced, edited and even authored in some cases. We will examine each of these activities and their support in more detail.

### Exploration

To understand the research being supported by the PRC and the processes that go on there, MRTS needs to give the learner information about the various systems, processes, rules and products of the center. The learner needs to indicate what system, process, product or research she is interested in.

While doing this exploration, the user is motivated to learn more about other research. She learns about the equipment's parts and operation, the processes supported by it and other related systems.

The MRTS uses a number of means to introduce the important systems and process in the PRC including:

- Diagrams
- Photographs
- Illustrations
- Definitions of systems
- Video and animated demonstrations
- Examples
- Lists of typical problems, symptoms of those problems and reasons for those problems
- Lists of parts
- Lists of related and connected systems

A user will interact with the system through the hypertext interface. With hypertext, one chooses to follow a link by choosing linked text or graphics. The exploration activity of MRTS comes at the beginning of the interaction with the user and requires the user to attend to the interface, while referring to the external environment they are in for information.

### Operating equipment and problem diagnosis and solving

Once a procedure has been chosen for operating the equipment or problem diagnosis and solving, the user will interact with the system while focusing on the external environment. Before starting the procedure, the user considers a number of factors:

- An overview of the procedure
- Risks
- Time
- Skill level required
- Tools and materials needed
- Main steps to complete

Then the user considers where they are in the process in comparison to the main steps listed on the page and chooses the step on which they are working. In this way, the user can jump into the procedure where it is appropriate.

Once within the process, step-by-step instructions are given through a vocal and graphical output. The recorded instruction for each step is played by the computer, and the text is also displayed on the screen. Diagrams, photographs or illustrations of the object being manipulated and of the tools mediating the manipulation are also provided for each step. The user can provide input to the system through simple one-word vocal commands or using a mouse.

Once a procedure is begun, the user is expected to attend to the object and equipment instead of the MRTS, and so the output and input is meant to keep the system non-intrusive. One can keep one's hands and eyes on the object while going through the procedure and glance to illustrations and diagrams when needed. There are two commands for the voice output, "Repeat" and "Stop." Repeat replays the step's recording. Stop pauses the procedure. Despite this emphasis on the voice interface, the interface during a procedure still can be referred to and interacted with using the traditional hypertext interface.

The step-by-step procedure uses scaffolding to accommodate the user's skill level and learning. There are two commands there for moving to the next step, "Next" and "More." Next means one has completed the step and would like the next step. More gives the user more information.

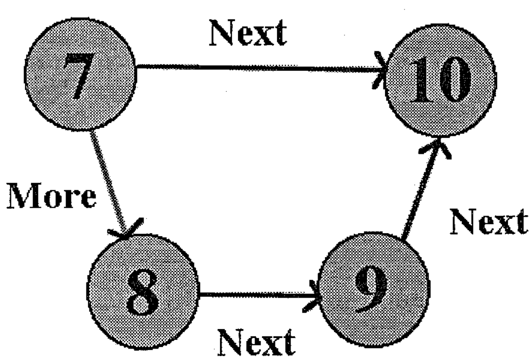


**Figure 2** Users can take two different routes from the high-level step on the seventh page of the system to the tenth page of the system.

One can also jump to another step in the task by using the Jump command. That command brings up a list of high-level steps, indicating where one is in the process and where one can jump to .

Figure 2 shows a graphic depiction of how one might travel among the steps demonstrated by pages six through nine of the system. Figure 3 shows a representation of a more complete traversal of a MRTS procedure. The advantage of the way the scaffolding is implemented in MRTS is that the user does not need to be aware of what level of the hierarchy he is on. For him, it's a linear process, one step to another, but to the system the user may have traveled to different levels depending on their needs.

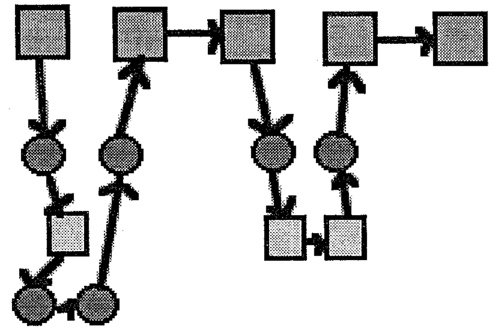

**Figure 3** A user may travel through a number of levels during a procedure, but as far as they are concerned, they have just been following a linear, step-by-step process.

A progress bar shows how far one is in completing the task, as well as an indicator to show what step they are currently on while working on the task. This helps accommodate someone who wants to jump ahead in the task and skip steps they have already completed.

Another thing to note about the way the problem diagnosis and problem solving procedures are implemented. The procedure for diagnosis goes straight into problem solving without the user being aware of it. However, if the user wanted to stop the program after diagnosing the problem without solving it, they could stop and reenter the procedure for solving the problem from another spot.

**Communication**

The community surrounding the learner is always important. It is important that the system facilitates the learning of the vocabulary of the community, and so that one can easily speak with others about the systems they are using.

MRTS facilitates the actual communication beyond giving the user the right vocabulary, though. It allows one's record keeping activities to be part of the actual learning system. Because students input information according to the cognitive role it plays, the system can automatically integrate that report into its database of knowledge and let others know important developments in processes and equipment automatically without a third party. The student who enters the information will have their name attached to all documentation generated from their report, so that someone can contact them if they have questions or problems with their report. This keep communication in the lab continuous. One then can lookup not just information about some equipment, but they can also look up who made the report about the equipment, what it has recently be used to produce, what the research behind that production was and how the equipment might have been altered or changed recently.

**Conclusions**

Designing a learning tool to be part of an authentic contex requires significant effort. As our initial efforts to develop MRTS shows, amany different aspects need to be considered in that design, including:

- the subject (the person who will use the equipment)

- their goal
- the object the subject is manipulating
- the other equipment being used to operate upon the *object*
- the community that supports the learning activity
- the environment it will be used in.

We are proposing to build a system that can accomdate learning in this authentic context and help the students construct their own learning space there.

MRTS has four main types of activity: exploration; operating equipment and problem diagnosis and solving; and communication. The activities have different interfaces and interaction styles for the situation the learner is operating in. The learner is expected to attend to the system in different ways during different tasks.

The theory of learning behind the system is based on constructivism and situated learning. Underlying this, though, is the idea that cognition is distributed among one's objects, tools and environment. Two mediating constructivist theories, learning on demand and cognitive flexibility also helped form the learning theory behind MRTS.

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