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Instructional Theory and Technology for a Post-Industrial World

Charles M. Reigeluth
Indiana University

One of the few things that practically everyone agrees on in both education and training is that people learn at different rates and have different learning needs. Yet our schools and training programs typically teach a predetermined, fixed amount of content in a set amount of time. Inevitably, slower learners are forced to move on before they have mastered the content, and they accumulate deficits in their learning that make it more difficult for them to learn related content in the future. Also, faster learners are bored to frustration and waste much valuable time waiting for the group to move on – a considerable squander of talent that our communities, companies, and society sorely need. A system that was truly designed to maximize learning would not force learners to move on before they had learned the current material, and it would not force faster learners to wait for the rest of the class.

Our current paradigm of education and training was developed during the industrial age. At that time, we could not afford to educate or train everyone to high levels, and we did not need to educate or train everyone to high levels. The predominant form of work was manual labor. In fact, if we educated everyone to high levels, few would be willing to work on assembly lines, doing mindless tasks over and over again. So, what we needed in the industrial age was an educational system that *sorted* students – one that separated the children who should do manual labor from the ones who should be managers or professionals. So the “less bright” students were flunked out, and the brighter ones were promoted to higher levels of education. This is why our schools use norm-referenced assessment systems rather than criterion-referenced assessment – to help sort the students. The same applied to our training systems. We must recognize that the main problem with our education and training systems is not the teachers or the students, it is the system – a system that is designed more for sorting than for learning (see Reigeluth, 1987; 1994, for examples).

Elsewhere, I have presented visions of what a post-industrial education system might be like – a system that is designed to maximize learning (Reigeluth, 1987; Reigeluth & Garfinkle, 1994). With minor adaptations, that vision could be applied to our training systems as well. The purpose of this chapter is to describe instructional theory and technology that support such post-industrial education and training systems. In particular, it will:

- Describe *universal methods* of instruction based on Dave Merrill’s “first principles”.
- Discuss the importance of tailoring methods to particular *situations* and resolve the apparent contradiction with universal methods.
- Describe the “*core ideas*” of the post-industrial paradigm of instruction.
- Present a *vision* of post-industrial instruction, complete with several major *instructional strategies*.
- Describe the *roles* that should be played by the “teacher”, the learner, and technology in the new paradigm.

Universal Methods of Instruction

M. David Merrill has proposed that there is a set of five prescriptive instructional principles (“First Principles”) that enhance the quality of instruction across all situations (Merrill, 2007,

2009). Those principles have to do with task-centeredness, activation, demonstration, application, and integration. Briefly, they are as follows:

Task-Centered Principle

- Instruction should use a *task-centered* instructional strategy.
- Instruction should use a *progression* of increasingly complex whole tasks.

Demonstration Principle

- Instruction should provide a demonstration of the skill. The demonstration should be *consistent* with the type of skill or component skill: kinds-of, how-to, or what-happens.
- Instruction should provide *guidance* that relates the demonstration to generalities.
- Instruction should engage learners in *peer-discussion* and *peer-demonstration*.
- Instruction should allow learners to observe the demonstration through *media* that are appropriate to the content.

Application Principle

- Instruction should have the learner apply the skill. The application should be *consistent* with the type of skill or component skill: kinds-of, how-to, and what-happens.
- Instruction should provide intrinsic or corrective *feedback*.
- Instruction should provide *coaching*, which should be gradually withdrawn to enhance application.
- Instruction should engage learners in *peer-collaboration*.

Activation Principle

- Instruction should activate relevant cognitive structures in learners by having them recall, describe, or demonstrate relevant *prior knowledge* or experience.
- Instruction should have learners *share* previous experience with each other.
- Instruction should have learners recall or acquire a *structure* for organizing new knowledge.

Integration Principle

- Instruction should integrate new knowledge into learners' cognitive structures by having them *reflect* on, discuss, or defend new knowledge or skills.
- Instruction should engage learners in *peer-critique*.
- Instruction should have learners create, invent, or explore *personal ways to use* their new knowledge or skill.
- Instruction should have learners *publicly demonstrate* their new knowledge or skill.

While these principles might apply universally to all instructional situations (situations involving aided learning), the specific methods by which each principle is implemented must vary from one situation to another for instruction to be of high quality (Reigeluth & Carr-Chellman, 2009a). For example, for "Instruction should use a *task-centered* instructional strategy," the nature of the task-centered strategy may need to vary considerably from one situation to another. Similarly, for "Instruction should provide coaching," the nature of the coaching should vary considerably from one situation to another. So let's explore these variations, or "situationalities."

Situational Methods of Instruction

Principles and methods of instruction can be described on many levels of precision (Reigeluth & Carr-Chellman, 2009b). For example, on the least precise level, Merrill states that instruction should provide coaching. On a highly precise level, one could state, "when teaching a procedure, if a learner skips a step during a performance of the procedure, the learner should be reminded of the step by asking the learner a question that prompts the learner to recognize the omission." When we provide more precision in a principle or method of instruction, we usually find

that it needs to be different for different situations. Reigeluth (1999a) referred to the contextual factors that influence the effects of methods as “situationalities.”

The challenge for instructional agents (and therefore instructional theorists) is to identify which situationalities are important for selecting each method. Furthermore, methods may be combined into a “package deal” that is made up of an interrelated and interdependent set of methods, in which case we need to identify which situationalities are important for selecting each “package” (set of methods).

Reigeluth and Carr-Chellman (2009a) propose that there are two major types of situationalities that call for fundamentally different sets of methods:

1. Situationalities based on different approaches to instruction (means), such as:
 - 1.1. Role play
 - 1.2. Synectics
 - 1.3. Mastery learning
 - 1.4. Direct instruction
 - 1.5. Discussion
 - 1.6. Conflict resolution
 - 1.7. Peer learning
 - 1.8. Experiential learning
 - 1.9. Problem-based learning
 - 1.10. Simulation-based learning
2. Situationalities based on different learning outcomes (ends), such as:
 - 2.1. Knowledge
 - 2.2. Comprehension
 - 2.3. Application
 - 2.4. Analysis
 - 2.5. Synthesis
 - 2.6. Evaluation
 - 2.7. Affective development
 - 2.8. Integrated learning (involves integration of subject areas, as in thematic learning, problem-based learning, task-based learning, and much project-based learning).

Reigeluth and Carr-Chellman (2009c) describe the current, generally agreed-upon knowledge (“common knowledge base”) for nine of those sets of methods.

In the remainder of this chapter, I provide a more holistic vision of what the post-industrial paradigm of instruction might be like. I start with “core ideas,” followed by one possible vision, and finally roles of key players for this paradigm of instruction.

Core Ideas for the Post-industrial Paradigm of Instruction

The following are some core ideas for the post-industrial paradigm of instruction. They are presented as dichotomies to contrast them with the core ideas that characterize the industrial-age paradigm of instruction, but it should be understood that dichotomies are usually false, and post-industrial thinking is characterized more by “both-and” than “either-or”.

Learning-focused vs. sorting focused. This core idea was discussed earlier in this chapter. All the following core ideas are chosen to support this central idea.

Learner-centered vs. teacher-centered instruction. McCombs and Whisler (1997) define learner centered as:

The perspective that couples a focus on individual learners (their heredity, experiences, perspectives, backgrounds, talents, interests, capacities, and needs) with a focus on learning (the best available knowledge about learning and how it occurs and about teaching practices that are most effective in promoting the highest levels of motivation, learning, and achievement for all learners). (p. 9)

To this I would add that the instructional methods are largely tailored to each learner and carried out by the learner rather than by the teacher. Learners also play a larger role in directing their own learning, including reflection on and in learning.

Learning by doing vs. teacher presenting. Most of a student's time is spent performing authentic tasks (e.g., problem-based learning, project-based learning, performance-based learning), rather than listening to a teacher. Some talk about such task-based instruction in terms of the "student as worker" and the "teacher as manager," rather than the teacher as worker (Schlechty, 2002). Others call this the teacher as "guide on the side" rather than "sage on the stage." Some call it the constructivist approach to learning. The bottom line is that task-based instruction is active, learner-centered, and largely self-directed.

Attainment-based vs. time-based progress. Each student moves on to a new topic or competency when she or he has attained a standard of achievement, rather than when a certain amount of time has passed. A student is not forced to move on before attaining the standard and is allowed to move on as soon as the standard is attained. This avoids the huge waste of student time that exists in the industrial-age paradigm of education. This is a standards-based approach to education in the truest sense of the term. Mastery learning (Block, 1971; Bloom, 1968, 1981) and the Personalized System of Instruction (Keller, 1968) were early implementations of this core idea.

Customized vs. standardized instruction. The new paradigm offers customized rather than standardized learning experiences. This goes beyond attainment-based progress (which is customized pacing) to include *customized content* and *customized methods*. While there is a core of knowledge, skills, and attitudes that all students learn, there is considerable time for students to cultivate their particular talents, interests, and strengths. Also, Howard Gardner has shown that students differ in their profile of seven major kinds of intelligence and has argued that a student's strongest intelligences can be used most effectively as "entry points" for learning knowledge, skills, and attitudes (Gardner, 1999). Methods are also customized for some other kinds of learner characteristics and preferences. *Personal learning plans* (different in important ways from IEPs¹) and learning contracts are valuable tools for customizing learning.

Criterion-referenced vs. norm-referenced testing. The two purposes of student assessment in the new paradigm are to guide student learning (formative assessment) and to certify student attainments (summative assessment). Norm-referenced assessment (another form of summative assessment) is no longer used. *Formative assessment* entails providing each student with immediate feedback on performance, with hints or other forms of guidance to help the student learn from mistakes. *Summative assessment* entails certifying when a student has reached the standard for any given attainment.

Collaborative vs. individual. In the workplace, most knowledge work is done in teams. Collaboration is important in work life, civic life, and family life. Therefore, students need experience in collaborating on small teams. Team-based learning on a task provides an excellent opportunity for students to develop their collaboration skills, but it also provides a valuable opportunity for students to learn from each other. Furthermore, it is strongly supported by social constructivism (Palincsar, 1998; Scardemalia & Bereiter, 1996).

Enjoyable vs. unpleasant. In the age of knowledge work, lifelong learning is essential to our citizens' quality of life and to the health of our communities. Lifelong learning is greatly enhanced by love of learning. The industrial-age paradigm of education makes many students dislike learning, and it has turned the culture of our schools into one that devalues and derides students who excel in learning. That mindset and culture work against lifelong learning. Although lifelong learning has, for many years, been a buzzword in education, the industrial-age paradigm

¹ Individualized Education Plans or Individualized Education Programs, used mainly in special education.

inherently impedes it. The post-industrial paradigm changes this by instilling a love of learning in students. This requires switching from extrinsic to *intrinsic motivation*, such as switching from motivation based on grades that compare students' performances to motivation based on the satisfaction of completing a valued task. It also requires learning through authentic, engaging tasks, as is typically done in problem-based and project-based learning.

These core ideas represent essential characteristics of post-industrial educational and training systems – ideas on a level of universality for post-industrial instruction as Merrill's First Principles of instruction are for all paradigms of instruction. However, the ways in which they are implemented are likely to vary considerably from one educational system to another. The following is a vision of instruction for one possible implementation of these core ideas.

A Vision of the Post-industrial Paradigm of Instruction

Task and instructional spaces. Think of the learning environment as comprised of two "spaces": the task space and the instructional space. In the task space, the students are introduced to an authentic problem or project, usually in small teams. They work on the task until they encounter a learning gap (knowledge, skills, understandings, values, attitudes, dispositions, etc.). At that point, each student leaves the task space and enters their personalized instructional space to work on acquiring what they are missing. For example, research shows that learning a skill is facilitated to the extent that instruction *tells* the students how to do it, *shows* them how to do it for diverse situations, and gives them *practice* with immediate feedback, again for diverse situations, so the students learn to generalize or transfer the skill to the range of situations they will encounter in the real world. Each student continues to practice until she or he reaches the standard of mastery for the skill. Upon reaching the standard, the student then returns to the "task space" to apply what he or she has learned to the task and continue working on it until the next learning gap is encountered, and this learning cycle is repeated. Well-validated instructional theories have been developed to offer guidance for the design of both the task space and the instructional space (see Reigeluth, 1999b; Reigeluth & Carr-Chellman, 2009c, for examples).

Team and individual assessment. One of the problems with task-based learning as it is often implemented is that students are assessed on the quality of the team "product." This gives you no idea as to who has acquired which competencies. It also does not give you any indication of each student's ability to transfer those competencies to other situations where they may be needed. Team assessment is important, but you also need individual assessment, and the instructional space offers an excellent opportunity to do this. Like the task space, the instructional space is performance oriented. The practice opportunities (offered primarily in a computer simulation for immediate, customized feedback and authenticity) continue to be offered to a student until the student reaches the criterion for number of correct performances in a row that is required by the standard. When automatization of a skill (Anderson, 1996) is important, there is also a criterion for speed of performance that must be met. In this manner, student assessment is fully integrated into the instruction, and there is no waste of time in conducting a separate assessment. Furthermore, the assessment assures that each student has attained the standard for the full range of situations in which the competency will be needed.

Instructional strategies for the task space. There is much validated guidance for the design of the task space, including universal and situational principles for the task space (see Savery, 2009, for a comprehensive summary). They include guidance for selecting a good task at the right level of complexity, forming small groups, self-directed learning, what the teacher should do, how debriefing should be done, and more. Computer-based simulations are often highly effective for creating and supporting the task environment, but the task space could be comprised entirely of places, objects, and people in the real world, or it could be a combination of computer simulation and real-world environments.

Instructional strategies for the instructional space. Selection of instructional strategies here is primarily based on the type of learning (ends of instruction) involved (see Unit 3 in Reigeluth & Carr-Chellman, 2009c). For memorization, drill and practice is most effective (Salisbury, 1990). For skill application, tutorials with generality, examples, practice, and immediate feedback are most effective (Romiszowski, 2009). For conceptual understanding, connecting new concepts to existing concepts in a student's cognitive structures requires the use of such methods as analogies, context (advance organizers), comparison and contrast, analysis of parts and kinds, and various other techniques based on the dimensions of understanding required (Reigeluth, 1983). For theoretical understanding, causal relationships are best learned through exploring causes (explanation), effects (prediction), and solutions (problem solving); and natural processes are best learned through description of the sequence of events in the natural process (Reigeluth & Schwartz, 1989). These sorts of instructional strategies have been well researched for their effectiveness, efficiency, and appeal. And they are often best implemented through computer-based tutorials, simulations, and games.

Again, this is but one vision of the post-industrial paradigm of instruction. I encourage you to try to think of additional visions that implement the core ideas of the post-industrial era. To do so, it may be helpful to consider the ways that roles are likely to change in the new paradigm of instruction.

Key Roles in the Post-industrial Paradigm of Instruction²

New roles for teachers

The teacher's role has changed dramatically in the new paradigm of instruction from the "sage on the stage" to the "guide on the side." I currently see three major roles involved in being a guide. First, the teacher is a *designer of student work* (Schlechty, 2002). The student work includes that which is done in both the task space and the instructional space. Second, the teacher is a *facilitator of the learning process*. This includes helping to develop a personal learning plan, coaching or scaffolding the student's learning when appropriate, facilitating discussion and reflection, and arranging availability of various human and material resources. Third, and perhaps most important in the public education sector, the teacher is a *caring mentor*, a person who is concerned with the full, well-rounded development of the student. These are only three of the most important new roles that teachers serve, but not all teachers need perform all the roles. Different kinds of teachers with different kinds and levels of training and expertise are involved (including students as teachers – see next section).

New roles for students

First, learning is an active process. The student must exert effort to learn. The teacher cannot do it for the student. This is why Schlechty (2002) characterizes the new paradigm as one in which *the student is the worker*, and that the teacher is the designer of the student's work.

Second, to prepare the student for lifelong learning, the teacher helps each student to become a *self-directed and self-motivated learner*. Students are self-motivated to learn when they first go to school. The industrial-age paradigm systematically destroys that self-motivation by removing all self-direction and giving students boring work that is not relevant to their lives. In contrast, the post-industrial system is designed to nurture self-motivation through self-direction and active learning. Student motivation is key to educational productivity and helping students to realize their potential. It also greatly reduces discipline problems, drug use, and much more.

Third, it is often said that the best way to learn something is to *teach* it. Students are perhaps the most under-utilized resource in our school systems. Furthermore, someone who has just learned something is often better at helping someone else learn it than is someone who learned

² Much of this section is based on Reigeluth (2009) and Reigeluth, Watson, S., Watson, W., Dutta, Chen, and Powell (2008).

it long ago. In addition to older students teaching slightly younger ones, peers can learn from each other in collaborative projects, and they can also serve as peer tutors. Therefore, new student roles include student as worker, self-directed learner, and teacher.

New roles for technology

I currently see four main roles for technology to make the new paradigm of instruction feasible and cost-effective (Reigeluth & Carr-Chellman, 2009c; Reigeluth et al., 2008). Each of these is described next for the public education sector, but the roles are equally relevant in higher education, corporate training, military training, and education and training in other contexts.

Record keeping for student learning. Attainment-based student progress requires a personal record of attainments for each student. Technology saves teachers huge amounts of time for this. In this role, technology replaces the current report card, and it has three parts. First, it has a *Standards Inventory* that contains both required educational standards (national, state, and local) and optional educational standards for access by the teacher, student, and parents. Domain Theory (Bunderson, Wiley, & McBride, 2009) is highly instrumental for designing this technological tool. It presents a list of attainments that should or can be learned, along with levels or standards or criteria at which each can be learned. Second, it has a *Personal Attainments Inventory* that contains a record of what each student knows. In essence, it maps each student's progress on the attainments listed in the Standards Inventory (and perhaps some that are not yet listed there). It shows when each attainment was reached, which ones are required, what the next required attainments are in each area, and links to evidence of each attainment (in the form of summary data and/or original artifacts). Third, it has a *Personal Characteristics Inventory* that keeps track of each student's characteristics that influence learning, such as learning styles, profile of multiple intelligences, student interests, and major life events (Reigeluth & Carr-Chellman, 2009c; Reigeluth et al., 2008).

Planning for student learning. The personal learning plan, or contract, could also be very difficult for teachers to develop for all of their students. Here, again, is a role that technology is ideally suited to play. It helps the student, parents, and teacher to (a) decide on *long-term goals*; (b) identify the full range of attainments that are presently *within reach* for the student; (c) select from those options the ones that the student wants to pursue now (*short-term goals*), based on requirements, long-term goals, interests, opportunities, etc.; (d) identify *tasks* for attaining the short-term goals; (e) identify *other students* who are interested in doing the same tasks (if collaboration is desired or needed); (f) specify the roles that the teacher, parent, and any others might play in supporting the student in learning from the task; and (g) develop a contract that specifies goals, tasks, teams, parent and teacher roles, and the deadline for each task (Reigeluth et al., 2008).

Instruction for student learning. Trying to "instruct" 25 students who are learning different things at any point in time could be very difficult for teachers – if they had to be the instructional agent all the time, as is typical in the industrial-age paradigm. However, technology can introduce the task to a student (or small team) in the task space, provide instructional tools (such as simulations, tutorials, drill & practice, research tools, communication tools, and learning objects) in the instructional space to support learning during the task, provide tools for monitoring and supporting student progress on the task, and even provide tools to help teachers and others develop new tasks and instructional tools. Instructional theory is extremely important to guide the design of these tools (Reigeluth et al., 2008).

Assessment for (and of) student learning. Once more, conducting formative and summative assessments of students could be a nightmare for teachers, since students are not all taking a given test at the same time. And once again, technology can offer great relief. First, as mentioned earlier, assessment is *integrated with instruction*. The plentiful performance opportunities that are used to cultivate competencies are used for both formative and summative assessments. Second, the assessments present *authentic tasks* on which the students demonstrate

their knowledge, understanding, and skill. Third, whether in a simulation or a tutorial or drill and practice, the technology is designed to evaluate whether or not the criterion was met on each performance and to provide *formative feedback* to the student immediately for the greatest impact. When the criteria for successful performance have been met on x out of the last y performances, the *summative assessment* is complete and the corresponding attainment is automatically checked off in the student's personal inventory of attainments. In the few cases where the technology cannot assess the performance, an observer has a handheld device with a rubric for assessment and personally provides the immediate feedback on student performances. The information from the handheld device is uploaded into the computer system, where it is placed in the student's personal inventory. Finally, technology provides tools to help teachers develop assessments and link them to the standards (Reigeluth et al., 2008).

Note that these four roles or functions are seamlessly integrated (Reigeluth & Carr-Chellman, 2009c). The record-keeping tool provides information automatically for the planning tool. The planning tool identifies instructional tools that are available. The assessment tool is integrated into the instructional tool. And the assessment tool feeds information automatically into the record-keeping tool (Reigeluth et al., 2008; Watson, Lee, & Reigeluth, 2007). In our earlier work we used the term "Learning Management System" for this comprehensive, personalized, integrated tool, but that term is often used to describe course management systems. Therefore, to avoid confusion, we have decided to call this the Personalized Integrated Educational System (PIES).

Also, please note that there are many other roles for the PIES (Reigeluth et al., 2008). These "secondary" roles include communications (email, blogs, web sites, discussion boards, wikis, whiteboards, instant messaging, podcasts, videocasts, etc.), PIES administration (offering access to information and authority to input information based on role and information type), general student data (student's address, parent/guardian information, mentor-teacher and school, student's location/attendance, health information), school personnel information (address, certifications and awards, location, assigned students, tools authored, student evaluations that they have performed, teacher professional development plan and records, repository of teaching tools, awards their students have received), and more.

It should be apparent that technology will play a crucial role in the success of the post-industrial paradigm of education. It will enable a quantum improvement in student learning, and likely at a lower cost per student per year than in the current industrial-age paradigm. Just as the electronic spreadsheet made the accountant's job quicker, easier, less expensive, and more enjoyable, so the PIES described here will make the teacher's job quicker, easier, less expensive, and more enjoyable. But instructional theory is sorely needed for technology to realize its potential contribution.

Conclusion

While much instructional theory has been generated to guide the design of the new paradigm of instruction, much remains to be learned. We need to learn how to better address the strong emotional basis of learning (Greenspan, 1997), foster emotional and social development, and promote the development of positive attitudes, values, morals, and ethics, among other things. It is my hope that you, the reader, will rise to the challenge and help further advance the knowledge we need to greatly improve our ability to help every student reach his or her potential.

Key Principles

1. In the post-industrial world, we need to transform most of our educational and training systems from ones that are designed for sorting students to ones that are designed to maximize learning – from ones in which student progress is time-based to ones in which it is attainment-based. This transformation will require advances in both instructional theory and instructional technology.

2. Merrill's First Principles (task-centeredness, activation, demonstration, application, and integration) provide a good, albeit general, summary of the most important features for high quality instruction. For more detailed guidance, we must look at the "situationalities" that determine the ways in which instruction should differ from one situation to another. Research to date indicates that these are based primarily on differing means (different approaches to instruction) and differing ends (different learning outcomes or kinds of learning).
3. It is helpful to look at a holistic vision of what the new paradigm of instruction might be like. I proposed that it will be characterized by the following core ideas: learning-focused, learner-centered, learning by doing, attainment-based progress, customized instruction, criterion-referenced testing, collaborative learning, and enjoyable learning.
4. I have proposed a vision of instruction for one possible implementation of these core ideas. It describes: task and instructional spaces, team and individual assessment, instructional strategies for the task space, and instructional strategies for the instructional space.
5. As part of the new paradigm of instruction, new roles for teachers include: designer of student work, facilitator of the learning process, and caring mentor; and new roles for students include: worker, self-directed learner, and teacher.
6. Under the new paradigm, technology will fill four major roles: record keeping for student learning, planning for student learning, providing instruction for student learning, and assessing for student learning.

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