The real Janus (Ianua) may have been an ancient king from Greece who encouraged his (adopted or conquered) people of Latium (now, a part of Italy) to acquire the skills of agriculture, industry, art, and religion. Over time, the Roman myth arose of a god who brought all things into the world, from the seasons to the ways of civilization. This god of gates and doorways opened and closed all things, including the gates of heaven. Janus was symbolized as a two-faced god, one face being that of a youth, the other of an elder. In his left hand, the youth held a key to open the gates. In his right, the elder held a scepter to master all comings and goings.

We find here an allegory to the apprentice-expert continuum in the acquisition of knowledge, and so we name a principle of human-centered computing after Janus. This principle deals with the distinction between performance and training, and its implications for intelligent technologies.

Training versus performance

We know from psychological research that performance and training are related in strong but complex ways. For instance, accelerated training doesn’t always transfer to the operational context. Because of traditions including the separation of disciplines (for example, instructional design in education versus control systems design in cognitive engineering), there is a widespread distinction between training systems (TSs) and performance support systems (PSSs).

A moment’s reflection reveals that this distinction runs counter to empirical fact. Consequently, it’s misleading, even potentially dangerous. As we can deduce from the psychology of learning, TS versus PSS forces an unnatural separation:

- To train, you must have opportunities to perform. In fact, trainers and educators—indeed, all of us—take for granted the idea that learning must involve a performance component. In introductory biology, we dissect frogs. In learning command-and-control skills, warfighters practice in simulations. In general, current training systems always include performance and practice components. If a training system doesn’t support practice, it’s a good bet that the training won’t transfer into the operational context.

- It’s an empirical fact that for people to perform in complex sociotechnical contexts, they must continually learn new things. Such work contexts are always moving targets (new software, new task goals, and so on), so learning on the job is both inevitable and necessary. If a PSS system doesn’t promote learning, or at least doesn’t make learning any easier, then it won’t lead to long-term performance enhancement. Furthermore, a defining aspect of expertise is the intrinsic motivation to learn and acquire new skills.

When training works and doesn’t work

It is often assumed that aids and instructional materials that accelerate and maximize performance during training will result in optimized performance when the trainee is in the operational context. However, training in which performance is maximized (especially what’s called “just in time” training) can actually fail to transfer when the trainee later confronts such things as multitasking, distractions, cascade failures, loss of data, and other factors of actual work contexts that often are sanitized out of the training context. Conversely, training that allows for learner error and
then provides feedback based on domain knowledge—even if this extends the training time—can lead to better performance when the trainee is later confronted with tasks in the operational context. Neither a TS nor a traditional PSS on its own can accomplish this fit between human, machine, and context.

In his Unified Theories of Cognition, Allen Newell argued that people learn continuously, so in his SOAR cognitive architecture, he modeled learning as a result of problem solving, implying performance. Thus, learning and problem solving (or performance) are necessarily intertwined.

One conclusion is possible.

**The Janus Principle**

We propose the following Janus Principle:

Human-centered systems do not force a separation between learning and performance. They integrate them.

We know this is possible. Here are two examples.

**Example 1: Oceanography**

The US Navy’s Naval Air Warfare Center sponsored the creation of a software and display tool to help train oceanographers and aerographers about sonar oceanography. The Interactive Multisensor Analysis Trainer (www.onr.navy.mil/sci_tech/personnel/cnb_sci/342/majapps/imat/imat5.htm) depicts a volume of ocean in horizontal view, with a ship at its surface. Sonar beams appear as ray tracings. Within the volume of water are colorized layers, representing different layers of temperature and salinity. These cause deflections in sonar-beam paths, which the learner can see after manipulating layer parameters.

The group that was trained using this system found it useful as a training aid and later as a performance aid. Indeed, they took it with them when they deployed to the fleet and were able to use it to visualize actual conditions. So, the system worked as a PSS. In this case, the training aid was well designed as a TS, so it also supported performance—and interestingly enough, it was the users, not the designers, who apparently discovered this.

**Example 2: Satellite Systems Operations**

The Air Force Research Lab, Human Effectiveness Directorate, is sponsoring the development of a PSS to help satellite operators maintain healthy satellites for the Space Tracking and Surveillance System. The tool, called the Adaptive Decision Enabling Performance Tracking toolkit, is under development. The ADEPT design process has been iterative and involved the users, and it revealed opportunities to support training by having the tool used in an operational context. ADEPT’s overarching theme is to provide “one-stop shopping” for all the information that satellite operators might need while performing their work. The tool offers a usable alphanumeric data display (leveraging useful characteristics from the previous software system’s data display), electronic availability and storage of forms, chat access to other team members, a visualization tool of the remote satellite environment, and electronic access to reference materials. To ensure a useful and usable tool, the developers identified and built these performance support functions in collaboration with subject matter experts.

One of the performance support functions is a visualization tool that helps satellite operators understand the alphanumeric data they receive by comparing it with a real-time simulation of the remote environment, updated by live data. For instance, the tool facilitates recognition of an anomalous situation: if a satellite enters into eclipse before the appropriate preparation procedure is administered, alarms sound. In this case, an operator can access the visualization tool and recognize, for instance, that the satellite is safe and the alarms were simply not prevented before the expected eclipse occurred.

One of the participating experts asserted something that psychologists would underscore: The more proactive and curious learners perform better. The visualization tool lets operators explore prior and upcoming situations by using rewind and fast-forward buttons. Thus, the tool enhances performance, as intended, but it also supports performance by enabling operators to improve their abilities and acquire expertise.

**Merging training and performance**

What general guidance is there for crafting systems that merge TS and PSS?

**Cognitive apprenticeship**

The traditional apprenticeship model emphasizes a special form of situational experience. Apprentices start with small, peripheral tasks but can see, by observing the full scope of the work, where their individual efforts fit. As their experience grows, apprentices are given opportunities for involvement in more central, more significant, and more critical activities. Such active and responsible involvement in an authentic environment facilitates learning.

In reality, not all apprenticeships promote active involvement in meaningful tasks or allow steady progression to more central work activities. Jean Lave and Etienne Wenger noted the case of butchers’ apprentices in a large supermarket who were separated from the experienced butchers. These apprentices had few opportunities to assist with progressively more central tasks or get legitimate access to the experienced butchers or their work. In addition, much of the formal instruction was outdated and therefore irrelevant, because butchers who no longer worked actively in the trade directed that part of the learning process.

We can apply the apprenticeship model to intellectual skills. Barbara Rogoff coined the term cognitive apprentice to make the point that development proceeds through appropriation of the intellectual tools and skills of the surrounding cultural community. Skills and knowledge acquired through this process are more likely to be applicable to real situations. There should be fewer occurrences of inert or partitioned knowledge that cannot be applied successfully to situational problems. Cognitive apprenticeship involves activity that extends students slightly beyond their level of competence and engages a gradual transition from peripheral to central activities.

People acquire expertise by abstracting and relating lessons from individual experiences, but a training program should use an explicit organizing framework to connect
and give meaning to specific experiences. Instead of students encountering a host of seemingly disparate facts, they’d discover and integrate facts as they explored the problem domain’s structure. The learning challenge becomes one of discovery and integration versus one of memorization.

Some may feel that course material should be structured to discourage error, but the performance of errors in a safe context helps students learn to recognize the consequences of error as they unfold and to practice error recovery.

Error feedback

The traditional perspective on error feedback is straightforward: We inform a student who errs as soon as possible about the error and possibly how to correct it. If the error persists, we might drill the student in the correct behavioral pattern. However, the treatment of error in the training context requires a more thoughtful approach.

Experimental psychologists and human factors professionals have known for some time that summarized, delayed, and adaptive feedback is more effective for learning than just saying that the learner erred and then saying it must provide a slight delay between the error and the feedback; and the feedback must empower the learner. Rather than just saying that the learner erred and how the learner erred, it must provide a concrete plan for how the learner can engage in corrective action.

This is difficult for the trainer to implement because errors rarely provide direct evidence of the nature of the underlying knowledge gap or skill deficiency. Errors tell us that something is going wrong, but they don’t inform us directly of the nature of the problem. For example, consider the problem of a weak and inaccurate tennis server. The mechanistic approach would show each serve’s strength and accuracy, implying that the server must strike the ball more accurately and with greater power. That, of course, is entirely consistent with the laws of physics, but it’s not diagnostic. It doesn’t tell the server how to correct the problem. Any direct attempt to generate more power will result in less accuracy, and vice versa. Worse, a direct attempt to generate more power will induce strain and eventually lend to injury. An experienced coach, in helping the server improve, will talk of body rotation, wrist snap, knee bend, and timing, which are properties of coordination. More generally, the nature of an error, taken by itself, rarely informs us directly about the required correction.

Human-centered intelligent systems merge training and performance. They must be demonstrably usable and useful in a training mode as well as a performance mode. This requirement is one more reason why the development of intelligent systems mandates full involvement of cognitive engineers.

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