Centralized vs. decentralized computer assisted instruction systems

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INTRODUCTION

This discussion deals with a qualitative comparison of two configuration alternatives in the design and implementation of a Computer Assisted Instruction (CAI) System. With CAI in its infancy and in a necessarily experimental stage, there is little available data upon which to develop quantitative support for the opinions expressed herein. In this respect, CAI bears a definite kinship with “time-sharing” systems. It can in fact be strongly argued that CAI is essentially a special form of the “time-sharing” system. At this stage of CAI development we are still dealing with “guesstimates” of mass storage requirements for course material, quantity of course material required to reside “on-line” at a given time and tolerable response times in the interaction among student, student terminal, and terminal controllers.

This discussion assumes that as a result of a procurement, CAI systems are to be installed in more than one school and that cost/capability tradeoffs are factors in addition to satisfaction of specification requirements.

Two important advantages accrue to a “centralized system” as opposed to a “decentralized system”: these are in the areas of mass storage facilities and in the flexibility and potential afforded by the “naturally” formed communications network.

Assumptions and definitions

The key assumption and definitions for this discussion are now stated.

It is assumed that a specification or requirement calls for the installation of one or more complexes of student terminals; i.e., installation in one or more geographically and/or physically separated schools. Further, if the specification calls for only one initial installation, then it is assumed that there exists a requirement for expansion capability of the system to provide for installation of similar systems in additional schools.

The collection of student terminals and associated equipment contained within a single school is referred to as a cluster.

A centralized system (Figure 1) is one in which cluster operation is dependent to a lesser or greater degree, but nevertheless dependent, upon hardware and software residing in central facilities not part of the cluster, but which are accessible to and shared by more than one cluster. In the centralized system, operation over extended time periods requires the availability of, and participation by, the central facility.

A decentralized system (Figure 2) is one in which each cluster is autonomous and independent. All hardware and software necessary for operation is available, and readily accessible from, within the cluster complex. In the decentralized system, operation over extended periods is dependent only upon the availability of resources which are part of the cluster complex.

Succeeding discussion will reference such items as cluster, cluster processor, central, central processor and so forth. Such references mean, in accordance

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From the collection of the Computer History Museum (www.computerhistory.org)
with the preceding definitions, the resources at a single school, the digital processor which is part of the cluster, etc.

**"N" INDEPENDENT CLUSTER SYSTEMS**

![Diagram of Independent Cluster Systems](https://www.computerhistory.org)

**Functions**

In either configuration the primary functions to be performed include but are not limited to: presentation of instructional material to the student, testing of the student, reaction to student responses, presentation of remedial or enrichment material as a function of instructional material to the student, testing of the student response, construction and/or modification of course material, require the use of mass storage facilities. Some of this storage must be rapid, random access in order to satisfy response time requirements as dictated by both student reaction time and the characteristics of CRT-type student terminals.

Many of the functions, but especially the presentation of course material, require the use of mass storage facilities. Some of this storage must be rapid, random access in order to satisfy response time requirements as dictated by both student reaction time and the characteristics of CRT-type student terminals.

The storage advantage in the centralized system

The centralized system approach can lead to economies in the allocation of mass storage facilities especially when course material is common to more than one cluster. In a centralized system each cluster requires only that sufficient mass storage capacity be available at the cluster location to maintain its immediate needs of lesson presentation as dictated by student and student-terminal characteristics. The cluster calls for additional material to be transmitted from the central prior to actual need and in accordance with daily schedules prepared in advance. At the central facilities, sufficient storage is implemented through a combination of serial access type storage (tapes), and random access storage (drums, discs), to maintain the current curriculum library. At the cluster, the quantity of storage on-line is sufficient to supply course material to n terminals for one, two, or more hours. The course material may be stored as "lesson segments" of quarter hour, half hour or other duration for each terminal. An analysis leading to the allocation of storage facilities may consider the effects of employing a console usage discipline incorporating combinations of time ordering, console ordering, and student ordering. The designer has a choice varying between two extremes:

(a) Complete freedom of access which permits any student to access any terminal at any time for any lesson in the curricula library. It is apparent that this maximizes both flexibility and local storage requirements.

(b) Restricted access which requires students to access the terminals at a given time for a given lesson. This approach tends to minimize both local storage requirements and flexibility.

It should be noted that in the centralized configuration we are not advocating the complete elimination of mass storage facilities at the cluster; to do so would place the cluster in a position of almost total dependence upon the central facility. The malfunction of the central or of the communication link from central to cluster would then be very shortly followed by a cluster's inability to support required operations. The capacity and type of storage to be located at the cluster becomes a function of central facility reliability and availability as determined by MTFs and MTRs and as defined by a predetermined minimum capability required at the cluster.

Complete decentralized operation, (independent and autonomous cluster operation), would require storage capacities, at each cluster location, capable of housing the entire curriculum library and data base through some combination of storage media; the cost for such capacity and capability is subject to multiplication in the presence of n clusters. Similar cost multiplication might be incurred in the decentralized system for peripheral devices (printers, punches) which under the centralized system are shared by the clusters.

What is suggested is a deliberate attempt to minimize the cost for storage while at the same time retaining capability for continuing operations at the cluster for a given length of time in the event of central unavailability.

**Expansion of system facilities**

The advantages of centralized shared storage facilities will become more pronounced as the number of clusters increase; the cost for the storage is now "shared" by a larger number of users. At some point, however, data transfer facilities, communication interfaces and central processor capabilities may become limited and the addition of clusters will require the expansion of central facilities resulting in a tem-
porary increase of the shared cost until more clusters are added. In considering the centralized configuration, items not to be discounted, but not dwelled upon here, are floor space and power consumption advantages for the cluster with the former almost always at a premium in the modern school.

The expansibility of a cluster operation from an “n” to an “n + m” terminal configuration is dependent upon “processor capacity” being expended in the operation of n terminals. If certain background programs (e.g. statistics, student records) are being run concurrently with terminal operation, then transfer of non-essential programs to the central processor allows the cluster processor function to approach pure student terminal operation. Thus, whatever the unused processor capacity is, virtually all of it can be devoted to terminal expansion subject to physical limits of hardware capability, storage, floor space and power.

Some negative factors

It is apparent that this conservation of storage and corresponding cost savings does not come about completely free of “negative” factors. Part of the price for the centralized system and its attendant advantages is an expenditure not encountered with the “free standing” clusters of the decentralized system. There is the matter of recurring monthly charges for the high-speed data lines from the central to each of the clusters. These data lines will be required to operate in the 2400 bps range; they must be leased from a common carrier and they are not inexpensive. Further, the implementation of even a small amount of rapid, random access mass storage at the cluster carries a cost factor which is not linear with capacity: namely the cost of controllers and interface equipment can be inordinate when amortized over small storage capacities. Careful consideration must be given to actual requirements with respect to transfer rates, access times, formats, and response times.

The centralized configuration introduces additional elements of complexity into the computer programs which are an integral part of the system. At the cluster the “executive” routine must now include provision for the communications between cluster and central; part of this routine must address itself to “check functions” to ensure the validity and integrity of transmitted information. The computer-to-computer interface calls for additional hardware. Both hardware and software must be incorporated in a manner which ensures timely transfer of data without degrading the primary function of the system; that is, the interaction between the student and his terminal. The incorporation of the control and bookkeeping routines necessary for the cluster/central interplay must be programmed so that from his position at the terminal, the student, or the instructor, or the curriculum generator believes that the machine is his and his alone.

Availability considerations

While the presence of a central facility permits transfer of considerable functional responsibility (data processing, statistics, curriculum storage, etc.), from cluster to central, care must be taken to ensure that the cluster operation does not become totally dependent upon central availability. Sufficient hardware and software capability must be retained in the cluster in order to establish a satisfactorily high probability that the primary function of providing instruction to students can be carried on for a given minimum time interval subsequent to the loss of central availability. Based on reliability characteristics (MTBF, MTR, etc.), of the central facility and communications links, enough capability should be present at the cluster so that operations can be sustained for a period of time during which a central failure can be detected, isolated and corrected and the central again made available to the cluster before the cluster has run “dry”; that is, before the cluster has run out of useful material. Tradeoffs to be considered here include consideration of hardware redundancy at the central facility versus increased facilities at the cluster. In configuring the system and assigning functions, the designer must continually keep in mind that a failure at the central potentially affects all clusters. Again, the number of clusters becomes an influencing factor; any cost incurred at the cluster level is subject to multiplication.

Other advantages

The communications network

The centralized system configuration presents additional, perhaps more subtle, important potential advantages which are derived from the fact that the presence of a central processor together with high-speed data links to and from the clusters provides the key elements of a real-time communications system among the clusters. The central processor may be viewed as the communications hub or message switch in this configuration.

In this view, we are not thinking of the wholesale exchange of administrative type messages but a rather special communications net which carries “traffic” pertinent to the primary application. The potential thus exists, not present in the decentralized configuration, for a dynamic interaction among the clusters or schools. While the techniques of learning through
intercluster dynamics are not yet defined, the future establishment of group learning sessions with participants in various separated locations communicating with each other will be facilitated by the existence of the communications network within the centralized configuration. As the requirements and techniques for group dynamics through cluster interaction are evolved and understood, implementation through the addition of necessary programs and equipment will be more easily accomplished.

Additional advantages potentially available through the communications network include the following items which I will mention briefly. I believe that others meritsing consideration will occur to you.

- The central processor can return to each cluster the statistical results of curricula, presented at other clusters. Comparisons and correlations can be made immediately available to authorized personnel. An extension could include the presentation of identical curricula or tests to geographically separated groups on a “real-time” basis with immediate data collection and distribution of results.
- The curriculum author at one location can “dry run” his material against an author or group at another location. Criticism, suggestions and unanticipated responses can be obtained and acted upon in a rapid and timely manner. This ability to present the material to a “different” audience and to monitor results in “real-time” could materially benefit and improve curriculum construction techniques. Variation in content or order of presentation for a particular course could be tried experimentally at remote locations with on-line monitoring of the activity. Experimental and control groups could be subjected to new situations by varying inputs and testing the efficiency of new approaches. Instructor-to-instructor communication during presentation of material would permit presentation of “on-the-spot” reactions to content.
- The essential equipment elements of a “timesharing” system are present in the centralized configuration. The availability of appropriate executive, monitoring and scheduling programs would permit the participating clusters to use the system in “off hours” for data processing and problem solving not necessarily associated with the CAI usage during the school day.

A system in development

General description

The Philco-Ford Corporation is currently engineer-
quently directed to the SAVI terminals by the processor.

The student terminals (SAVIs) provide integrated input-output capability for the student, produce displays and provide a communications link to the processor through its keyboard. An optional capability provides audio input-output utilizing the terminal's sound system which is also program controlled. The console comprises a cathode ray tube, a light pen, a keyboard device, and expansion capability to include audio.

The software
The programs, designed to meet the needs of computer assisted instruction, include:

Functional software for the central processor:
- Multi-station control programs
- Lesson distribution programs
- Data acquisition programs
- Student status interrogation programs

Functional software for the cluster processors:
- Lesson control programs
- Instructional monitoring programs
- Activity recording programs
- Data transmission programs

Curriculum generation programs:
- Initial curriculum generation programs
- Curriculum modification programs
- Curriculum check-out programs
- Master curriculum file protection programs

Test and diagnostic software:
- For the central processor
- For the cluster processors
- For the SAVI terminals.

CONCLUSION
I have attempted to highlight some advantages which are achievable by employing a centralized CAI configuration. These considerations have been made from a qualitative "narrowview" (many factors remain to be considered), which in simple terms means that at this time I have neither facts nor figures to support the viewpoint. It is anticipated that further investigations, analysis and experience will permit a quantification of the key parameters leading to a model for "tradeoff" evaluation. It is intended that future reports will convey the results of our analysis.

If this presentation serves to motivate some of our colleagues in the field of education to learn more about system design and implementation considerations of Computer Assisted Instruction, then the time has been, in my opinion, well spent. Hopefully, this discussion has suggested that there are many facets to system requirements which should be defined before the specification—RFQ—aware-implementation cycle can properly take place. In spite of the fact that systems engineers and designers always cry that they "need more information" there nevertheless exists a need for improved definition in CAI procurement specifications if industry is to be responsive. Only through better definition can the user make a true "apples-to-apples" comparison of the variety of systems, costs and capabilities proposed. If statements of firm minimum requirements are not detailed, the educators may be in for a painful education; the system may meet the contractual requirements as determined by legal counsel but it may fall far short of the user's intent.

The field is in its infancy and some of the needed improvement will evolve with experience; but frustration and disappointment in the interim can be minimized only through concentrated and deliberate effort. It has been said of industry, with justification, that "their ignorance of education is gargantuan. But they impress me. They'll sit down and learn it." Similarly, educators have a need to be better informed about computer technology. The two fields have much to offer and teach each other. Only through the communication and understanding of the disciplines involved can educators and industry provide the effective and efficient CAI systems to help meet the demands for quality education in the face of an expanding population.

Government at all levels, the nation's educators and industry are involved in the embryonic phases of a nationally significant joint venture. In a keynote address at the 1966 FJCC, Ulric Neisser suggested the image of the computer expert awakening in the morning, looking into a mirror and smugly thinking, "I have social impact." True or false, through evolution or revolution, there should be no question that CAI will have social impact.

It should be obvious that the great potential afforded by CAI also presents a significant technical challenge and awesome responsibility. It should be equally apparent to all concerned and to our industry in particular that any attention to the "rustle of the new money that is falling like autumn leaves on the educational ground" must be transcended by an imaginative response to the technical challenge and by a mature fulfillment of the civic responsibility.

*P. Suppes, quoted in The Computer as a Tutor, Life Magazine, January 27, 1967.
**The Computer as a Tutor, Ezra Bowen, Life Magazine, January 27, 1967