

AN INTELLIGENT TUTORIAL SYSTEM FOR STATISTICAL QUALITY CONTROL

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ABSTRACT

This paper presents the development of STCEQ, an Intelligent Tutorial System directed to support Statistical Quality Control teaching. The paper discusses the main characteristics of the system, its functioning, benefits of using such a system and the results we obtained while using this system.

KEY WORDS: Intelligent Tutorial System, Statistical Quality Control.

1. INTRODUCTION

Statistical Quality Control (SQC) has been used for more than 70 years around the world, and it has greatly contributed to improve the Quality of many products and services. In spite of its widespread use, SQC is often misused, either by choosing inappropriate techniques to solve the problems or ignoring the underlying assumptions to use those techniques [1]. This situation occurs in Brazilian companies as well, where sometimes no SQC technique is used.

One of the causes of such SQC misuse can be the inadequate training: those who could use SQC techniques did not fully understand the concepts and the necessary assumptions. Therefore we decided to develop an intelligent tutorial system to teach Statistical Quality Control, the STCEQ (Sistema Tutorial Inteligente para Controle Estatístico da Qualidade), which could provide a friendly environment to learn and practice SQC.

2. STATISTICAL QUALITY CONTROL

Statistical Quality Control is defined in this work as [2]: “with the help of numbers, or data (Statistical), to study the characteristics of our process (Quality) in order to make it behave the way we want it to behave (Control).” The main issue is quality evaluation, because quality is vital to the organization survival and growth. Therefore one needs to systematically study a process variability to assure its quality. The only way of doing it is by using statistical methods.

There are three major components of Statistical Quality Control: Statistical Process Control (SPC), Acceptance Sampling and Design of Experiments.

Statistical Process Control includes Control Charts, which monitor a process performance, and Process Capability Studies, which measure the process’ ability of producing items according to specifications. SPC also includes some “opportunity tools,” like the Ishikawa diagram and the fluxogram, and statistical tools, like Pareto diagram and the histogram (those tools are used to find the causes of a process misbehaving, perhaps an opportunity for improving its quality).

Acceptance Sampling can be defined as the group of statistical techniques used to accept or reject lots of finished goods or raw material received from suppliers. Some authors [3] emphasize that Acceptance Sampling does not estimate lot quality, it just recommends a course of action: to accept or reject the lot based on a random sample from it.

Design of Experiments is a broad statistical issue. Properly designed statistical experiments can discover what variables are causing a process to misbehave and also the magnitude of the effect.

In the current stage STCEQ includes problems only to SPC. However, tutorials for Acceptance Sampling and Design of Experiments were added to provide a complete description of Statistical Quality Control.

3. STCEQ CONCEPTS

STCEQ was developed as a doctoral dissertation research using artificial intelligence to build a learning environment for Statistical Quality Control, as part of a teaching proposal. The research relied on our previous experience with using artificial intelligence to support Statistics teaching, the SEstat expert system [4], [5]. The research work on this system still continues [6].

The SEstat expert system was designed to support Statistics teaching. In such environment the user could open a database, choose a statistical study, and answer questions about that study: which variable is independent, which is dependent, if the variables are quantitative or

qualitative, how many values for a qualitative value and so on. Based on those answers SEstat chooses the proper technique and apply it to the database, producing statistical results. SEstat is used to make the students understand how to choose a statistical technique to a certain problem, and to realize the effects of a bad choice on the results. After two years of application in undergraduate engineering courses the results are very good. Despite its usefulness, SEstat does not address SQC issues, nor provides a constant monitoring of user's answers, which might be of great help in a learning environment. In addition SEstat would have been practically rebuilt to accomplish some features, like simulation, that one wanted to have it in a SQC learning environment. Therefore one decided to develop a new application, called STCEQ.

STCEQ is an Intelligent Tutorial System (ITS). Here an ITS is understood as a computer program which uses artificial intelligence techniques to simulate human thinking in a certain domain, attempting to help an "apprentice" in building strategies to solve problems or take decisions [7]. Intelligent Tutorial Systems are also known as ICAIs (Intelligent Computer Assisted Instruction) or Knowledge Communication Systems [8]. The idea was to create an environment in which a user could freely search for SQC concepts and could solve real SQC problems under supervision (automated supervision).

Among its requirements STCEQ should include items, such as the following:

1) **Friendly environment.** STCEQ should provide a friendly learning environment, minimizing the time needed to master the system interaction, thus allowing the user to get down to business as soon as possible. STCEQ includes two ways of interaction, free consulting of tutorials, or solving SQC problems. In the former the user navigates SQC tutorials as in a multimedia document, and in the latter he answer items regarding a production process.

2) **Real SQC problems.** The problems embedded in STCEQ should be "real" SQC problems, with real production flows and real data. Unfortunately obtaining real data was quite a task; very few Brazilian companies permitted their data to be used, even with a promise of not using the real company name. Therefore we decided to simulate the data using a random number generator. However, the production flows used are real ones. The problems include interpretation of results, choosing and detailing techniques, and choosing what to be evaluated in order to monitor and improve quality.

3) **Supervision.** A SQC expert and a tutor are embedded in STCEQ. The former is responsible by the "correct" answers to the questions, and the latter compares user's and expert's answers, calculates user's performance, and suggests what he should do next (next problem to solve, which tutorials to consult).

STCEQ also should show a user's activities in previous interactions (tutorials consulted, problems solved, performance), allowing the user to plan a better

course of action. And, last but not the least, the user has full control of the interaction: he can choose to follow or ignore tutor's recommendations.

4. STCEQ STRUCTURE

STCEQ is a modular system, using a object-oriented approach. This allows future expansion and also turns maintenance easier. Its structure includes the following modules.

- **Apprentice.** It stores all information from all STCEQ users, each user is an instance of this module. Every time a user accesses the system the related information is updated, and user's previous activities (problems solved, performance and tutorials consulted) are presented, to give directions to the new interaction.

- **Simulator.** It includes a random number generator, and all Statistical Process Control techniques (Control charts and capability studies). It generates all results used in problems and tutorials. Its algorithms [9] were statistically tested for randomness and distribution fitting.

- **Problem.** It stores all problems that can be presented to the user (including the tutorials associated with each problem), each problem is an instance of this module. It also sends the needed information to the Simulator module to generate the proper data and to the Expert module to reason about the questions.

- **Tutorial.** It stores all tutorials that can be consulted. Each tutorial is an instance of this module.

- **Expert.** It solves the problems along with the user and evaluates his/her performance. It also sends all conclusions to Tutor module.

- **Tutor.** It contains all pedagogical information, and based on Expert conclusions presents a diagnosis about user's answers, and the best course of action to take next. It also updates Apprentice with the problem just solved and user's performance on it.

- **Interface.** It presents all information to the user. The interface was written in Portuguese, aimed at Brazilian users.

Figure 1 summarizes STCEQ structure.

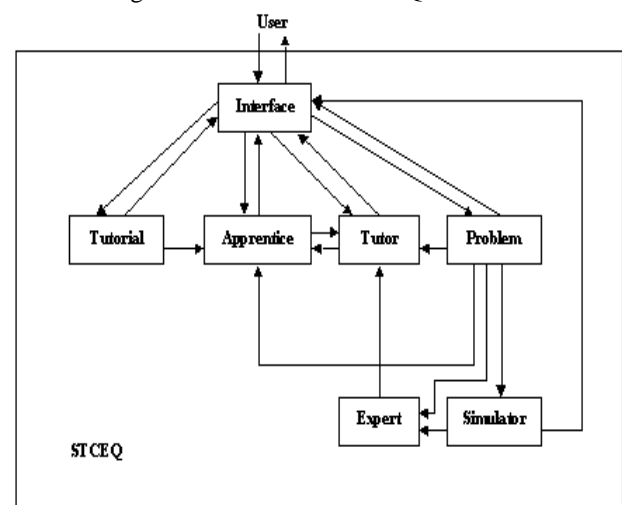


Figure 1 – STCEQ structure

The tutorials were developed as PowerPoint™ presentation files, which can ease maintenance. However, in the next versions simulation will be included. The problems' presentations (company description, production process, quality problem) were also implemented as PowerPoint™ presentations, but the results come from the Simulator module.

STCEQ has been developed as a stand-alone application (in near future we intend to build a web-based version) in a Windows-based, IBM-PC compatible platform. An expert-system shell, Kappa-PC™ 2.4, has been used to develop the prototype. The system is aimed at undergraduate engineering students who are taking a regular Quality Control or Statistical Quality Control course.

5. EXAMPLE OF INTERACTION

Some STCEQ screens are presented in the next pages (they are originally in an 800X600 pixels size and are written in Portuguese, we can provide the needed translation to an interested reader).

Once the user accesses the system an identification is asked, with first and last names. After writing the required name the user can continue the interaction or quit STCEQ. The Apprentice module will scan its instances for a name that matches the concatenation of user's names. If none matches STCEQ will present a welcome message and recommend to solve the first problem. If the user has previously accessed STCEQ the Apprentice module will present a report with all previous activities (Figure 2).



Figure 2 – User's previous activities

In the upper left corner are the tutorials freely consulted (titles and description). In the lower left corner are tutorials consulted when solving problems. In the

upper right corner are the solved problems (number and description). Finally, in the lower right corner are the performances. Therefore, the user will have an idea of all previous activities, intending to help future choices. If the user decides to continue (CONTINUAR) a main menu will be shown.

In the STCEQ main menu the user can choose between freely consult tutorials, much like a multimedia document (as an encyclopedia), or to solve some Statistical Quality Control problems.

If the user decides to freely consult tutorials a screen containing the major areas covered by STCEQ is presented, figure 3.

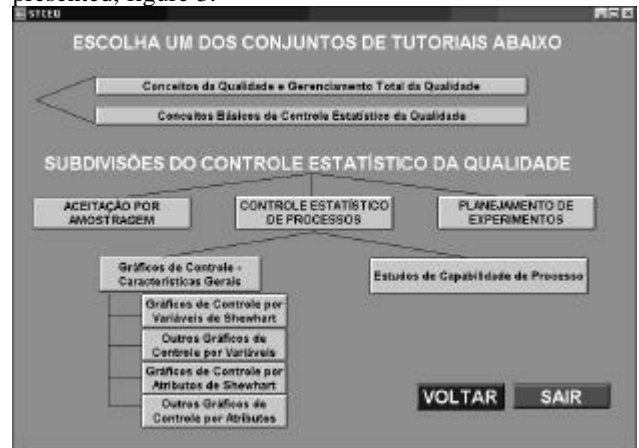


Figure 3 – STCEQ Tutorials menu

The tutorials are grouped in 5 main areas: basic concepts about quality and TQM, basic concepts about Statistical Quality Control, Acceptance Sampling, Statistical Process Control (with its subdivisions) and Design of Experiments. SPC was divided in two major areas: Control Charts and Capability Studies. Control Charts were divided in Shewhart Variables Charts, Other Variables Charts, Shewhart Attributes Charts, and Other Attributes Charts. The user can return to the main menu (by pressing VOLTAR – Return), quit the system (by pressing SAIR – Quit) or press a button that will lead to other screens, each one with all tutorials from a specific area or subdivision: the tutorial will be presented once the user presses the related button (whose name is the tutorial's title).

If the user decides to solve SQC problems a screen like figure 4 will be shown. The problems are grouped in three major types, according with the techniques involved: Control Charts (Gráficos de Controle), Capability Studies (Estudos de Capacidade), Control Charts plus Capability Studies (Gráficos de Controle seguidos de Estudos de Capacidade). In the current version STCEQ has one difficulty level only: the user answers questions about the results generated by STCEQ. The problems that the user previously solved are shown in a different color; they are highlighted to prevent the user from solving them again. Moreover, after seeing previous performance the user can make a more careful choice for the next step to take. Once a problem is chosen STCEQ shows its description to the user, and also a

PowerPoint™ presentation about it. The user can decide to solve the problem or to return to the previous screen. Once deciding to solve it, the Problem module sends a message to the Simulator module, which produces all the results, like the X-bar and R control charts as shown in Figure 5.

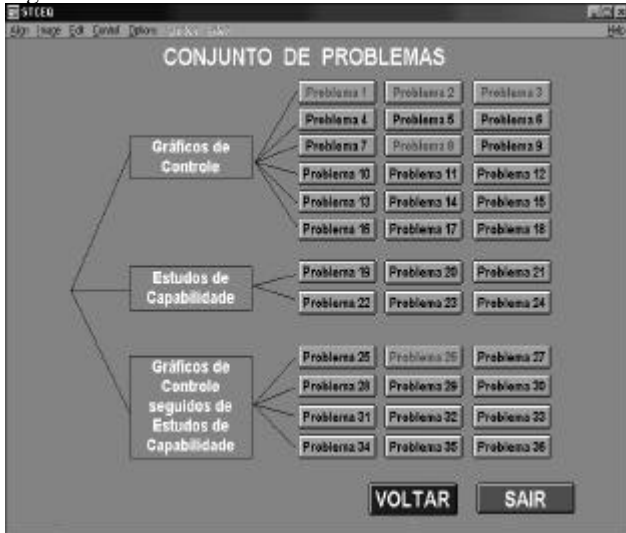


Figure 4 – STCEQ Problems

The user will answer items based on statistical results, for instance, if the process from which the charts were plotted is under statistical control and why. The Expert module will also answer the same questions, and the Tutor module will compare both answers, evaluate user’s performance and recommend the best course of action. The user can anytime quit STCEQ, or return to a previous step. He she can also ignore the tutor recommendation, and choose not to consult all listed tutorials.

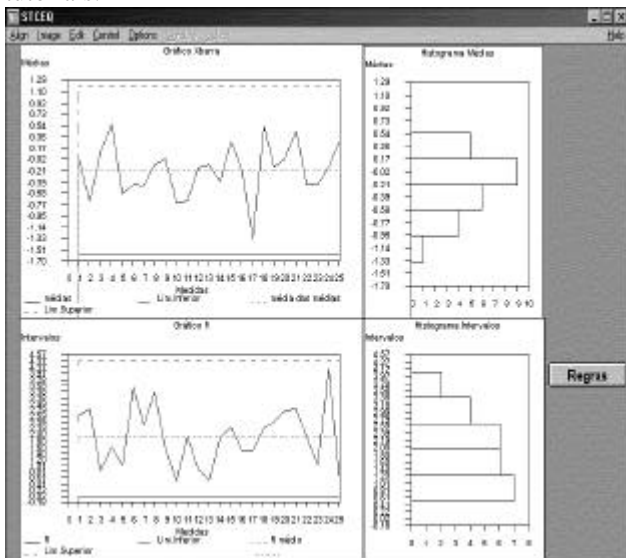


Figure 5 – STCEQ’s Simulator Module Results

6. EXAMPLE

A small example of interaction will be presented. A user decides to solve SQC problems. The user must choose

among those presented in figure 4. In this example the user chose “Problema 11” (Problem 11). This will trigger the problem’s presentation, which is shown in figure 6.

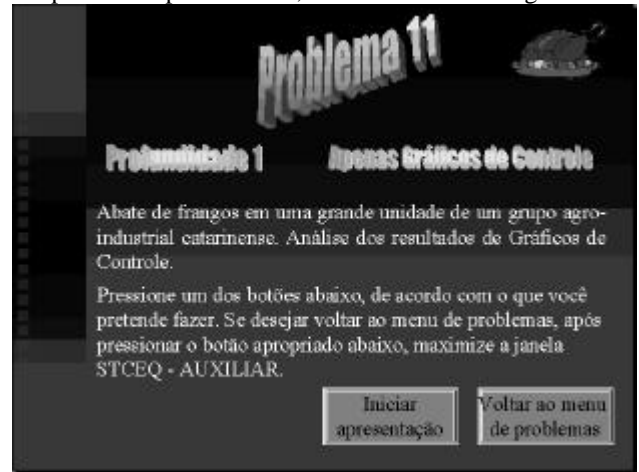


Figure 6 – Problem’s presentation

The presentation states the techniques involved (“Apenas Gráficos de Controle” – Only Control Charts), the depth (“Profundidade 1”), and a brief description of the problem (analysis of a poultry industrialization process). The user can really initiate the presentation (by pressing “Iniciar apresentação”) or return to STCEQ problems (by pressing “Voltar ao menu de problemas”). In this example the user decided to really initiate the presentation: all information about the company, its production process and the quality problem is shown to the user, who can control the presentation’s pace and replay it many times. In this problem the user must analyze a p control chart in order to verify what is happening to the process. Once the presentation is finished STCEQ asks the user about the next step: solve the problem or return to STCEQ problems? Again, one supposes that the user chose solve the problem.

With the information provided by the Problem module (its instance “Problem 11”), the Simulator module generates the data needed to plot the p control chart. The results are presented in figure 7.

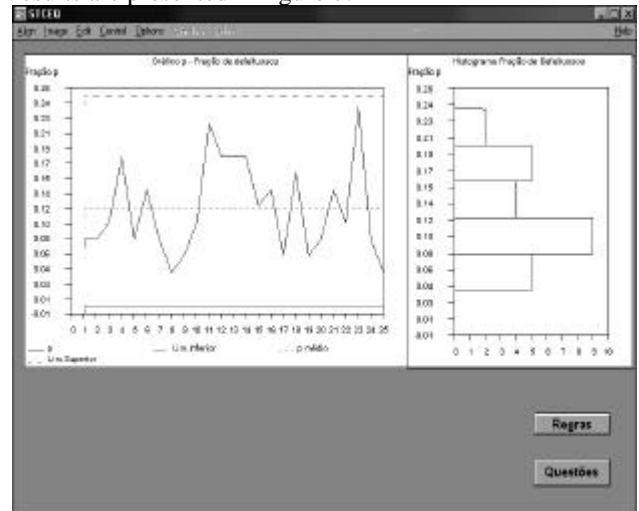


Figure 7 – p control chart

On the left side of figure 7 is the p control chart (25 subgroups, 25 fractions of non-conforming poultry). At the right side is the associated five-bar histogram of all 25 p fractions (allowing the user to visually analyze if the data are normally distributed). On the lower right corner there are two buttons: Rules (“Regras”), which will lead to a screen (not shown here) where the user can apply a series of rules to the control chart (in order to identify if the process is out of control); and Questions (“Questões”), which will present the first two questions related to the problem. There are nine rules that can be applied to a single control chart (if there are two control charts, for averages and ranges, e.g., the rules are presented for each chart). Based on all rules, and on the control chart, a user can surely say that if the process is under statistical control or not. The user must decide when such rules are appropriate to be used: for instance, some rules designed for average and range control charts (in which the observations are considered independent and identically distributed) cannot be used in a CUSUM or EWMA control charts (in which the observations are related).

If the user decides to answer the questions (by pressing “Questões”), the screen in figure 8 will be shown.

Figure 8 – Some STCEQ questions

In the first question the user will simply say if the process is under control (“SIM”) or not (“NÃO”). Only one answer is allowable. In the second question the user will state the reasons for the first answer, choosing among a wide range of options, more than one option can be checked. The user must answer based on the control chart appearance and the rules result.

The user also has the option of examining the charts again (by pressing “MOSTRAR GRÁFICOS NOVAMENTE”), or returning to STCEQ problems screen (by pressing “VOLTAR AO MENU DE PROBLEMAS”), or reviewing the problem presentation (by choosing a menu on the top of the screen), or consulting a tutorial (again by choosing a menu on the top if of the screen) or even leaving the system (by pressing “SAIR DO STCEQ”). Once the user had answered the question, he/she can ask the system to evaluate them (by

pressing “AVALIAR RESPOSTAS”). The user can’t go the next question (by pressing “PRÓXIMA QUESTÃO”), without having an acceptable answer to these two first questions.

How the evaluation works? STCEQ compares user’s answers and expert’s (the expert is embedded in the system). According to the differences found, some recommendations are made, in order to help the user to perceive the mistake (of course, if there’s no mistake, a congratulation message is shown). Incomplete diagnosis is also considered, but only in some cases. To conclude that the process is under statistical control, the user must check all options which indicate that, but to conclude that the process is out of control, the user can check only some options that were identified (an incomplete but acceptable diagnosis). This approach is used in all questions that allow multiple options to be checked.

Once the problem is finished, STCEQ prepares a report to the user. This report is divided in three parts.

The first part contains some basic information about the problem just solved: problem number (“Problema”), problem depth (“Profundidade”), number of questions (“N. de Questões”), and problem type (“Tipo de Problema”): control charts only, capability studies only, control charts plus capability studies. In addition it shows user’s performance in each question (a number from 0 to 100, 0 meaning the worst performance and 100 the best). Those performances are calculated according with the number of repetitions (wrong answers) the user gave to each question: one repetition means a reduction of 10 on performance. Incomplete but acceptable diagnosis implies on a reduction of 5 (applied only in multiple-answer questions). The first part of the report is shown in figure 9.

Figure 9 – First part of the STCEQ report

The second part of the report issues a general diagnosis about user’s performance in the problem just solved: the overall performance can be categorized as excellent (above 90%), satisfactory (between 70% and 90%) or unsatisfactory (below 70%). According with such categorization, STCEQ can recommend some tutorials in order to enhance the user’s knowledge about the problem: for an excellent performance no tutorial will be recommended; for a satisfactory performance, only the

complex tutorials (associated with the problem); and for a unsatisfactory performance all associated tutorials will be recommended. The second part of the report is shown in figure 10, in this case user's performance was unsatisfactory (65.79%), therefore all associated tutorials were recommended.

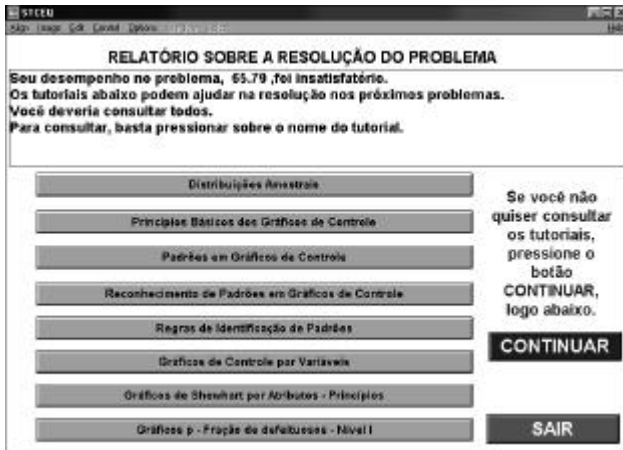


Figure 10 – Second part of the STCEQ report

The user is allowed to choose the tutorial in any order, or even choosing none of them and continuing the interaction (by pressing “CONTINUAR”).

The third part of the report presents a summary of user's performance in all types of problems previously solved. It also verifies the remaining problems and recommends which one, in each type, the user should solve after. Figure 11 shows the third part.

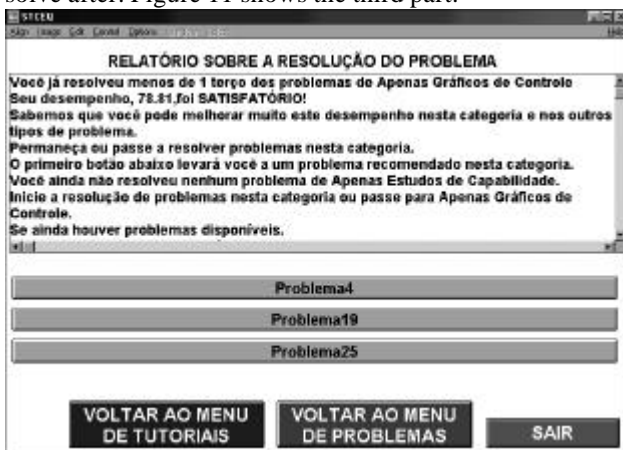


Figure 12 – Third part of the STCEQ report

Again, the user can choose any recommended problem, or none of them. The user can return to STCEQ tutorial menu (by pressing “VOLTAR AO MENU DE TUTORIAIS”), or to STCEQ problems (by pressing “VOLTAR AO MENU DE PROBLEMAS”), or even quit the system (by pressing SAIR).

7. CONCLUSIONS

Series of exams with undergraduate students, from production engineering, were conducted at Universidade Federal de Santa Catarina, Brazil. Students considered STCEQ a very useful resource to support SQC

teaching. It seems that STCEQ's features can greatly enhance the learning of Statistical Quality Control concepts. It provides a friendly environment for a practicing engineer (having previous SQC knowledge) or someone acquiring new knowledge. Because of the random number generator inside the Simulator module the user faces new situations every time the user solves a problem, even the same problem, forcing him/her to really analyze the results. The report presented with a user's previous activities helps him/her to plan the current interaction. The Tutor module provides a very good way to support learning.

We intend to expand the system, adding more difficulty levels (problems about choosing and designing the techniques), and also include problems regarding Acceptance Sampling and Design of Experiments, and also improve the interface. But the most ambitious goal is to implement a web-based version of STCEQ, to make it useful for distance learning programs.

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