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# Modifying CAD Courses to Improve Proficiency in Interpretation of Engineering Drawings Using Modified Constructivism Approach

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Abstract

In this paper we will discuss ways to incorporate basic drafting principles in our introductory class and strengthen the students' learning experience through multiple courses in our engineering technology programs. Students will gain the basic knowledge of CAD in EGT 212 (Computer-Aided Drafting and Design), and strengthen their learning experiences by applying their knowledge in other courses such as: EGT116 (Introduction to Manufacturing), 265 (Manufacturing Processes and Metrology), 365 (CNC & Manufacturing Process Planning), 405 (Metrology and Geometric Tolerancing), 465 (Automated Manufacturing Systems) and 380 (Machine Design). They will learn the advanced features of CAD in our advanced CAD design classes. There is no doubt in the benefits of computer generated graphics in teaching CAD. This course as well as other related courses in engineering/technology design will be taught with the constructivism teaching philosophy. Specialized literature abounds on ways to provide instruction on interpretation of technical drawings utilizing this method, A brief overview of the constructivist learning approach in CAD education is also discussed, offering another approach to this subject.

## Introduction

The interpretation of engineering documentation (including working drawings) is an essential competence for any technician, technologist or engineer graduate. Understanding orthographic views, cross sectional, auxiliary views, as well as linear and geometric constraints requires spatial visualization skills. Also, crucial in most engineering fields is the ability to produce, read and correctly interpret engineering documentation (including drawings) [1]. There is a common belief that topics related to geometric and technical drawing are nowadays a high school subject, and most universities focus only on teaching CAD (Computer Aided Design) using computer software such as AutoCAD, Inventor, Solidworks, Creo and others; many educators are surprised to realize that there is still a need for graduates to produce sketches by hand in industrial environment. In the minds of some, all work in practice is now done with CAD [2]. It is also important to emphasize that the inability to interpret mechanical drawings also may impair the learning on more advanced engineering classes such machine design (often referred as Machine Elements) or Tolerances Design (Often referred as Geometric Dimensioning and Tolerancing – GDT); only a few universities teach tolerancing and it is quite common for young engineers not to understand the concept and struggle to select fits and limits [1]; lack of technical drawing interpretation knowledge potentialize that problem. Also, an additional difficulty for students and newly graduate professionals alike is to achieve full understanding of technical literature such as catalogs (bearings, seals, fastenings), procedures, manuals, etc. G. Romero and others [3] have also pointed out that the lack of spatial vision can hinder the engineering students' ability to understand properly more complex technical subjects. Spatial vision training is also addressed by Sorby in view of its importance as a thinking process [4]. The discussion on the instruction of technical drawing is not new. Clifford Scheidler discussed the issue of lack of instruction of the discipline in high schools

as a preparation for the engineering course in college, back on 1963 [5]; it is a recurrent complaint from employers of new graduates and it is still an issue not properly addressed.
One source of information for the assessment of the knowledge level in technical drawing is a survey conducted among senior students of the engineering technology B.S. program (mechanical and manufacturing as well as electronics majors). The survey is composed by a set of fifty questions covering the basic standards of technical drawing, as well as basic geometry. The questions are of a level of difficulty consistent with basic levels of knowledge.

## Survey Results

*The survey contains 31 questions related to basic geometry and projections and 19 related to standards. The results for both group of students are summarized in*

Table *1*:

:

| Senior Engineering Technology Students | | |
|---|---|---|
| Total respondents: | 51 | |
| Total answers: | 2542 | |
| Answers to questions on Standards & Basic Geometry | Correct | 53.41% |
| | Wrong | 46.59% |

Table 1 Survey Results - Summary

In the engineering technology B.S. program, 53.41% of the students answered correctly the complete pool of questions, 36.50% of the high school students answered the basic geometry questions correctly. These results are far below the expectations from that group, as they are almost ready to graduate (and gain employment); they should be proficient in the subject.

## The Need of the Teaching of Technical Drawing

No one can dispute the fact that technical drawings are an essential part in the design process and the most common way by which technical information is disseminated, thus becoming a critical skill to professional engineers. Misinterpretation of technical information has created a number of embarrassing situations, with consequences of variable degrees [1].
Examples are numerous in industry and academia about expressing the need for attention to this issue. A study conducted among members of the Engineering Design Graphics Division of the ASEE [6] indicated that a strong need exists for degrees and/or training to be offered at either the undergraduate or graduate level to produce teachers of technical/engineering graphics for both secondary and post-secondary education.

Table 2 depicts a competence model established by SME for the certification of manufacturing technologists and engineers, identifying the following skills and abilities these professional should have to achieve those certifications [7]:

| Drafting/Drawing/Engineering Graphics/Modeling | |
|---|---|
| **Technologist** | **Engineer** |
| Understand drawings | Develop preliminary processing |
| Provide feedback on drawings | Understand drawings and blueprint standards |
| | Review and interpret drawings |
| | Analyze and do basic through complex drafting |
| | Understand and do basic modeling |
| | Provide graphics for processing |
| | Provide feedback and communicate with design |
| | Conduct model manipulation |
| | Provide strong compute skills |

Table 2 SME Summary of Competencies in Drawing/Drafting

## The Approach on the Technical Drawing Instruction

In the area of computer instruction, there is a clear trend towards teaching constraint based modeling and computer-aided manufacturing. Instruction in these areas needs to be fully implemented in programs and the relationship of CAM and CAD needs to be incorporated into instruction. [6]. There is no doubt of the obvious benefits of computer generated graphics; in fact, CAD tools replaces the traditional tools of drafting [8] with great efficiency. However, as noted by Lawson, "there seems to be a growing body of experiential and anecdotal evidence that CAD might conspire against creative thought" [9]. That seems to justify the fact that many students, even showing adequate knowledge on the use of the CAD software packages still fall short in technical drawing interpretation. Thus, supporting the idea that while CAD software proficiency is important, encouraging critical thinking and the development of spatial abilities is equally crucial.

As many students come to higher education without training in basic geometry and/or engineering graphics, the contents definition become increasingly more difficult to accommodate into the scheduling grids; in engineering schools a trend exists in the reduction of teaching hours dedicated to engineering design graphics, which adversely affects the students' visual-spatial abilities. Remedial courses combining hand-sketching with CAD training to help develop spatial abilities has been devised and implemented by Martin-Dorta, Saorin and Contero [10]. New curriculums have been developed for reading and interpretation skills, such as the ones implemented at Engineering technology programs at Youngstown State University [11].

In this paper, we will discuss an additional way to incorporate basic drafting principles in our introductory classes and strengthen the students' learning experience through multiple courses in our engineering technology programs. In EGT 116 (Introduction to Manufacturing) class students are introduced to basic drafting and sketching concepts. They will gain the basic knowledge of CAD in EGT 212 (Computer-Aided Drafting and Design), while their reading and interpretation skills will be strengthened through learning experiences from application of their knowledge in other courses such as: EGT116 (Introduction to Manufacturing), 265 (Manufacturing Processes and Metrology), 365 (CNC & Manufacturing Process Planning), 405 (Metrology and Geometric Tolerancing), 465 (Automated Manufacturing Systems) and 380 (Machine Design). The changes in the EGT 212 course will be made under the basic assumptions of constructivism teaching philosophy.

Constructivism

It is a theory based on scientific and observational studies about how people learn.

> "It says that people construct their own understanding and knowledge of the world, through experiencing things and reflecting on those experiences." [12]

When we learn something new it has to be reconciled with our previous experiences and knowledge. In the process we might change how we perceived and create new knowledge. This process requires us to ask questions, explore and assess what we know.

Educators using constructivist methodology encourage their class to constantly access how the activity is helping them gain understanding by questioning themselves. Learners in the constructivist teaching environment become "expert learners", giving them tools to keep learning, that is what ETAC-ABET called "an ability to engage in self-directed continuing professional development" [13]. With well-planned educational environment, students will learn "HOW TO LEARN" [12].

In a science class the teacher knows how to solve a problem and he/she helps students restate their questions in useful and constructive ways. Students are encouraged to reflect and examine their existing knowledge of the problem and once a student comes up with the relevant concept, the instructor seizes upon it, indicating to the group that this is a fruitful venue to explore and solve the problem, as depicted in Figure 1.

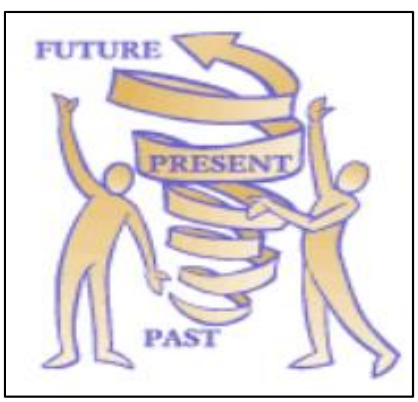

Figure 1 Constructivist learning spiral (source*: http://www.thirteen.org/donline/concept2class/ constructivism/index.html*)

Constructivism Assumptions of Learning

Constructivism says people are not “empty vessels” to be filled, rather knowledge is built on top of students existing knowledge [14]. As per Biggs [15], in higher education the Constructivist learning theory and the instructional design literature are two concepts of increasingly importance: Constructivism consists of a family of theories but all these theories have in common the centrality of the learner's activities in creating meaning. These ideas have important implications for teaching and assessment. “Constructive alignment” refers to the alignment between the objectives of a course and the targets for student assessments. It represents coming together for the two thrusts of course objectives and student assessments for those objectives. Constructivism is used as a framework to guide decision-making at different stages of instructional design. The frame work proposed by Driscoll [16] is depicted in Figure 2. Some of these instructional design stages are: deriving curriculum objectives in terms of performances, deciding teaching/learning activities judged to prompt those performances, and assessing and reporting student performance.

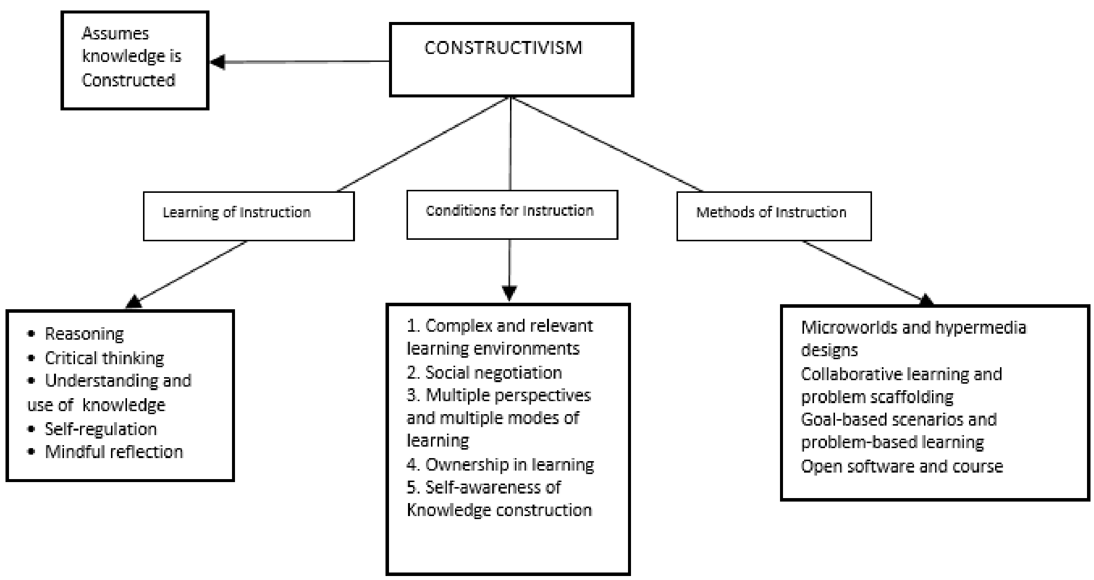


Figure 2 Psychology of Learning for Instruction.

Emerging constructivist often contract their ideas with the epistemological assumption of the objectivist theories. Objectivism is defined by Driscoll [16] as the view that knowledge of the world comes through an individual’s experience and performance of tasks.

Both theories of behavioral and cognitive information-processing emerged from the objectivist tradition. Behaviorist is defined as the desired learning goals independent of any learner and proceeded with arrange reinforcement contingencies perceived to be effective with the learner. Constructivist theory assumes that knowledge is constructed by learners as attempts to make sense of experiences.

The role of teachers, as per Driscoll [16] is to allow learners to test their own understandings against those of teachers or more advanced peers. The learner’s sense of their environment and their experiences must have some limits. The limits are constructed in the form of suggestions and guidelines from teachers and more advanced peers.

Method in Teaching Design and Drafting Course (EGT212) Using Modified Constructivist Approach

1. Start with the construct and drive at the theory (for example, a project comprising the design of a component, depicting one cross section):

- Step 1: Identify the Course: EGT212 – Computer Aided Design
    - Layout the project Method (team approach, some projects can be done individually)
    - Establish Criteria (Construct): organize course content into smaller projects leading up into the final project.
        - Project 1 – Creating a basic 2D shape.
          Basic Commands;
          Project outcomes.
        - Project 2 – Creating a cross sectional model for a part
          Project outcomes
        - Project 3 – Creating a rapid prototype of the model created above.
    - List components of the project;
    - Discussion about team work (20 min.);
    - Discussion project management (1 hour):
        - Students write specification following example;
        - The team submits a proposal.

    This is applicable to freshmen through junior years "cup project" or a project that they can do a certain class section. They can do this with material selection in higher level courses.
- Step 2: Identify the information leading to the study by asking the following questions:
    - Project based/activity based learning?
    - Rubrics for accessing student learning?
    - Other questions.
- Step 3: Refine the question.
- Step 4: Identify dependent variables
    - Sample size?
    - Other variables.
- Step 5: Identify independent variables.
- Step 6: Identify how measure the variables – define instruments and measures to study the questions.
- Step 7: What is the underlying theory?

2. Layout the activities that make up the project

Instructor's tasks are to design the curriculum and promote constructivism approach in the class by:

- Provide learning goals that include: reasoning, critical thinking, understanding and use of knowledge, self-regulation, and mindful reflection.
- Provide the necessary conditions for:
    a. Complex and relevant learning environments;

b. Social negotiation;
c. Multiple perspectives and learning modes;
d. Ownership in learning;
e. Self-awareness of knowledge construction.

3. What students do as learners and as teams:
In each project ask students to form a team and collaborate to complete the assigned project; for larger groups teams select a team leader. Team leader is provided with instructions on how to manage the team and prioritize tasks, divide the required tasks between team members and report their progress periodically.

Project 1

- Learning goals: To create the basic shapes, as per drawing (Figure 3).
- Instructor provided a basic understanding of drawing environment, use of coordinate systems, use of peripheral devices and some commands such as basic line, erase, view, and zoom commands.
- Students were introduced to the concept of constructivism, asked to introduce and work with the person sitting next to them and collaborate on how to create the images.

The following questions were posed to class for them to better understand the subject:
1. What commands are needed to draw these shapes?
2. What is the coordinate system?
3. What are absolute vs. relative coordinates applications in this drawing?
4. What is the unit used?
5. What is the drawing limit size?

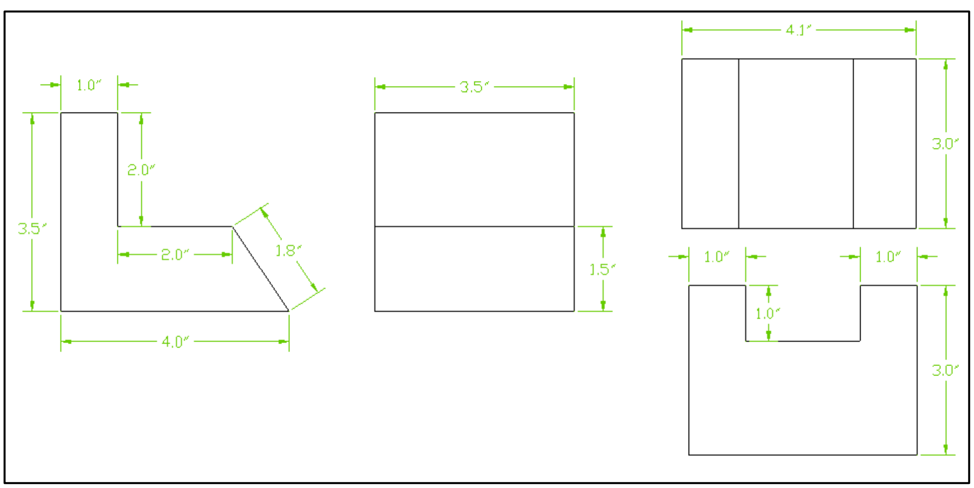


Figure 3 Basic Shapes for Project 1

Project 2

- Learning goals: To create a solid model for Figure 4 below.
- The instructor provides the process of creating a solid model.

- Students were asked to brainstorm on how to create the shape below.
- Rubrics for assessing student learning

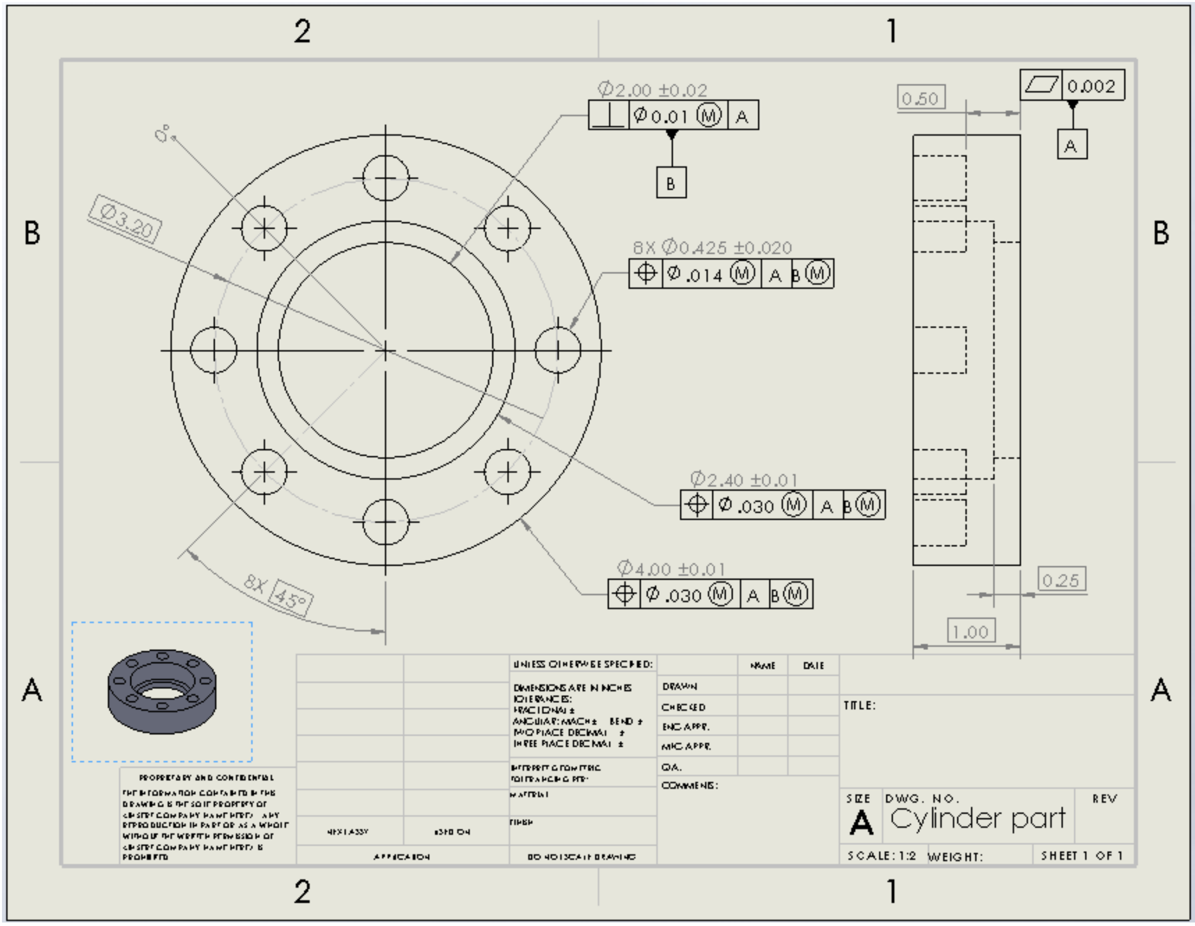


Figure 4 Solid Model for project 2.

Project 3:

- Learning goals: (from project 2), to create a relatively complex object, such the one depicted in Figure 5, using a rapid prototype machine.
- Instructor provided: file extraction to .stl format (supported by many CAD/CAM and rapid-prototyping software packages) and how to setup the part to save on materials.
- Students were provided the boundaries of operating the Dimension machine and assistant in the process of converting their files and setup process.
- Rubrics for accessing student learning

Figure 5 Part Created by Rapid-prototyping

## Conclusion

The proposed way to improve the proficiency in mechanical drawing interpretation is a two-fold approach. First, the EGT 212 (Computer-Aided Drafting and Design) is being modified to incorporate teaching on basic drafting and standards, by use of constructivism methodology. With the constructivism approach, the instructor will take the time necessary to get to know his/her students in depth. The instructor in turn will integrate what is learned about the students' prior knowledge of drafting and design into their instruction plan. This method of teaching is a student-centered classroom with instruction tailored to students based on their understanding of the subject matter. Then, the instructor will provide additional instruction as needed. In this way, students will utilize their already existing knowledge of the subject matter as well as the new content presented to them to solve the problems at hand. A constructivist approach to teaching is not one-size-fits-all. Curriculum is not rigidly pre-packaged, which often times results in overlooking the unique resources that students from non-mainstream backgrounds bring to a class. While all students are required to master the intended knowledge for the class, this approach does not allow students to remain at the knowledge level that they already possess, rather it pushes them to further their understanding. Students will be motivate and encouraged to learn when they are recognized for the knowledge they bring to the table. Under this approach, often project-based and hands-on approaches are utilized with sufficiently open-ended instructions to support all backgrounds and learning styles, and allow students to work at their own pace. This results in collaborative learning among students by learning from one-another with an appropriate level of supervision and interaction by the instructor to keep students focused on the leaning outcomes.

Also, students will be required consistently to employ these skills in different classes, with different levels of complexity within the engineering technology program. The competencies that requires skills in drawing interpretation are depicted in Table 3; other classes beside computer drafting and design courses may also require these skills, although not with the same emphasis.

| **Course Title** | **Catalog Description** | **Requires understanding of:** |
|---|---|---|
| EGT 116 Introduction to Manufacturing | Fundamentals of welding and metal processing methods; metal casting, shaping, metal forming, bulk deformation processes. | • Working drawings<br>• Routing sheets |
| EGT 265 Manufacturing Processes and Metrology | Principles and applications of precision machining, volume production, assembly methodology, advanced concepts in manufacturing operations, and introduction to metrology (e.g. calibration, documentation, and standards are discussed) | • Working drawings<br>• Routing sheets<br>• Drawings of tools, jigs, etc.<br>• Machining handbooks |
| EGT 365 CNC & Manufacturing Process Planning | Course provides knowledge needed to set up and program Computer Numerical Control (CNC) machines equipped with EIA or Conversational programming formats. The general application of information will be discussed, along with practical training on CNC machines. Topics such as: Manufacturing process planning, selecting resources for use in the execution and completion of a CNC project will be covered. | • Working drawings<br>• Routing sheets<br>• Drawings of tools, jigs, etc.<br>• Machining handbooks |
| EGT 380 Machine Design | Techniques involved in designing and selecting individual machine parts. An integrated approach to the design of machine elements. | • Working drawings<br>• Engineering design handbooks<br>• Manufacturers' catalogs<br>• Specification sheets |
| EGT 405 Metrology and Geometric Tolerancing | Metrology requirements and geometric tolerancing; calibration systems, gauge studies, measurement elements, analysis and presentation of measurement data, quality implications. | • Working drawings<br>• Drawings of tools, jigs, etc.<br>• Engineering design handbooks<br>• Machining handbooks<br>• Manufacturers catalogs<br>• Specification sheets |
| EGT 465 Automated Manufacturing Systems | Integrated manufacturing automation including CIM/FMS, system controls, fixed systems, robotics, and economics of automation. | • Working drawings<br>• Routing sheets<br>• Drawings of tools, jigs, etc.<br>• Machining handbooks<br>• Manufacturers catalogs<br>• Specification sheets |

Table 3 Competencies Required by the Various Courses in the Engineering Technology Program

The basic goals of adopting a constructivist approach are very simple. The goals are retention, understating, active use of knowledge and skills, hence the integration with other classes is essential to this strategy. Engineering Technology curriculum should be designed to direct towards a more attentive approach in valuing knowledge integration [17], bearing in mind that from the educational point of view, curricular integration has been a recurring recommendation [18].

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