

# Chapter 39

## Student Clustering Based on Learning Behavior Data in the Intelligent Tutoring System

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### ABSTRACT

*The idea of clustering students according to their online learning behavior has the potential of providing more adaptive scaffolding by the intelligent tutoring system itself or by a human teacher. With the aim of identifying student groups who would benefit from the same intervention in AC-ware Tutor, this research examined online learning behavior using 8 tracking variables: the total number of content pages seen in the learning process; the total number of concepts; the total online score; the total time spent online; the total number of logins; the stereotype after the initial test, the final stereotype, and the mean stereotype variability. The previous measures were used in a four-step analysis that consisted of data preprocessing, dimensionality reduction, the clustering, and the analysis of a posttest performance on a content proficiency exam. The results were also used to construct the decision tree in order to get a human-readable description of student clusters.*

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## INTRODUCTION

Feedback is an essential part of education since it helps students raise their awareness of personal strengths and areas for improvement and helps to identify actions for improving their performance. Researchers have revealed that broad-based and personalized interventions can change students' course of learning (Lin-Siegler et al., 2016; Mojarad et al., 2018). A major limitation to the development of classroom-wide interventions is that students' characteristics are highly variable, making it difficult to identify the right intervention. On the other hand, personalized interventions can be time-consuming for teachers, especially when used in large classes. An approach that researchers have used to address these challenges is to identify groups of students who could potentially benefit from the same intervention. The idea of clustering students according to their behavior has the potential of providing more adaptive scaffolding by the system itself (for example in an agent-based intelligent tutoring system) or by a human teacher (Bouchet et al., 2013; Vellido et al., 2010).

There are several research studies that have clustered students into meaningful groups with the goal of informing student interventions (Amershi & Conati, 2010; Bouchet et al., 2013; Ferguson & Clow, 2015; Mojarad et al., 2018; Rodrigo et al., 2008). Each of these research studies deals with the specific learning environment and the clustering (analysis) approach. However, all these clustering studies are exclusively related to online learning and self-regulated learning using intelligent tutor systems. In this research study, we specifically focus on a blended learning environment that combines face-to-face environment with the teacher and online intelligent tutoring system that students use according to preferred pace, time, and a location. The combination of traditional learning and online learning gives students time to reflect, empowering every student to participate, and enables teacher oversight and feedback anytime and anywhere. In our research study with an introductory computer programming course, the blended learning experience uses a flipped classroom environment. In the used flipped classroom environment, the main concepts of traditional in-class lectures are delivered outside of the class, whereas in-class time is used for activities that allow students to engage with content viewed outside of and before class at a deeper cognitive level. Along with face-to-face lectures and laboratory exercises, students use an ontology-based intelligent tutoring system, AC-ware Tutor.

In the following "Literature review" section we summarize the approaches and findings of several clustering research studies. Then, in the 'Methodology' section we describe the AC-ware Tutor used in the research study, the protocol of the research study including the tracking variables of online learning behavior, as well as, methods and techniques used in the four-step analysis process. The results and conclusion are presented in the last two sections.

## LITERATURE REVIEW

As it was previously mentioned, there are several research studies that deal with data-driven student clustering according to online learning behavior.

Mojarad et al. (2018) investigated data-driven student profiling in a web-based, adaptive assessment and learning system (ALEKS). The study grouped students into a set of clusters using data from the first half of the semester and 6 key characteristics: the initial assessment score percentage, the total number of assessments, the average days between assessments, the number of days since the initial assessment was taken, an average percentage score increase between assessments, and students' final assessment

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