Adaptive Learning Pedagogy for Universal Design for Learning and Multi-Modal Training

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Traditionally, students or trainees usually receive training through a unidirectional instructional approach that can lack interactive activities or through a single material source in classrooms. Therefore, it is possible that some trainees might encounter a sink-or-swim situation if they are not able to understand the materials presented during classroom lectures nor execute correct procedures during laboratory sessions with time-intensive training. To address this issue, the Universal Design for Learning (UDL) asserts that trainees can increase their performance if instructors can provide the trainees with diversified means of information representation, expression opportunities, and engagement means. However, we lack the framework on how to adapt and integrate the process of evaluating the trainees' learning styles with the UDL principles, especially in the context of time-intensive tasks such as air traffic control training. In this article, we propose an adapted framework that (1) utilizes the Index of Learning Styles (ILS) based on categories such as perception, input, processing, and understanding, (2) maps the UDL methods with the ILS outcomes, and (3) provides possible approaches to address any issues with the teaching materials. The developed approach might be used to investigate whether and how we could enhance the air traffic trainees' performances at the Federal Aviation Administration (FAA) Academy with minimum need to elongate the training time. The proposed approaches were benchmarked with a small group of qualified Aviation students at the University of Oklahoma who are preparing for the FAA training program to see whether we could find ways to support their learning styles given the time and resource constraints. This preliminary research provides a foundation to improve our approaches when we investigate the learning styles of the trainees' at the Federal Aviation Administration (FAA) Academy in the near future.

I. INTRODUCTION

The Federal Aviation Administration (FAA) has been searching for effective ways to train a large number of air traffic control specialists (ATCSs) to fill the growing number of vacant positions; however, it has been challenging to increase the trainees' passing rate. It might be possible that the traditional ways of teaching (e.g. using a single information display type such as text summarized in PowerPoint slides, providing information using a fixed format that prevents customization based on each trainee's needs, or being unable to provide multiple means to engage in activities or manage anxiety) can affect the performance of the trainees if diversified needs among the students exist. For example, some trainees who are identified as "average" might show similar performances regardless of whether the information is presented visually or verbally; however, other trainees might perform exceptionally well when visual information is presented but perform poorly when auditory information is played. If a course was taught using mostly verbal instructions, then those other trainees would not perform well unless they are provided with appropriate scaffolding techniques that might give them time to adapt.

To address the students' needs, the concept of Universal Design for Learning (UDL) was introduced to provide as many diversified teaching methods as possible based on three classifications (i.e. information display methods, action and expression methods, and engagement methods) (Hall, Meyer, & Rose, 2012; Hitchcock et al., 2002; Rose, 2000; Rose & Meyer, 2002). The UDL approaches have been applied not only in K-12 classrooms (Hall, Meyer, & Rose, 2012; Edyburn, 2010; Rose, Meyer, & Hitchcock, 2005) but also in postsecondary education (Dean, Lee-Post, & Hapke, 2017; Schelly, Davies, & Spooner, 2011; Morra & Reynolds, 2010; Rose et al., 2006). However, creating such diversified materials takes much time and effort; therefore, we might need a better approach to reduce those efforts while still obtaining similar increases of performances.

One of the approaches that might reduce the efforts of developing UDL-based materials is to identify the preferred learning styles of the trainee population. While many models of learning styles exist (Hawk & Shah, 2007), the Index of Learning Styles (ILS) is unique in its approach. The ILS divides student characteristics largely based on four classifications: perception, input, processing, and understanding (Felder & Silverman, 1988; Felder & Soloman, 2000; Felder & Brent, 2005), and the learning styles of the student can be assessed through asking approximately forty binary choice questions (Felder & Soloman). Accordingly, some general teaching guidelines are provided based on each classified learning style. This is a highly respected model that has been applied to a diverse range of areas, some of which include adaptive e-learning systems (Hwang, Sung, Hung, & Huang, 2013), graduate nursing programs (Gonzales et al., 2017), and even web-based educational gaming (Khenissi, 2016).

Although UDL and ILS are very closely related, there is no clear mapping process among the three classification of UDL and the four classifications of ILS. If we can better map the classifications, we would be able to effectively identify and address possible issues with the traditional teaching approaches to save the cost, time, and effort to develop the materials to increase the students' performance.

The next sections provide some more insights on ILS and UDL. Then, the framework to map the ILS classifications with the UDL classifications is presented followed bycase study including some students who are preparing to qualify for training at the FAA Academy. Finally, the results are discussed in the context of ATCS training methods followed by the capabilities, limitations, and future research topics regarding the proposed framework.

A. Learning Styles

Felder and Silverman (1988) published one of the most widely cited pieces of work on the topic of learning styles. In it, they outlined four learning style dimensions and developed a web-based questionnaire called the *Index of Learning Styles* (ILS) designed to determine one's learning style preferences. The proposed model includes the following learning styles: active/reflective, sensory/intuitive, visual/verbal, and sequential/global that maps with perception, input, processing, and understanding abilities respectively (Table 1). For example, one student could be a sensory/visual/active/global learner. Originally, the publication also included a fifth dimension – inductive/deductive – but it was later removed as the authors believed that induction is ultimately the "best" method of learning. Then, the appropriate teaching methods were outlined according to each learning style. It is noted that a person can have both traits (e.g. being both active and reflective) with a preference of each trait being mild, moderate, or strong. A summary of the learning styles explained by Felder and Silverman (1988) and Felder and Soloman (2000) is as follows.

Table 1. Felder-Silverman model for learning styles.

Preferred learning style		***Corresponding teaching style***	
Categorization	**Levels**	**Categorization**	**Levels**
Processing	Active Reflective	Student participation	Active Passive
Perception	Sensory Intuitive	Content	Concrete Abstract
Input	Visual Auditory	Presentation	Visual Verbal
Understanding	Sequential Global	Perspective	Sequential Global

Active vs. reflective refers to the method by which information is processed. Active learners prefer active experimentation or discussions to better learn, whereas reflective learners need time to introspectively examine the information. Active learners like to try it out first to see what would happen, whereas reflective learners like to thoroughly think about the processes and consequences first before indulging in experiments. Reflective learners prefer working alone or with those they know well. Active learners might have difficulties attending lectures that do not have interactions or physical activities.

Sensing vs. intuitive refers to the way in which students perceive the information being presented to them. Sensing involves observation and gathering data through the physical senses, whereas intuitive learners prefer an indirect method of perception through insights, hunches, and speculation. Put simply, sensing learners (or sensors) like data and facts, while intuitive learners (or intuitors) like theories and concepts. Sensors are patient with details, good at memorizing facts, and prefer hands-on laboratory sessions. Sensors prefer practical applications and are careful on what they do, whereas intuitors are more innovative and accomplish tasks more quickly. Intuitors can be better at grasping new concepts and are more comfortable with abstractions and mathematical formulations, but they dislike repetition. College engineering courses are designed to favor intuitors because they emphasize concepts rather than facts; however, most engineering students are sensors (Felder and Soloman, 2000).

Visual vs. verbal refers to a student's preferred input modality. Visual learners best remember pictures, images, and demonstrations, whereas verbal learners best learn from written or spoken explanations. Most college-aged students tend to be visual learners while most college courses are taught verbally and teaching materials are written on boards or provided as text-heavy handouts.

Sequential vs. global refers to the way in which students progress toward understanding content. While most college courses are taught very sequentially by following a strict calendar that dictates when to move onto the next subject, some students prefer to learn the major underlying concepts and context before delving into specifics. Sequential learners prefer following logical steps, whereas global learners tend to first try to grasp the whole picture by randomly processing bits of information; then as they learn, they come to a stage when they understand everything at once.

The ILS model utilizes a scaled system to classify each student's learning styles. Each student has preferences in each of these categories and the ILS questionnaire provides a simple yet effective means of determining the learning styles that any particular student tends to favor. There are 44 redundant yet differently expressed questions to assess each learning style classification.

The ILS provides an excellent means to define and measure each student's learning style; however, the suggested teaching approaches are not very specific and are not directly associated with the UDL classifications. The next section describes some details of the UDL classifications.

B. Universal Design for Learning

Universal Design for Learning was originally developed to meet the needs of students with disabilities in the classroom and is still used for such purposes (Fuentes et al., 2016); however, its principles can be expanded to the general classroom to include students of all learning types. This is accomplished by providing flexible means of representation, action and expression, and engagement to students (Rose and Meyer, 2002). UDL understands the different neural networks (recognition, strategic, and affective) that are engaged during learning. Recognition networks dictate the "what" of learning, regarding the content that is displayed to students. These networks assist in finding patterns and making sense of information. Strategic networks are responsible for the "how" of learning; or, they determine the strategy and plan for completing an assigned task. Last, affective networks engage the purpose, or the "why" of learning (Hall et al., 2012). Combined, these networks illustrate how a student perceives information, their strategy to understand that information, and their motivation for pursing an understanding.

The first guideline of UDL, representation, seeks to provide multiple pathways to display information to students. To accomplish this, instructors can provide many examples and counter-examples of strategies and methods for solving a problem. They can highlight critical characteristics to support bottom-up processes and to ease in understanding new information. To scaffold top-bottom processing, instructors can give background information and connect concepts from previous lessons. Multiple forms of media can support the learning styles of many students and provide redundancy to the lesson (Rose and Meyer, 2002). In detail, the first guideline is associated with offering options for (1) relaying perceptual information (e.g. visual and auditory), (2) representing vocabulary, mathematical notations, and symbols, and (3) providing options for comprehension (UDL Guidelines, 2014). Overall, these methods should be flexible and adaptable to the classroom to meet the needs of the students.

The second guideline seeks to provide multiple methods for action and expression, detailing the problem-solving skills a student uses. To develop this proficiency, instructors can show many correct examples of solving a problem so that students can form patterns for answering the problem on their own. In addition, students need many opportunities to practice with feedback to develop the problem-solving approach and apply new skills (Rose and Meyer, 2002). Furthermore, identifying effective interaction means between the instructor and the students, or possibly among the students themselves, is important. In detail, the second guideline is associated with providing options for (1) executing physical actions and communication and (2) developing executive functions to reach long-term goals (UDL Guidelines, 2014).

The third guideline provides multiple opportunities for engagement in the classroom. This includes creating a suitable and adaptable difficulty level to best motivate students. If a task is too easy, students are likely to become bored and disengage; conversely, if the challenge is too difficult, students can become frustrated and give up on learning the material. It is important for students to be able to self-regulate their own progress and set goals for themselves (Rose and Meyer, 2002). In a broader manner, the third guideline is associated with providing methods to (1) promote interest and (2) provide options for sustaining effort and self-regulations (UDL Guidelines, 2014).

Most applications of UDL are realized in the K-12 classroom; however, more research and implementation strategies are being applied to higher education. Means of representation should teach students how to use information beneficially, exceeding expectations of simply having access to information. This includes teaching students how to discover, consolidate, and apply information into the context of learning. Supporting students in expression includes providing review periods, feedback sessions for assignments, and additional readings to supplement class materials. Engagement in higher education allows students to motivate themselves to meet personal learning criteria. Professors can encourage passion for the field of study and give students options with opportunities for self-regulation (Rose et al., 2006). These principles are applicable to online courses in higher education and mobile learning, as well (Dell, Dell, & Blackwell, 2015; Tobin, 2016).

An issue with implementing the UDL methods is that they require substantial cost, time, and effort to provide all the diversified ways of learning. In addition, the FAA has a policy to provide the same materials and instructional guides to the students; therefore, an instructor is not allowed to apply different teaching methods based on the individual student's needs. Furthermore, the UDL approach takes more time to teach compared to the traditional approach due to the multiple sources of teaching materials and interactions required; however, the ATC trainees go through intensive training and the instructors have limited time. Therefore, we need to adapt the implement procedures of the UDL methods in order to accommodate those constraints.

II. PROPOSED APPROACHES

The proposed mapping of the learning styles with the UDL methods is provided in Tables 1, 2, and 3. Tables 1 and 2 show the specific implementation examples based on the mapping. Table 1 provides the mappings for information representation and comprehension of UDL, and Table 2 provides the mappings for action and expression of UDL. Table 3 only provides the examples of the engagement of UDL since all learning styles would be able to benefit from such engagement options.

It is important to note that we can easily develop ways to address the combinations of the learning styles using the proposed mapping approach. As an example, for visual and sequential learners, we can provide them with visual prompts for each step in a sequential process. For active, sensing, global learners, we can have the students to form a study group, brainstorm specific examples, and perform a what-if analysis. The proposed tables enable us to effectively combine implementation examples based on the four learning style classifications.

Next, the proposed adapted implementation procedure is provided in Figure 1. The procedure is designed to effectively use the time and resources available to implement the UDL methods into the current curriculum. In detail, after assessing the overall learning styles of the student population using Felder and Silverman's ILS, we would identify some of the prominent learning style combinations among all identified combinations. For example, if 70% of the population is active+sensing+visual+global, 30% showing other combinations, then we would first address the needs of the 70% of the population). After, the UDL implementation examples are extracted from the mapped tables; therefore, those examples take the highest immediate priorities for implementation to create the most impact on increasing the overall performance given the limited time and resources. The UDL examples of other less prominent learning style combination would be implemented at a later stage when additional time and resources are available.

Table 2. Proposed mapping of learning styles and UDL method 1 (information representation and comprehension).

UDL	Learning styles	Mapping of UDL and learning styles through practical scaffolding implementations
1.1. Provide options of customize the display of information	(ALL) All types	ALL.1.1.1. Provide options to change the size or contrast of text, figures, graphs, or tables. ALL.1.1.2. Provide options to highlight information for emphasis. ALL.1.1.3. Provide video or audio recordings that allows options (e.g. change speed or volume, toggle caption).
1.2. Offer alternatives to visual information (e.g. figures, graphs)	(VER) Verbal learners	VER.1.2.1. Provide auditory and text descriptions. VER.1.2.2. Provide auditory queues for key concepts. VER.1.2.3. provide text-to-speech software. VER.1.2.4. provide audio clips as needed.
1.3. Offer alternatives to auditory information	(VIS) Visual learners	VIS.1.3.1. Provide additional visual guidance as a scaffold if only verbal guidance is provided. VIS.1.3.2. Provide captions. VIS.1.3.3. Provide speech-to-text software. VIS.1.3.4. Provide video clips as needed.
1.4. Provide scaffolding options for comprehending vocabulary or symbols	(ALL) All types	ALL.1.4.1. Connect vocabulary or symbols that promote connection to previous experience or knowledge. ALL.1.4.2. Highlight how complex vocabulary can be composed of simpler words. ALL.1.4.3. Embed hyperlinks, footnotes, or illustrations to further explain vocabulary or symbols.
1.5. Provide scaffolding options for comprehending key concepts	(ALL) All types	ALL.1.5.1. Show explicit links among the slides, text, and lab sessions (e.g. if a slide is from a text book, then show the narrowed range of the page numbers) ALL.1.5.2. Use analogy and metaphors as needed.
	(ACT) Active learners	ACT.1.5.3. Provide lectures that include problem-solving activities (9pprox.. 5 minutes or less per activity). ACT.1.5.4. Provide material links of real life examples.
	(REF) Reflective learners	REF.1.5.5. Provide occasional pause during lectures and lab sessions. REF.1.5.6. Provide material links that emphasize fundamental understanding,
	(SEN) Sensing learners	SEN.1.5.7. Provide links to facts, data, and observable phenomena. SEN.1.5.8. Provide material links that emphasize specific examples.
	(INT) Intuitive learners	INT.1.5.9. Show the relationships and associated interpretations among the concepts, procedures, and theories.
	(SEQ) Sequential learners	SEQ.1.5.10. Give explicit prompts (or cues) for each step in a sequential process. SEQ.1.5.11. Provide options to change the organization and layout of the class contents. SEQ.1.5.12. Progressively release information (a.k.a sequential highlighting).
	(GLO) Global learners	GLO.1.5.13. Provide options to connect the new class contents with the contents that the students already know. GLO.1.5.14. Provide opportunities to synthesize concepts (e.g. expose them with advanced concepts before the concepts would normally be introduced). GLO.1.5.15. Provide "What-if" questions.

Table 3. Proposed mapping of learning styles and UDL method 2 (action and expression).

UDL method details	Learning styles	Mapping of UDL and learning styles through practical scaffolding implementations
2.1. Provide multiple media for communication	(ALL) All types	ALL.2.1.1. Provide interactive online tools embedded within the teaching materials for effective communication between the instructors and students. ALL.2.1.2. Provide exercises that allow alternative problem solution procedures or actions. ALL.2.1.3. Show progress representations and prompt learners to identify the feedback or advice that they are seeking. ALL.2.1.4. Provide interactive checklists/rubrics and links to multiple examples of how students acted and expressed correct answers.
2.2. Provide alternative ways to express themselves	(ACT) Active learners	ACT.2.2.1. Provide options to create a study group: Members can take turns explaining different concepts to foster discussion or take turns asking/answering questions. ACT.2.2.2. Provide hands on experience examples.
	(REF) Reflective learners	REF.2.2.3. Allow some time to the students to write their own short summaries of the slides, textbooks, and lab session materials.
	(SEN) Sensing learners	SEN.2.2.4. Allow the students to request more examples: Provide free access to the additional examples not explained to them during time limited lectures or lab sessions.
	(INT) Intuitive learners	INT.2.2.5. Allow the students to request additional interpretations of, and relationships among, the concepts, procedures, and theories.
	(VIS) Visual learners	VIS.2.2.6. Provide an opportunity to foster visual imagery (as an intermediate step) before they provide answers or execute actions.
	(VER) Verbal learners	VER.2.2.7. Provide an opportunity to apply the think-aloud method or to paraphrase the procedures (as an intermediate step) before they answer or execute actions.
	(SEQ) Sequential learners	SEQ.2.2.8. Provide feedback through having them express their logical steps or critical thinking processes.
	(GLO) Global learners	GLO.2.2.9. Let the students first devise their own methods for solving problems rather than forcing the instructor's strategy.

Furthermore, the approach will enable us to better identify the more critical mismatches between the learning styles and the current teaching methods based on the prominent learning style combinations of the student population. For example, if it turns out that the majority of the students are visual learners but most of the laboratory sessions are provided verbally (e.g. verbal intensive communications during enroute or terminal simulation sessions), then we can apply the mapped UDL examples into the laboratory settings by providing a visual aid as a scaffold until the students fully adapt to the environment. It is noted that we want to emphasize less on the individual burdens that might increase for each instructor, but more on implementing the UDL methods into the teaching materials (e.g. developing software that supports UDL) so that the students are empowered to choose different learning options based on their needs. In other words, a “universal” implementation is required so that all students have the opportunity to equally access the UDL-based materials and interaction approaches which will meet the requirements of the FAA’s training policies.

Table 4. UDL method 3 (engagement) classifications regardless of learning styles

3.1. Provide options for recruiting interest	3.1.1. Provide what challenges are to be expected and what are the types of awards or recognitions available per area and/or topic. 3.1.2. Provide checklists, sticky notes, and electronic reminders for them to follow up during the training process. 3.1.3. Allow the students to create their own expectations and necessary activities. 3.1.4. Provide tasks that require active participation, exploration, and experimentation. Passive learning does not help any learning styles. 3.1.5. Encourage division of long-term goals into short-term objectives. 3.1.6. Demonstrate the use of available technology and information access/customization methods.
	3.1.7. Vary the levels of novelty or risk. 3.1.8. Vary the levels of sensory stimulation. 3.1.9. Vary the degrees of freedom for acceptable performance. 3.1.10. Address language barriers and cultural differences.
3.2. Provide options for sustaining effort and persistence.	3.2.1. Provide frequent, timely, and specific feedback with emphasis on identification of patterns of errors, efforts, and improvements rather than relative performance. 3.2.2. Provide self-regulatory prompts, guidelines, rubrics, checklists to reduce stress and aggressive actions in response to frustration. 3.2.3. Provide feedback on strengths and weaknesses.
3.3. Provide options for self-regulation	3.3.1. Provide scaffolds or feedback to the students so that they can seek emotional support, cope with schedules, and apply natural aptitudes (e.g. having them think "how can I improve on this topic?" rather than "I'm not good at this topic") 3.3.2. Provide scaffolds so that the students can monitor their own progress (e.g. charts, feedback notes). 3.3.3. Create school-wide programs to support positive behaviors.

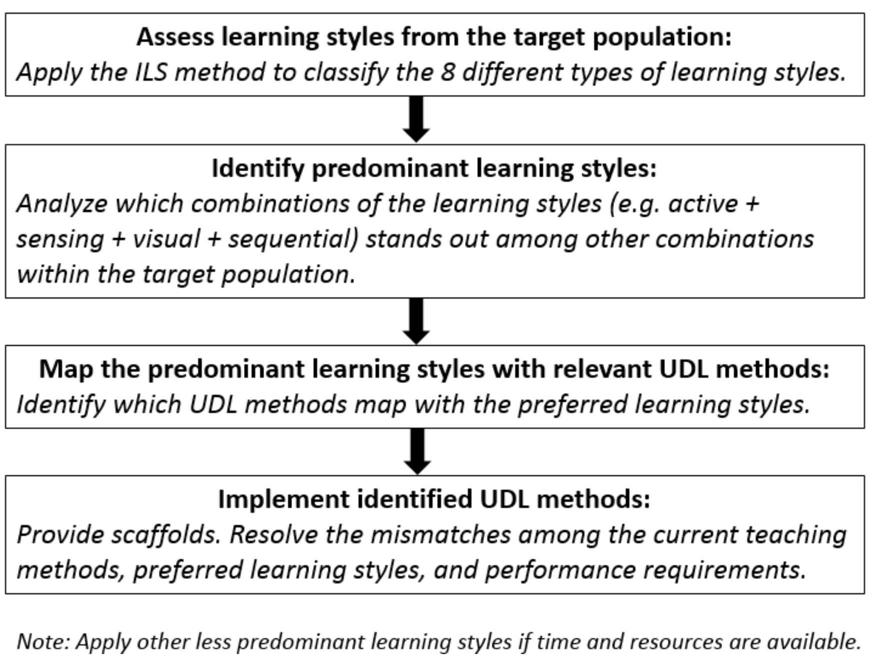

Figure 1. Proposed adapted implementation approach.

III. CASE STUDY

In order to benchmark the effectiveness of our proposed approach, an experiment was performed with a small group of four qualified University students at the University of Oklahoma (OU) Aviation Laboratory with the goal of identifying methods to better and more efficiently train ATC candidates. The purpose of the case study was to verify whether our proposed approaches would indeed be effective and identify possible ways address the small, but an important, group's needs. In addition, it is important to note that the proposed approaches would show different mapping results with different sets of student population.

Learning style assessments and classroom observations were conducted to determine which UDL methods should be implemented with highest priorities and how the UDL methods are implemented in the current curriculum.

With the support of the Department of Aviation at OU, four students with mean age of 21.2 (*S.D.* = 1.3) who have been preparing to enter the FAA Academy training program participated in the learning style assessment. The students were taking courses such as AVIA 4013 En-Route Radar Lab, AVIA 4023 Tracon Radar Lab, and the AVIA 1013 Intro to Air Traffic Control classes at the OU Aviation Laboratory. In addition, classroom observations were conducted by two analysts to see whether and how any of the UDL methods were already being applied.

For the learning style assessment, the students were given the ILS questionnaire to determine their preferred learning style. Sample ILS questions are provided in Table 5 based on each classification. We strictly followed Felder and Silverman's ILS approach (1998). The ILS approach provides 44 questions (11 per classification); then for each classification, subtracts the tallied number of answers that relate to one learning style (e.g. verbal) from the higher tallied number of answers that relates to the other learning style (e.g. visual). If the subtracted amount is positive, then the person is classified as a visual learner; otherwise, a verbal learner. For example, out of 11 question for the "input" classification, if a student provides 9 answers that relate to visual and 2 answers that relate to verbal, then the 9-2 returns a positive 7; therefore, the student is classified as a visual learner. To better analyze the ILS evaluation results, we first applied the aggregation procedure provided by Feldman and Silverman. In addition, we applied statistical tests to identify whether there would be significant differences between the learning styles within each of the classification using the tallies of the students' answers per learning style. Finally, we identified the prominent learning style combinations and identified the mapped UDL methods for those learning styles.

For the classroom observation, the two analysts attended several classes and observed how the lectures and laboratory sessions were being taught. The analysts observed from the back of the classrooms and simulation rooms in order to minimize any possible distraction. These observations were instrumental in identifying the current teaching methods being applied in the classroom.

Table 5. Sample ILS questions and classifications: Following Felder and Silverman's ILS evaluation guidelines, a total of 44 questions were asked.

Sample question		**Classification**
I understand something better after I	a) try it out	Active
	b) think it through	Reflective
I prefer to study	a) in a group	Active
	b) alone	Reflective
If I were a teacher, I would rather teach a course	a) that deals with facts and real life situations	Sensing
	b) that deals with ideas or theories	Intuitive
In reading nonfiction, I prefer	a) something that teaches me new facts or tells me how to do something	Sensing
	b) something that gives me new ideas to think about	Intuitive
When I think about what I did yesterday, I am most likely to get	a) a picture	Visual
	b) words	Verbal
When I get directions to a new place, I prefer	a) a map	Visual
	b) written or verbal directions	Verbal
It is more important to me that an instructor	a) lay out material in clear sequential steps	Sequential
	b) give me an overall picture and relate materials to other subjects	Global
When I solve problems	a) I usually work my way to the solutions one step at a time	Sequential
	b) I often just see the solutions but then have to struggle to figure out the steps to get to them	Global

IV. CASE STUDY RESULTS

Again, the purpose of the case study was to verify whether our proposed approaches would indeed be effective and would lead to identifying possible ways address the small group's needs associated with the classroom observations at the Department of Aviation at OU; therefore, the proposed approaches would show different mapping results with different sets of student population. It is important to note that the purpose of this results section is to show the analysis procedure of the proposed approaches rather than showing a generalize outcome of a student population.

The results of the ILS approach are provided in Figure 2. We can see that the majority of the participants preferred active, sensing, visual, and global. To better understand the similarity of the students' learning styles, the detailed assessment results are created into a tree shown in Figure 3.

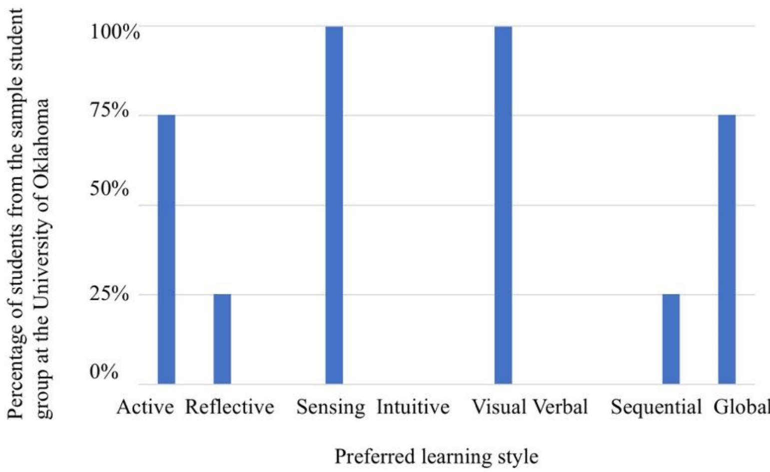

Figure 2. Percentage of OU Aviation students with assessed learning style using the ILS approach (N=4).

Based on the results we can determine that there are two distinctive preferred learning styles: (1) type VSSR: Visual+Sensing+Sequential+Reflective and (2) type VSGA: Visual+Sensing+ Global+Active. Note that the type names were given arbitrary using the initials of the identified combined learning styles. Using Tables 1 and 2, the mapped UDL implementation examples for the type VSSR are VIS.1.3.1.-1.3.4., VIS.2.2.6., SEN.1.5.7.-1.5.8., SEN.2.2.4., SEQ.1.5.10-1.5.12., SEQ.2.2.8., REF.1.5.5-1.5.6., and REF.2.2.3. Similarly, the mapped UDL implementation example for the type VSGA are VIS.1.3.1-1.3.4., VIS.2.2.6., SEN.1.5.7.-1.5.8., SEN.2.2.4., ACT.1.5.3-1.5.4., ACT.2.2.1.-2.2.2., GLO.1.5.13-1.5.15 and GLO.2.2.9.

Since two of the four students are of type VSGA, we would first choose to implement the UDL examples for type VSGA followed by type VSSR if time and resources are allowed. It is noted that the UDL examples that maps with "all types" should be implemented in one way or another regardless of the learning styles.

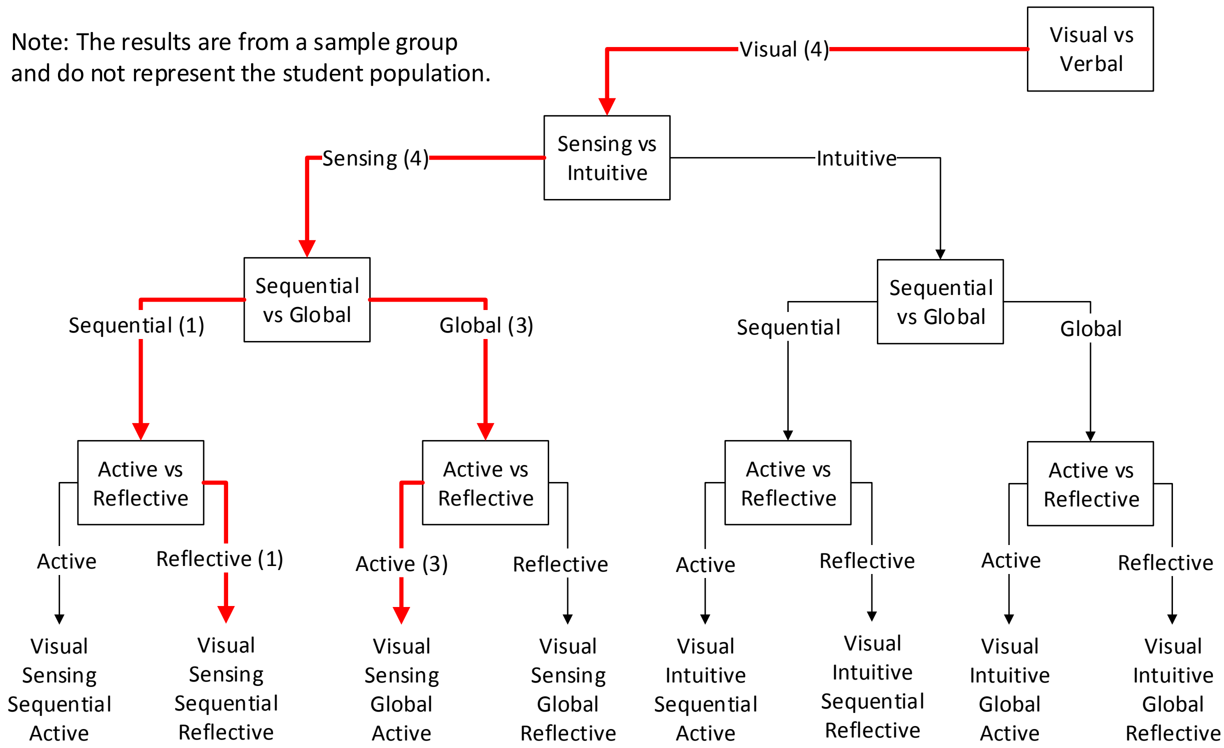

Figure 3. Details of the learning styles assessment results of the OU Aviation students

Statistical analysis of the tallied number of responses within each learning style classification for the four students showed a different outcome of the mapped UDL examples. The plots based on the number of responses for each learning style the students answered are provided in Figure 4 below. A couple of learning style classifications such as active/reflective and sequential/global seemed to be much more balanced whereas other learning style classifications such as sensing/intuitive and visual/ verbal showed noticeable differences. Specifically, Mann-Whitney-Wilcoxon tests showed if the students overall favored one learning style over another. For the active/reflective classification, students did not favor either style (p =

0.47, W = 21.00). For the sensing/intuitive classification, the results were marginally significant as students favored sensing (p = 0.06, W = 26.00). For the visual/verbal classification, the results were marginally significant as students favored visual (p = 0.06, W = 26.00). For the sequential/global classification, students did not favor either style (p = 0.44, W = 17.00).

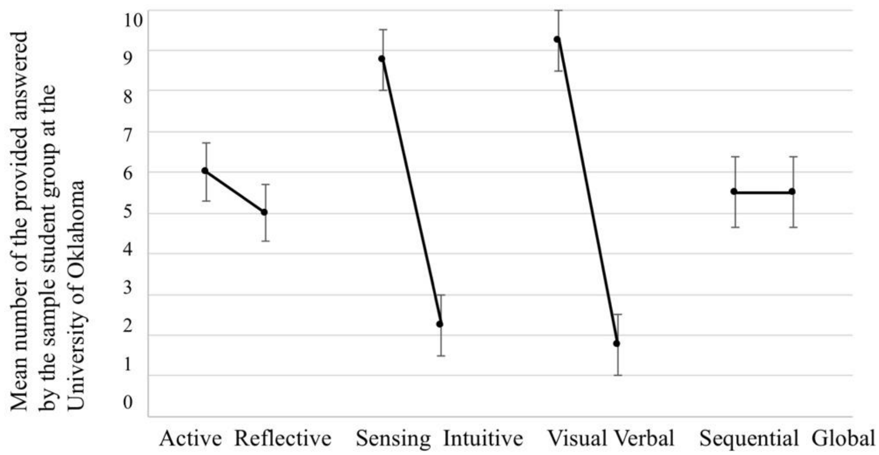

Figure 4: Plot of means and standard errors

The statistical test indicated that the biggest mismatch of teaching style vs. learning style might arise from sensing/intuition and visual/verbal classifications. In this case study, the statistical analysis results indicate that we should focus more on addressing the issues of sensing and visual learners; therefore, the mapped UDL examples are narrowed down to VIS.1.3.1-1.3.4., VIS.2.2.6., SEN.1.5.7.-1.5.8., and SEN.2.2.4. which should take highest implementation priorities over others if those UDL examples have not been previously implemented into the teaching curriculum. Since no significant differences were found in other classifications, the effect of implementing the UDL example of one learning style over another would be less than those identified as the highest priorities.

Classroom observations at the Department of Aviation at OU showed that some of the UDL methods were already well implemented while some other were not as evident. The detailed classroom observation results based on the UDL methods are as follows.

Methods of representation at the OU Aviation Laboratory featured traditional PowerPoint lectures (AVIA 1013) and simulations (AVIA 4013 and AVIA 4023). The AVIA 1013, Air Traffic Basics, class was taught with PowerPoint lectures of phraseology and images to accompany the verbal lecture. The PowerPoint came with audio cues that tested the students' ability to say the phrase while they were studying. The instructor interacted with the students, having them repeat phrases back to him to create a stronger mind-to-mouth connection. To ease in understanding more complex concepts, the instructor used the whiteboard to illustrate and highlight important details that better answered the students' questions. Last, the PowerPoint slides were made available on Canvas, an online file storage for classes, for student review. The TRACON and enroute simulation classes provided visual scenarios to students as a direct application of the material previously covered in classes. Students had to give an auditory response to the visual components, activating multiple pathways. Students in both classes used the 7110.65 Air Traffic Control Manual that features rules and phraseology for the field. It is mostly text, and it seemed that the students found it difficult to understand and learn without application in the classroom simulations. Additionally, students used LiveATC—a live broadcast of ATC towers across the United States.

Next, the means of action and expression were observed in the classroom. In the Air Traffic Basics course, the instructor gave examples to help the students distinguish between concepts, such as when to use "nine" or "niner." The instructor interacted with the students, asking them questions and testing their understanding of the material throughout the lesson. Students also took a 10-question short-answer quiz at the beginning of class that reviewed material from previous lectures. The instructor then reviewed the answers with the students after the quiz by calling on each of them to provide an answer. In the simulation classes, the students had a very high level of instructor feedback. In these classes, there were two instructors and a lab technician for three students. The instructors sat behind the students asking questions and giving instructions as the students ran through the simulation so that the students could organize their thought processes for the actions they were taking. They also had the ability to pause the scenario and clarify any confusion the students were experiencing. The students frequently asked questions of the instructors when they encountered a problem that was difficult to mitigate. Also, students had the option to practice in the lab on Fridays for a couple of hours. Instructors were available for the session to run the simulations for the students. The students also were given time to practice scenarios with each other during the class, pretending to be the plane and controller to better practice the phraseology.

For fostering engagement, at the beginning of the ATC Basics course, the instructor reemphasized the importance of the lecture. Because the lecture featured material the students had seen before, he understood their tendency to zone out. However, this lecture applied the previously learned phraseology and could provide challenges to students if they did not pay closer attention. Also, the interactive quality of this lecture also helped students to pay better attention and to focus during the class period.

V. DISCUSSION OF THE PROPOSED APPROACHES AND CASE STUDY RESULTS

The proposed approaches showed promise in identifying the highest priorities of the UDL methods that should be applied by identifying the preferred learning styles of a student group. If the size of the student group is big, then we would be able to first apply the UDL methods that would map with the dominant preferred learning styles. If time and resources are allowed, then we would address the lesser dominant styles. To better address the issues with learning styles, the mapped tables of learning styles and UDL methods proposed above can be used as a checklist to systematically identify the gaps and address those gaps given the limited time and resources.

It is important to note that the proposed approaches should be applied to every batch of new students since their dominant learning style might differ from others. Furthermore, the learning styles should be evaluated multiple times periodically since some students might have changed their preferred learning styles over the years of training.

The results from both the learning style mapping and the classroom observations at the Department of Aviation at OU indicate that there are already many UDL principles being implemented into the teaching curriculum and there can still be room for improvement further support the students' learning styles using the proposed matching approach. We can provide visual learners with scaffolding options such as introducing visual support tools when they verbally interact with the instructors during the laboratory sessions. For example, we could provide a separate monitor for the students to interact with the materials learned during class (e.g. PowerPoint slide notes) if they struggle understanding the verbal instructions provided by the instructor(s). In addition, sensing learners might benefit from going through many more example scenarios during their own time if the scenarios that they learn during the laboratory sessions are not sufficient to them. A scaffolding system that allows additional examples for the students to review (e.g. a software that can show the video recordings of the additional scenarios along with visual guidelines of how issues are addressed). As the students adapt to the verbal communications with the instructors and better understand the structure of the laboratory examples, then the scaffolds could be gradually removed.

The contributions of this case study are (1) developing a specific mapping approach between the learning styles and UDL methods that leaves out possible vagueness, (2) proposing an implementing approach to first address the needs of the dominant learning tendencies of a student group that can be expanded to a student population, and (3) validating the capabilities of the adapted approaches. The examples laid out above are limited to better address the needs of the dominating preferred learning styles of the students who participated in the case study. Although the sample size was small, it was sufficient to evaluate the capabilities of our proposed evaluation approaches. It is important to note that if the characteristics of the population change, then the mapping results will be different. The proposed mapping approach and implementation process provide a foundation to effectively address the needs of the student population who might show specific tendencies of their preferred learning styles.

VI. LIMITATIONS AND FUTURE RESEARCH

Although we mapped the learning styles with the UDL methods to provide practical scaffolding implementation examples, there is much more room for improvement. Some of them include identifying as many implementation examples as possible, mapping the examples to the actual teaching materials (e.g. providing more specific examples using the contents within the current teaching course slides), and accommodating other factors such as diversified populations or language barriers.

In addition, the case study served the purpose of evaluating our mapping and implementation approaches; therefore, the outcomes support only the needs of the participants and should not be used to generalize the whole student population. Therefore, in order to provide a more generalized outcome from applying our approaches, we have currently received permission to interact with the FAA Academy trainees and instructors. Interviews and learning styles assessments are currently being conducted.

Furthermore, it is possible that the characteristics of the students who are entering the training program have been drastically changing due their exposure to technology such as cell phones or virtual reality devices. They are comfortable with using technology and there has been research that the use of such technology can improve performance (Goyal, Yadav, & Choubey, 2012, Strangman, Hall, & Meyer, 2003; Bacca, Baldiris, Fabregat, & Graf, 2014; Merchant et al., 2014; Hew & Cheung, 2010; Farrokhnia & Esmailpour, 2010). However, we do not know whether the application of the technologies will benefit the trainees at the FAA Academy; therefore, we need to investigate the possibilities of intertwining the learning styles, UDL, and the advanced available technologies (e.g. eye tracking embedded into wearable immersive VR devices) in the context of technical training. Application of the UDL and learning styles with the use of technology can be instrumental in creating a framework that can be applied to the training solution for the FAA.

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