Instructional Design for Developing Informatics Competencies

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Abstract: *This paper describes a brief overview of an instructional design in the Informatics discipline, which is based on the SOLO taxonomy, Bloom's taxonomy, ASSURE instructional design model, Honey and Mumford learning style questionnaire, and flipped classroom strategy. The purpose of implementing this instructional design is to promote personalised and differentiated learning, develop competencies in the informatics discipline, and increase the students' results. The learning activities were differentiated according to the student's learning style, as it is important in teaching to take into consideration the student's learning preferences just at the beginning of the instructional design. It investigated the instructional design effects on the teaching process and student acquisitions framework in order to improve learning. By implementing the flipped classroom strategy, the students become more active, engaged in the learning tasks, and have a higher responsibility for their learning. The result shows the impact of the described instructional design and its pros and cons.*

Keywords: Instructional design, Informatics competencies, ASSURE model, BLOOM's taxonomy, SOLO taxonomy.

1. Introduction

Today, technologies are part of the educational process, as we are in an increasingly complex digital age. Due to the Covid-19 pandemic and the transition of the educational process to online format, technologies are used in education on a much wider scale than before. During the pandemic time, huge improvements have been made in the technologies and applications offered for use in education, as well as advances in teachers' understanding of how to use these opportunities to promote and facilitate learning. Certainly, teachers gained more confidence in technologies and have used them to lighten their workload, to improve teaching and to facilitate learning. Thus, the instructional design has developed greatly. It was adapted to contemporary requirements and emerging trends as well as future opportunities of students that tend to form the competencies within the discipline

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students need to integrate into society. All systems in society require specialists who could easily integrate and adapt to the rapid changes that occur due to technologies, who could learn continuously and approach things critically. Therefore, the instructional design presented in this research bases on the learner-centred paradigm, the effectiveness of the educational process and the student's intrinsic motivation, developing to students the self-instruction of their own learning. The students will be able to manage their own instructional process by themselves guided by the teacher.

According to Gagne (Gagne, 1992, p. 3), the instructions are "a set of events that affect learners in such a way that learning is facilitated". Branch (2018, p. 23) emphasises the instructional design as "a system of procedures for developing education and training materials in a consistent and reliable fashion". Both interpretations are focused on a design to accomplish a goal of learning and have a direct effect on students' learning. The goal of instructional design is "to make learning more efficient, more effective, and less difficult" (Morrison et al., 2019, p. 4), determine the relevant content and techniques, and improve the students' performance in the most effective and efficient manner by solving an instructional problem. Currently, although we have a competency-based curriculum, many teachers often approach the instructional course design from the perspective of content, determining what needs to be covered in the allocated time. Instead, an instructional designer approaches the task by first defining the problem, identifying learning needs, and establishing students' learning style and their level of knowledge, applying the initial tests, learning style questionnaires, and formative assessments. Subsequently, it provides insight into the designed course revision and after that, determines what knowledge, skills, techniques, and methods are needed to solve the instructional problem and avoid including irrelevant content and spending extra time. Therefore, the instructional design is founded on "what we know about learning theories, information technology, systematic analysis, educational research, and management methods" (Morrison et al., 2019, p. 8). Further, Branch (2018, p. 23) considers instructional design as also founded on the general systems concept, which is described as being "systematic, systemic, responsive, interdependent, redundant, dynamic, cybernetic, synergistic, and creative". These features allow a systems approach to facilitate the complexity of an instructional design in order to increase learning outcomes by requiring diverse implementations of the components that form the system.

Regardless of the discipline teachers deliver or the locations in which they teach, their success depends on their own ability to design effective instruction adapted to the individual and shared learning needs of students. Although an unprecedented variety of powerful teaching resources are available online, i.e. educational courses, educational games, educational platforms, educational software, podcasts, etc., they are only effective if teachers know when to use them and how to facilitate learning using them.

The trends of the 21st century and their influence on the education of contemporary students demand a change in the field of education. Hence, teachers, who will act as educational designers, are needed. Success teachers require the skills of an educational designer to approach instruction with clear purpose and objectives, and to identify and frame instructional challenges, using a broad repertoire of instructional models, strategies, and technologies. According to Kilbane and Milman (2014, p. 4), an educational designer involves a new mindset, a wide skill set, and a high-quality tool set. They emphasise the new mindset enables a teacher to approach the practice with augmented control over relevant aspects of the instructional process; the various skill sets include systematic approaches to instructional planning and assessment processes; the high-quality tool set encompasses a collection of powerful models, strategies, and technologies for teaching. Thus, the teachers will be able to effectively support various students, coordinate the many resources available for teaching, and adapt and implement instruction flexibly in contemporary classrooms.

2. Instructional Design Model

During the pandemic, teachers began to use technologies much more often in the educational process to make teaching and learning possible. Although it has returned to a classroom teaching-learning regime, teachers continue to make their work easier by taking advantage of the possibilities offered by technology. Despite all these opportunities, education still faces some deficiencies as the inefficient use of technologies in accordance with the specific contents, needs of the students, their attitudes, and their interest. Morrison et al. (2019, p. 5) state that instructional design is “a process for solving skill and knowledge deficiencies”, for overcoming educational lacks, and for facilitating learning using technology, as educational technologies are at their means. Burlacu (2012, pp. 235-241) emphasised an approach to instructional design in the digital age, based on educational software. Therefore, well-designed instruction helps teachers to elaborate more suitable activities in accordance with students’ needs.

The instructional design, presented in this paper, aims to detect deficiencies that directly affect student performance at the Informatics lessons in the Lyceum "Spiru Haret" from Chisinau, the Republic of Moldova, and then use a systematic process to design instruction to acquire more efficient and effective outcomes than in regular learning. Thus, in this study, the ASSURE learning model was applied. The ASSURE instructional model consists of six stages, i.e. Analyse, State, Select, Utilise, Require and Evaluate (ASSURE), which require to follow for creating effective learning and teaching.

2.1. Analyse Learners

The first stage in planning provides a systematic approach for analysing student characteristics that influence their ability to learn. According to Smaldino

et al. (2005, p. 49), the students' analysis consists of the general characteristics, specific entry competencies, and learning styles. The analysis information is used to design the lesson plan for learning conforming to the needs of every student. Thus, in accordance with the Education Code of the Republic of Moldova (2014, p. 18), Article 31, the students from "Spiru Haret" lyceum are organised in science and humanities profiles, and level classes as K-10, K-11 and K-12. In order to benefit from instruction, diagnostic tests were applied in each class at the first Informatics classes or at the beginning of a new module to determine the specific possessed level of skills and knowledge of each student. The identification of the specific entry students' competencies is a decisive component of designing lessons and help teachers to design more appropriate activities to the student's needs. It can also be done in an informal way, by asking questions to students in class.

However, to increase the involvement of students in the learning process and to design the activities and assessments for achieving the goals, it was taken into consideration the appropriate student's learning styles. Honey and Mumford's learning style questionnaire was applied at the beginning of the academic year. The questionnaire categorises students as theorists, activists, pragmatists, and reflectors. Although most students have characteristics of all four types of styles, Honey and Mumford's questionnaire helps them to find out which predominant learning style they own, completing the 80 statements, 20 of which are related to each type. The results of the questionnaire help teachers design activities appropriate to students' needs to improve their achievements, and classify and organise students in efficient working groups, thus differentiating learning tasks. In addition, the Mint Human Resources provides to complete online the Honey and Mumford's questionnaire, English version. At the end of the accomplishment, the platform displays the accumulated score for all four types of style.

Pritchard (2009, p. 43) highlights the Honey and Mumford styles by giving a description of each one. He relates activists as learners who prefer to practise new experiences and activities rather than to read, listen, or plan; reflectors as learners who prefer to stand back and observe, to collect data painstakingly, including previous experiences and the ideas of others, before reaching any conclusions or decisions; theorists as learners who prefer to adapt and integrate all of their ascertainment of new information into new or existing frameworks of understanding, determining the relationship between their and others' observations, therefore, they are highly successful in problem-solving approaches, taking logical and one-step-at-a-time approach; pragmatists as learners who prefer to seek out and use new ideas before making a judgement on their value, and therefore, they are highly successful in problem-solving situations.

Therefore, on the one hand, knowing the student's learning styles, the teacher can differentiate the tasks so that each student is actively involved in the educational process, effectively conducting the activity when working individually. On the other hand, by grouping students into work groups in accordance with their learning styles, we could encounter impediments according to the insufficient

number of students with the same learning style, while the activity planned requires group work. In these cases, these "unpaired" students are joined to the work group appropriate to the second dominant learning style.

2.2. State Objectives

In the second stage of ASSURE model (Smaldino et al., 2005, p. 53), the teachers have to state the goals and objectives as accurately as possible into a more focused and delimited form, linked to a subject content and its curriculum, and specify the degree of acceptable performance. The instructional goals and objectives are highly significant in both the instructional process and the assessment process, being guidelines for both teachers and students. The goal points out what students have to achieve. Thus, the objectives describe the expected learning performance by showing progress toward the intended goal and they help both teachers and students focus their attention and efforts, and allow instruction to be more relevant and effective. Objectives help students best organise their time and effort. In Mager's view (1997, p. 31), useful objectives include performance, describing what the student is expected to do, conditions under which the performance is expected to occur, and criteria, which describe the level of competencies that must be reached.

Accordingly, in the case of this experiment, the SMART framework, established by Doran in 1981 (p.36), was used to create the instructional objectives. It helps teachers to define Specific, Measurable, Assignable, Realistic, and Time-related (SMART) objectives. The objectives, formulated by using the SMART framework, are specific to the improvement content, precise and clear for students; measurable, which suggests an indicator of progress; assignable, which specifies who will achieve it; realistic, which states what relevant results can really be achieved by given available resources; time-related, which specify when the result can be achieved (Doran, 1981, p.36). However, to formulate the objectives, measurable verbs such as those associated with BLOOM's taxonomy and SOLO (Structure of the Observed Learning Outcome) taxonomy were used. The cognitive dimension of the reviewed BLOOM's taxonomy is organized into six categories (Anderson et al., 2001, p. 5): (1) Remember; (2) Understand; (3) Apply; (4) Analyse; (5) Evaluate; and (6) Create, while SOLO taxonomy, it has five aspects which are: (1) Prestructural – no idea; (2) Unistructural – one idea; (3) Multistructural – many ideas; (4) Relational – relate ideas; (5) Extended abstract – extend ideas (Biggs & Collis, 1982, p.36). Anderson et al. (2001) defined each category of the cognitive process dimension of BLOOM’s taxonomy in detail, making comparisons with other cognitive processes, and reuniting cognitive processes with knowledge. According to their interpretation (Anderson, 2001, p.66), each instructional objective should be formulated by preceding the phrase "The student is able to ..." or "The student learns to...", followed by a measurable verb. A list of measurable verbs for each category of the cognitive dimension was also specified by the authors.

In this experiment, the flipped BLOOM's taxonomy was used. For instance, in the topic "Loop statements", i.e. For loop, While loop or Repeat loop (Pascal programming)/Do ... While loop (C/C++ programming), students will receive a sheet with a program sequence. The code sequence will make a continuous repetition of the code using the "goto" statements. The resumption will be stopped with the "if" statement, checking a condition and redirecting the execution either to repeating the run of the code or to the end of the code, interrupting the execution.

In the case of this task, the SMART objective is based on BLOOM's taxonomy and will be formulated as follows: The students will be able to rewrite the program sequence in five minutes, using at least one type of loop statement, i.e. For loop, While loop or Repeat/Do ... while loop. This objective is specific to the subject and, therewith, it is clear what the students have to accomplish.

It is measurable. The quantitative measurement will be the accomplishment of the task using at least one loop statement. However, the student can accomplish the task in three ways, using all three types of learned loop statements. The measurement is also qualitative, the execution of the task being done in the allocated time.

The objective is achievable. It is supposed that at the time when the task was given, all students are able to achieve it, using at least one type of loop statement. If it happens that a student did not complete the task in any way, then the instructional model will have to be reviewed and the instruction redesigned with the intention that all students succeed in completing the task in at least one way.

The objective is also relevant because of the students' involvement in examining the program sequence, in making the transfer of knowledge to rewrite the code sequence, in finding the most optimal way to rewrite the code in the allocated time. Both the objective and the task follow the development of intrinsic motivation by allowing the students to choose the way in carrying out the task. Each student usually chooses the achievement way, which was understood best. Therefore, the teacher can give new tasks that strengthen knowledge where necessary.

In addition, the objective includes a limited time (five minutes) for completing the task. The time to accomplish a task was calculated from the teacher's done task time multiplied by three. Thus, for the achievement of a task for the students, it is allocated three times more time in relation to the time that the teacher need to achieve the task.

Another SMART objective example, however based on the SOLO taxonomy, is as follows: The student will be able to argue in two minutes about what would happen if the While/Do...while statements does not exist, giving at least one real-life example. Before the task, students will watch a short film in which daily life based on actions that require loop statements will be shown. Then the students will have to find an example either from the watched video or from their personal life and to argue the given example. Arguing the necessity of the loop statements, it will give the students much more confidence and motivation for

learning programming. Living in a digitised world, every transaction or authentication requires entering a verification code. This code is obviously checked using the Do ... while statement. There are many other real-life examples that require confirmations, checking passwords, checking whether certain fields have been filled in an online form, etc., where their execution would be much more difficult without the While or Do ... while loop statements.

Therefore, the BLOOM's taxonomy is used mostly to set questions and items, not to evaluate open-ended responses to formulated questions and item types. The SOLO Taxonomy (Biggs &Collins, 1982, p. xi) is "the only instrument available for assessing quality retrospectively in an objective and systematic way that is also easily understandable by both teacher and student" and it may be used as an instructional evaluative tool of student's learning quality. SOLO Taxonomy provides a deeper understanding and learning based on complexity. In Table 1, it is described the specific aspects of BLOOM's taxonomy versus SOLO taxonomy.

Table 1. BLOOM's Taxonomy vs SOLO Taxonomy

BLOOM's taxonomy	**SOLO taxonomy**
A traditional taxonomy focuses on knowledge based on the judgments of the teacher.	It is focused on the teaching and learning processes based on research on student learning.
It refers to the type of thinking or processing required in completing tasks or answering questions.	It refers to the type of structural thinking required in completing tasks by increasing the complexity.
The teacher decides the complexity and difficulty of the activities and creates tasks for accomplishment.	Both the student and the teacher can create new learning tasks involving the complexity of thinking.
It refers more to tasks with increasing difficulty and less to tasks based on complexity.	It refers to tasks based on complexity relating to other knowledge, subjects, and domains. Increasing difficulty is not required.
It is not established the assessment criteria for judging the outcomes of the activity.	It is established explicitly as the assessment criteria for judging the outcomes.
It gives students an ambiguity in the intended purpose and, most of the time, the task is less connected with real-life situations.	It provides students with clarity in the intended purpose and the connection of tasks with real life.

In fact, both taxonomies are useful and help to increase the students' achievements, improve learning, and enhance their involvement in the educational process. In addition, both are easy to adapt to any subject, provide direction to the instructional process, convey instructional purpose to students, and provide a foundation for assessing students' learning.

Because of this experiment, we can say that the activities should be designed with the objectives pursued and the assessment criteria as points of reference. It should not be announced all the lesson objectives at the beginning of the lesson at once, it should be announced before each activity to make students comprehend what skills and knowledge have to be achieved. Thus, we will have a much more productive and efficient feedback and evaluation process. Otherwise, it is a risk that students will complete the task by misinterpreting what was asked of them. These confusions are encountered, most of the time, in learning tasks based on experiments, learning through problematization, learning through discovery, learning based on projects, case studies, and other learning methods that involve a more extensive study.

2.3. Select Methods, Technology, Media, and Materials

In the third stage of the ASSURE model (Smaldino et al., 2005, p. 56), the teachers need to select strategies, technology, media, and materials, which would connect the students to the stated objectives. The process involves selecting the appropriate methods for the established learning tasks, choosing media and technology suitable for accomplishing the method, and selecting, modifying, or designing specific materials for achieving the objectives.

For instance, in this instructional design, it was used a wide range of techniques and methods, i.e. one-sentence summary, think-pair-share, some-minutes (1/2/3/4/5 minutes) paper, as easy as 6 – 3 – 5, input-output, idea links, problem-based learning, Phillips 66, case studies, jigsaw, misconception check, mind mapping, organised random search, classroom opinion polls, infographic, pass the problem, product improvement checklist, jeopardy, etc., as well as media resources such as flip charts, slides, video-tutorial, graphics, posters, animation, simulation, online courses, online discussion, and virtual classes (Google classroom).

Furthermore, a wide range of online tools and platforms was used that facilitate the teaching process, i.e. Kahoot, Google Forms, Quizlet, Mentimeter, LearningApps, LiveWorksheets, Biteable, Fotobabble, Canva, Padlet, Symbaloo, Filmora, QR Generator, Crossword Labs, Wheel of names, Jeopardy Labs, GitHub, etc. Several models, techniques, and methods that would reduce the teacher's workload and improve the educational process were emphasised by Pearsall (2018), VanGundy (2005), and Higgins (1994). The development of a new lesson design asks the teacher to select other strategies, technologies, media, and materials relevant to the topic that could enhance the lesson.

Some selected materials were often modified, and other ones were designed and redesigned to the students' characteristics, as it was not possible to find suitable materials for all topics according to the student's needs and objectives in the online environment. If the students know where they are going, know exactly what they are trying to learn, and have adequate material for learning, then their progress is more accurate and their learning becomes easier and more relevant.

2.4. Utilise Media and Materials

The fourth stage of the ASSURE model (Smaldino et al., 2005, p. 61) concerns making a lesson or activity plan as to how to use the media, materials, and technology that were selected. In this step, it is important to follow the "5 Ps" (i.e. Preview the materials, Prepare the materials, Prepare the environment, Prepare the learners, and Provide the learning experience), applying to either teacher-based or student-centred instruction. The preview materials stage assumes viewing selected materials before using them as instructional materials to eliminate any impediments and gaps. If the needed materials were not found, the teachers have to collect all the materials, media, and equipment that need to carry out the activities and redesign them to secure any necessary additional materials. Prepare the environment stage involves the factors granted for any instructional situation, such as comfortable seating, climate control, a convenient power source, and suitable lighting. Sometimes, it requires a darkened room. Preparing the learners' stage implies defining clearly the learning objectives for students. In addition, the teachers highlight certain specific aspects of the lesson and the assessment criteria. The students have to know about assessment criteria before learning the content. These aspects would increase the students' attention and motivation. Providing the learning experience step involves the effectiveness of the instructional experience. In this research, the activities are student-centred in accordance with flipped classroom strategy. Being limited by class hours, the teacher applied the flipped classroom method, involving students in the design of transmedia learning activities guided by their teacher (Gutu, 2019, p. 241). The flipped classroom method promotes personalised education opportunities, engages and motivates students in their learning, improves the students' achievements, and is easy to apply in any classroom.

2.5. Require Learner Participation

The fifth stage of the ASSURE model (Smaldino et al., 2005, p. 61) requires learner participation. The active participation of students in the learning process enhances their learning. In this step of instructional design, the assessment activities involving self-assessment, peer assessment and co-assessment were planned. The assessment activities help students to recognize their weaknesses and strengths, and to work on areas that need improvement (Gutu, 2022). The self-assessment facilitates self-directed learning and allows students to reflect on their own work by setting achievement goals. Peer assessment enables students to improve their work speed and improve critical reflection on their peers' work by making constructive assessment judgments. The co-assessment leads to deeper learning, improves learning skills, and stimulates the acquisition of the necessary skills. To have more involved students, the activities have to be design as student-centred, be connected with real life, and be provided in a trendy way.

Another approach to actively involve students in the educational process is to apply the flipped teacher approach. The student-teacher will be involved in the

design of the lesson and the activities, and their accomplishment. He will guide the class students in the learning process by giving them descriptive feedback. Therefore, the student-teacher will come to the lesson with the learned content to be able to carry out the lesson. The teacher will monitor the entire course of the lesson and make suggestions when necessary.

2.6. Evaluate and Revise

The final stage of the ASSURE model (Smaldino et al., 2005, p. 68) is to evaluate and revise the instructional design. After instruction, the teachers have to evaluate the impact and effectiveness, methods and media, assess students' achievements, detect the discrepancies between what was designed and what was achieved, and revise the instructional design to improve it. The assessment procedure should correspond to the specified objectives in the second stage of the ASSURE model. Evaluation of methods and media is also very important as they help to deliver information to students. An activity carried out with an inappropriate method can lead to ambiguities and uncertainties. For this reason, teaching methods and techniques must be selected very carefully, as well as how to use them, and adapt them to the various needs of students. The ASSURE instructional model is only successful if it is used consistently to improve the quality of instruction.

The instructional design is based on some questions that the teacher have to ask himself before starting the design, such as: What will the student do? What will the student use this for? What has to happen next? Will students be able to do this differently in a new way? Will this task make students reflect, judge, criticise or hypothesise? What should be highlighted from this topic? Is this the suitable method/technique to provide the information on the topic? etc.

This instructional model described above was applied to Informatics lessons with the aim of developing subject-specific competencies (Gutu, 2022), ensuring active engagement in deep learning, enhancing students' outcomes, and increasing the number of students who choose Informatics as a baccalaureate exam. In the design/redesign of the instruction, it was taken into consideration all the aspects that affected the teaching and learning in this experiment.

3. Instructional Design Pros and Cons

The instructional design described above is a student-centred model, which helps to maintain a greater emotional and safe environment, detect each student's readiness for learning, and increase students' engagement and success. It can be used to design the activities that are carried out in both in-class and online education due to the use of technologies.

This instructional design involves the formulation of clear, measurable, and SMART objectives in accordance with the BLOOM's and SOLO taxonomy for each student and differentiates the learning tasks within the diverse needs of

students and their own learning style, being a considerable advantage in motivating the student in learning. It enhances structural-complex thinking skills and depth of knowledge. It provides an assessment for learning. The instructional design promotes the understanding of goals and assessment criteria by the students, setting future goals for achievements. It can be applied to each lesson or individual activity.

A disadvantage of this instructional model is the increased attention it requires when developing learning activities to maintain a balance between their difficulty and complexity. Obviously, to go through all the steps in designing the lesson or activities, it is time-consuming in stating the objectives and criteria, creating the materials, and selecting the appropriate strategies. However, once the necessary content, needed media, designed lessons plan, assessment criteria, strategies, and technologies suitable for the activities have been found or have been designed, they can be reused many times with some insignificant changes.

Another disadvantage of this instructional design is that some students may not embrace the flipped classroom approach (Gutu, 2018, p. 125) or one of the types of assessment for learning. In this case, the teacher have to have an alternative way for these students.

In fact, after rigorous work, well-structured activities are collected, with appropriate strategies for the accomplishment of the activities, which will lead to an increase in school results, develop a deep understanding for each student, and enhance the involvement of students in the educational process. Nevertheless, education is constantly changing and when the students' success depends on their future life, the teachers have to predict this future and design learning experiences that will develop understanding and skills suitable for the future.

4. Conclusion

The instructional design described in this paper, uses both BLOOM's and SOLO taxonomies, which help us to formulate suitable learning objectives based on both difficulty and complexity. Thus, the set of assessment criteria was created to guide the students in their learning. In addition, it was used for assessment of learning activities (i.e. self-assessment, peer assessment, and co-assessment) to help students to detect their weaknesses and strengths, and work on the areas that need improvement. This increase the students' achievements and involvements in the learning activities, promoting an assessment culture. By applying the instructional design, the activities become well-structured, deeply understood, and easy to carry out. The collected tool set embraces specific materials, media, strategies, and technologies for teaching, making learning more effective, efficient, and engaging.

The application of this instructional design made the students more involved in the learning process, even in the development of the didactic material, made them more motivated due to the deep understanding, made them more aware of

what they need to learn due to the evaluation criteria, and all of this contributed to enhanced learning and improved student results. The implementation of activities involving assessment for learning made the students more confident, reflective, engaged in their learning, and less worried about summative assessments.

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