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An Ontology Framework for Instructional Strategies Selection

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IMPORTANT INFORMATIVE STATEMENTS

Support to Training and Education Modernization

An Ontology Framework for Instructional Strategies Selection

Annex number: DND/NRC/DT/A1-021848

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Canada

Training and Education Modernization: **An Ontology Framework for Instructional Strategies Selection**

DND/NRC/DT/A1-021848
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Abstract

DRDC has identified a requirement to better support DND instructional designers to meet CAF learning needs with a structured framework for the selection of instructional strategies. The report reviews CFITES and S6000T instructional design elements, and common instructional strategies selection models. The report proposes an ontology framework to meet the instructional designer needs. A CFITES ontology using the Protégé software demonstrates how an alignment of taxonomy categories between learning objectives (teaching points) and instructional methods supports the inference of additional instructional methods in the context of a given teaching point. The augmented list of methods allows for an enriched instructional methods selection by instructional designers. The report concludes with a list of current limitations and future work.

Le RDDC a identifié la nécessité de mieux soutenir les concepteurs de formation du MDN pour répondre aux besoins d'apprentissage des FAC avec un cadre structuré pour la sélection des stratégies d'enseignement. Le rapport examine les éléments de conception pédagogique de CFITES et S6000T, ainsi que les modèles courants de sélection de stratégies d'enseignement. Le rapport propose un cadre d'ontologie pour répondre aux besoins des concepteurs de formation. Une ontologie CFITES utilisant le logiciel Protégé démontre comment une correspondance des catégories taxonomiques pour les objectifs d'apprentissage (points d'enseignement) et les méthodes pédagogiques soutient l'inférence de méthodes suppélentaires dans le contexte d'un point d'enseignement donné. La liste augmentée des méthodes permet aux concepteurs d'instructions de faire une sélection enrichie parmis les méthodes d'enseignement. Le rapport conclut par une liste des limites actuelles et des travaux futurs.

Keywords: Instructional strategies selection, CFITES, S6000T, Instructional design, Ontology.

Contents

Acronyms

ADDIE Analysis, Design, Development, Implementation, Evaluation.

CAF Canadian Forces.

CFITES Canadian Forces Individual Training and Education System.

DND Department of National Defence.

DRDC Defence Research Development Canada.

KSA Knowledge - Skills - Attitudes.

NRC National Research Council Canada.

OWL Web Ontology Language.

S6000T International specification for training analysis and design.

SWRL Semantic Web Rule Language

UML Unified Modeling Language.

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Introduction

Statement of work. DRDC has identified a requirement to better support DND instructional designers in the process of selecting instructional strategies to meet CAF learning needs. To address this requirement, NRC will develop a structured framework, mapping types of learning to different instructional strategies as defined in the Canadian Forces Individual Training and Education System - CFITES (DND, 1999, Volume 4). The framework will be supported by a review of field-relevant literature, and instructional design best practices as jointly determined by NRC and DRDC based on the most current research literature. From this background research, NRC will adapt and extend existing work to date, including any existing solutions that may be suitable to being adapted for use in the CAF training context, to propose a well-supported framework designed to specifically meet the CAF instructional design needs. NRC will develop and refine this framework with the guidance of DRDC as feasible within the resources available. The framework could be presented as an ontology, knowledge graph, flowchart, spreadsheet or other depiction deemed suitable by NRC, while the supporting documentation will follow a typical scientific report format.

Project tasks and scope. The main task from the statement of work is *to develop a structured framework to support instructional designers in the selection of instructional strategies.* A set of related sub-tasks to this main task includes: (a) to clarify key concepts related to the selection of instructional strategies and methods in the context of CFITES (DND, 1999, Volume 4), (b) to review relevant literature on the issue of instructional strategies selection; (c) to formalize a framework for instructional strategies selection. Figure 1 and Table 1 summarize the statement of work scope.

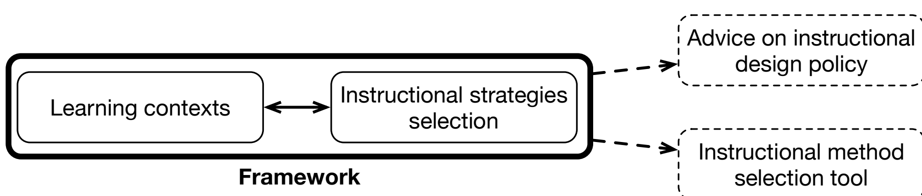

Figure 1. *The figure represents the statement of work scope in a graph format. The main task is the development of a framework which should map learning contexts to means to select instructional strategies. Tools implementing the framework or advice on instructional design policy are envisioned applications of the framework, but are out of scope.*

Method. The method used for the main statement of work task can be loosely defined as conceptual analysis. The approach will use means to represent concepts and their relations to facilitate analysis and processing by both humans and machines. The latter providing support for an eventual framework software implementation. A review of key literature relevant to the task will support the conceptual analysis, and instructional strategies selection methods.

Report structure. The report is divided in four sections. The first section (Instructional Design) addresses the task of clarifying key concepts related to the selection of instructional strategies. The formalization of the Analysis, Design, Development, Implementation, and Evaluation development stages (ADDIE) in the International Specification for Training Analysis and Design (ASD/AIA, 2021) will be used for this purpose. The

Table 1. *"In scope" and "Out of scope" themes for the report.*

Status	Scope
In	• CFITES implementation of the ADDIE design phase. • Instructional design inputs, outputs, and processes directly relevant to the selection of instructional strategies. • Conceptual and algorithmic elements that can be used in an instructional strategies selection framework. • Best practices in the selection of instructional strategies. • Pedagogical dimensions in instructional strategy selection such as learning objectives, learner and instructor characteristics, assessments, and teaching/learning methods. • Human resources knowledge, skills, roles and responsibilities in applying a framework for the selection of instructional strategies.
Out	• CFITES implementation of other ADDIE phases (not design): Analysis, Development, Implementation, Evaluation, and Validation. • Instructional design inputs, outputs, and processes not directly relevant to the selection of instructional strategies. • Non-pedagogical dimensions in instructional strategy selection such costs and development options. • Specific issues related to the implementation of a framework in a tool, such as application workflows, and user interface design. • Specific advice on instructional design policy.

section will also review the CFITES approach to the selection of instructional strategies as it is specified in the Canadian Forces Individual Training and Education System (CFITES) design phase (DND, 1999, Volume 4). The second section (Instructional Strategies Selection Models) reviews relevant literature for the issue of instructional strategies selection. The objective of this section is to identify best practices, possible gaps and extensions that could be included in a selection framework. The third section (A Framework for Instructional Strategies Selection) presents a structured framework to support instructional designers in the selection of instructional strategies. The framework takes the form of an ontology (WC3, 2012a). Finally, the last section (Conclusion) discusses the main results of the work, limitations and future developments. The report has also two appendices. The first one contains long tables that would not fit well within the body of the text. The second appendix contains a taxonomy categorization of instructional methods.

Instructional Design

The purpose of this section is to situate the instructional strategies selection activity within the general instructional design phase. The section presents overviews of the International Specification for Training Analysis and Design (S6000T) (ASD/AIA, 2021), and of the Canadian Forces Individual Training and Education System (CFITES) (DND, 1999, Volume 4). Both S6000T and CFITES are instances of the ADDIE instruction development process, which has five phases: Analysis, Design, Development, Implementation, and Evaluation. The section focus on the general design phase.

S6000T

Figure 2 presents all processes within the S6000T general design phase. As the figure shows, the main input to the instructional strategy selection is an assessment strategy, which is itself dependent on the identification of the target audience, learning gap, and a learning objective. The output of the instructional strategy selection consists of conducting an analysis of possible training system alternatives, identifying training system requirements, and getting the approval for a curriculum. It is important to note that in Figure 2, (1) the determination of an instructional strategy, (2) the definition and selection of media, and (3) the sequencing of learning objectives are tightly coupled with back-and-forth efforts being applied during the execution of these three activities.

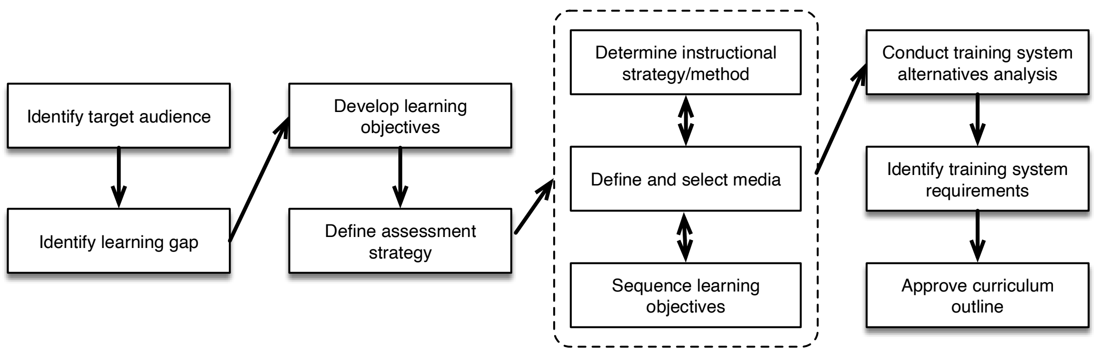

Figure 2. *Sequence of activities within the S6000T general design phase (ASD/AIA, 2021, Chap 4.1).*

The following paragraphs present short descriptions of elements of the design sequence activities. Because the CAF learning context is not restricted to learning how to operate specific material products, the terminology is often adapted to reflect a more generic context. In particular, the expression "training objective" is often substituted to the S6000T expression "product to be operated".

Target Audience Description: A target audience description uses among other elements a *training task analysis*; and produces a general *KSA learner profile*, and *training prerequisites* (ASD/AIA, 2021, Chap 4.2).

Learning Gaps: Learning gaps uses among other elements a *training task analysis*, and a **target audience description**; and produces *gaps between current and required KSA* for successful performance (ASD/AIA, 2021, Chap 4.3).

Learning Objectives: A learning objective uses among other elements a **target audience description**, and **learning gaps** to produce a precise statement of the *behaviour trainees are expected* to demonstrate, the *conditions* under which that behaviour is to be performed, and performance *measurement standards* (ASD/AIA, 2021, Chap 4.4).

Assessment strategy: An assessment strategy describes the requirements for measuring and asserting a target audience's attainment of learning objectives. It uses among other elements **learning objectives**, available *measurement instruments*, and a **target audience description**; and produces a *rational for using testing instruments* for each learning objective (ASD/AIA, 2021, Chap 4.5).

Instructional strategy: An instructional strategy identifies the training method(s), which is the type of activity used to impart the required KSA for each learning objective. The instructional strategy uses among other elements **learning objectives**, a **target audience description**, and an **assessment strategy**; and produces a selection of *methods*, and a *rational for using each method* (ASD/AIA, 2021, Chap 4.6).

Media selection: A media selection identifies a media and define the level of fidelity required to enable the methods defined in the instructional strategy. It uses among other elements an **instructional strategy**, a **assessment strategy**, **learning objectives**, and a **target audience description**; and produces a *media* selection and a *rational for using a media* for each learning objective (ASD/AIA, 2021, Chap 4.7).

Learning objective sequencing: A learning objective sequence uses among other elements an **instructional strategy**, an **assessment strategy**, **learning objectives**, a **media selection**, and a **target audience description**; and produces a grouping

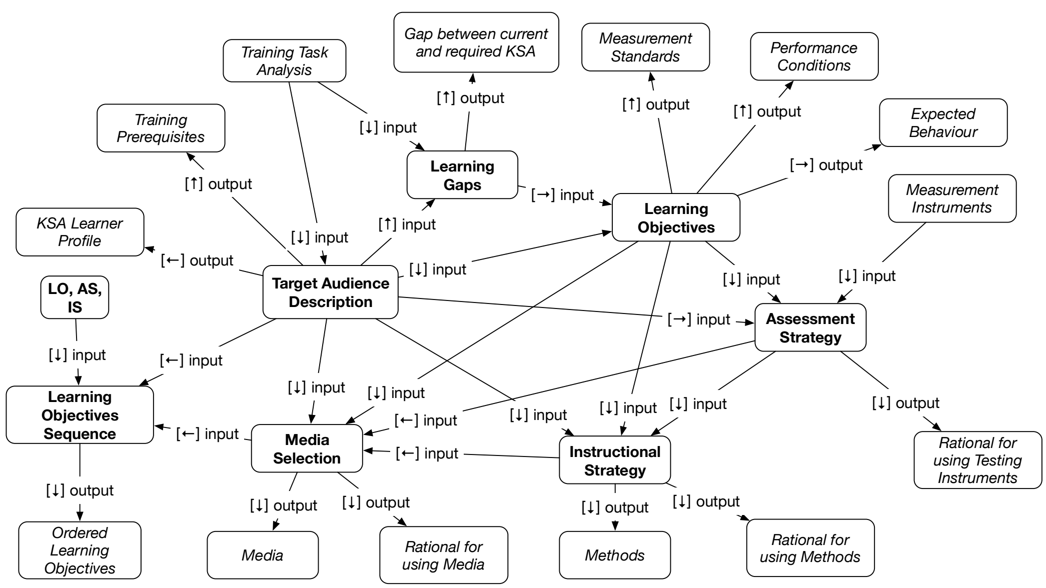

Figure 3. *The graph represents relationships between the principal S6000T design elements and activities. Elements in bold are objects described in the body of the text. The graph intends to capture the input and products generated during the design phase. Some links to the learning objective sequence are left out to avoid cluttering the figure. The graph also does not include the following business objects: training system alternatives, requirements, and curriculum approval and release.*

and ordering of learning objectives for a course and its component course elements. (ASD/AIA, 2021, Chap 4.8).

Training system alternatives: A training system alternative defines optional ways to enable the training system's design based on program constraints (ASD/AIA, 2021, Chap 4.9).

Training system requirements: The training system requirements describes all resource requirements for the development and delivery of a curriculum (ASD/AIA, 2021, Chap 4.10).

Curriculum outline approval and release: Results in the release of a customer-approved curriculum outline for planning and acquiring resources, communicating requirements for training product development, and training delivery (ASD/AIA, 2021, Chap 4.11).

Figure 3 presents a graphical representation of the relationships between S6000T design elements and activities. The graph indicates that here are many cross-references between design products, and that the design and selection of instructional strategies are processes that require the consideration of many information sources.

CFITES

The Canadian Forces Individual Training and Education System (CFITES) is an augmented version of the ADDIE instructional design development model with the addition of a phase to determine whether the training performance objectives and qualification standards meet the demands of the real world job requirements (Martin et al., 2016). Figure 4 presents the sequence of CFITES phases with an expanded description of the tasks within the design phase.

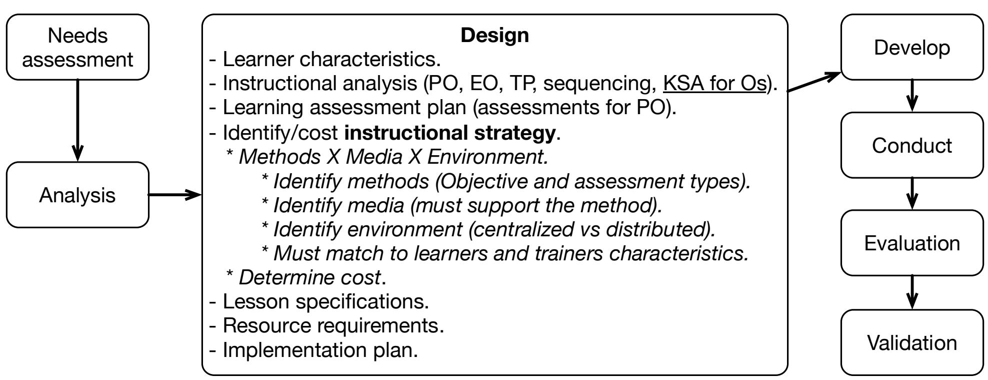

Figure 4. *CFITES processes sequence with an emphasis on the tasks within the design phase (DND, 1999). The tasks associated with the identification of instructional strategies and their costs include the identification of methods, media, and environment.*

Figure 5 outlines the main elements of the design phase. In similarity with S6000T, the identification of instructional strategies requires the consideration of many information sources.

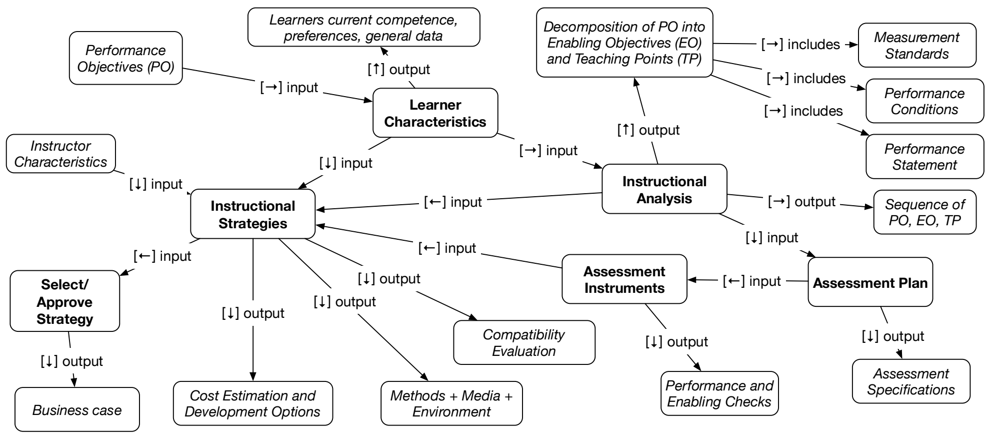

Figure 5. *A graph representing relationships between the principal elements of the CFITES design process. The graph does not include course content specification and lesson guidance elements, which is the last step in the CFITES design phase.*

Section Summary

The purpose of this section on instructional design was to give a general overview of S6000T (ASD/AIA, 2021) and CFITES (DND, 1999) design processes. The review left many details out, but shows that S6000T and CFITES instructional design processes are fairly similar. However, there is a difference that is important to notice. CFITES makes an explicit distinction between instructional strategies and methods. In CFITES, methods are specific teaching or learning activities (ex. demonstration and practice), while an instructional strategy is a combination of method, media and environment. In S6000T, instructional strategies are associated with all relevant information surrounding the use of a specific teaching or learning activity including the definition and selection of a media, and the sequencing of learning objectives (see Figure 2).

There are other interesting differences between S6000T and CFITES, such as the role of instructor characteristics in the selection of instructional strategies (in CFITES), and the CFITES early determination of learning objectives sequence during the design process. Learning objectives sequencing comes later in S6000T. Table 2 compares CFITES and S6000T terminologies.

A review of S6000T and CFITES in light of Gibbons's paper 2020 indicates that both provide exhaustive analysis of instructional strategies. Gibbons propose a theory-agnostic definition of *instructional strategy* that designers could use to discuss and create instructional plans at all design levels (Gibbons, 2020). The definition focuses on twelve dimensions of instructions that are independent of the theoretical basis that might be used to justify a certain method selection (ex. cognitive psychology, social learning theory). According to Gibbons, an instructional method is an instructional event, and any missing specification of the one of the twelve dimensions of this event reduces its specificity and completeness. Table 4 in the "Long Tables" appendix briefly describes each of the dimensions. Both S6000T and CFITES touch on these dimensions.

Table 2. *Comparison between CFITES and S6000T terminologies. The table shows a mapping between the main instructional design elements of CFITES and S6000T, including their use of same educational/instructional taxonomies.*

CFITES	**S6000T**
Learner characteristics	Target audience description Learning gaps
Instructional analysis	Learning objectives Learning objectives sequence
Assessment plan Assessment instruments	Assessment strategy
Instructional strategies (methods, media, environment)	Instructional strategy Media selection
Instructional strategies (cost estimation and development options)	Training system alternatives Training system requirements
Select/approve instructional strategy	Curriculum outline approval and release
Instructional taxonomies Cognitive: (Bloom et al., 1956) Affective: (Krathwohl et al., 1964) Psychomotor: (Simpson, 1972)	Educational Taxonomies Cognitive: (Bloom et al., 1956) Affective: (Krathwohl et al., 1964) Psychomotor: (Simpson, 1972)

Instructional Strategies Selection Models

The previous section gave an overview of the instructional design process in S6000T and CFITES. The current section focuses specifically on instructional strategies selection models. The objective is to determine the necessary and sufficient elements to support instructional strategies selection. There are three main models for selecting instructional strategies: taxonomies, flowcharts, and sequencing.

Taxonomies

One aspect of the S6000T design phase that is not represented in Figure 3 is the frequent reference to educational taxonomies as means to categorize design products, and align target audience characteristics, learning gaps, learning objectives, assessment strategies, instructional strategies, media selection, and learning objective sequencing. Figure 6, gives a simple representation of the importance of educational taxonomies within design activities. The figure also shows fidelity types that help determine how similar a training media should be to the operating environment.

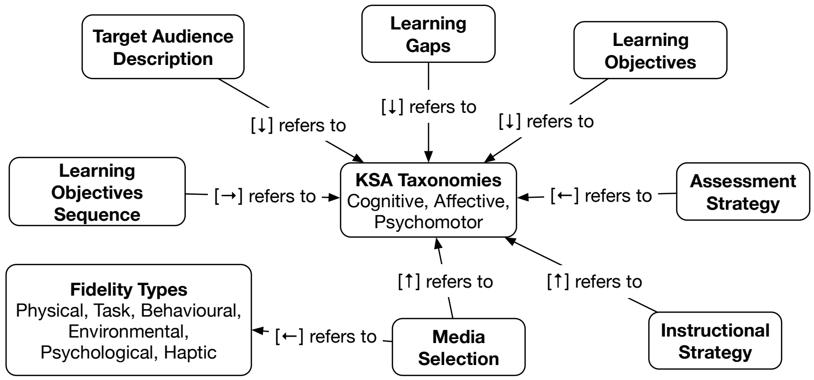

Figure 6. *Knowledge - Skills - Attitude (KSA). In the figure, KSA taxonomies refer to three sets of categories: (1) Cognitive taxonomy relates to knowledge and includes the recall or recognition of specific facts, patterns and concepts that serve in the development of intellectual abilities (Bloom et al., 1956); (2) Affective taxonomy relates to the way individuals deal with things emotionally, such as feelings, values, appreciation, enthusiasm, motivations, and attitudes (Krathwohl et al., 1964); and (3) Psychomotor taxonomy relates to the development of physical movement, coordination and skills which are normally achieved through repetitive practice (Simpson, 1972). KSA taxonomies are often referenced in all aspects of S6000T instructional design (ASD/AIA, 2021, Chap 3.5).*

	Knowledge dimension			
Process dimension	Factual	Conceptual	Procedural	Meta-cognitive
Remember				
Understand				
Apply				
Analyse				
Evaluate				
Create				

Figure 7. *The revised Bloom's taxonomy of learning objectives, assessments and instruction activities (Anderson et al., 2001). In addition to modifying Bloom's original list of categories (Bloom et al., 1956), the revised taxonomy introduced a second dimension, giving the taxonomy a matrix structure. The revised taxonomy has two dimensions to classify learning objectives, cognitive processes and knowledge types. The cognitive process dimension has six categories: remembering, understanding, applying, analyzing, evaluating, and creating. Like the original taxonomy, the categories are arranged hierarchically, such that complex skills require the achievement of prior ones. The knowledge dimension has four categories: factual, conceptual, procedural, and metacognitive. The knowledge types categories are also ordered hierarchically, from concrete to abstract.*

A classic example of using taxonomies for the selection of instruction activities using alignment of educational objects is the revised Bloom's taxonomy (Anderson et al., 2001). Figure 7 presents the revised Bloom's taxonomy of learning objectives, assessments and learning activities in a matrix format (Anderson et al., 2001). Beside providing a means to organize learning objectives, taxonomies can also be used to align objectives, instructions, and assessments. By categorizing learning objectives, assessments, and instruction activities into the taxonomy table, it is possible to identify weak (dispersed cell content) and strong alignment (all in one or very near cell content). This examination emphasizes consistency in terms of intended student learning (Anderson et al., 2001).

Both the AeroSpace and Defence Industries Association of Europe and Aerospace Industries Association (ASD/AIA, 2021), and the International Civil Aviation Organization (2016) have developed taxonomy selection tables. In the former case, the table helps in method selection, while in the latter, it is to support the decision to use a classroom, e-learning, or blended learning approach (combination of classroom and e-learning). These tables combine cognitive, affective, and psychomotor taxonomies with other classifications and fill the table cells with consistent combinations. Figure 8 is an adaptation of the International Civil Aviation Organization table and illustrates how a combination of classification schemes can be used to reduce the decision space.

	Conditions						Taxonomic Domain			Instruction method		
	Population		Location		SME							
Options	<50	>50	1	>1	Local	Ext.	Cognitive	Affective	Psychomotor	Classroom	E-learning	Blended
1	X		X		X		X	X	X	X		
2		X		X	X		X				X	
3	X			X	X			X			X	
4		X		X	X	X	X					X
...												

Figure 8. *An adaptation of the International Alliance of Carer Organizations matrix (International Civil Aviation Organization, 2016) for deciding on an appropriate learning method/environment (classroom, E-learning, or blended learning).*

Another example of a table approach is the work of Vogel-Walcutt et al. According to them, instructional strategies selection should be based on three factors: (a) the phase at which a strategy is implemented within a training cycle, (b) the expertise level of trainees, and (c) the type of knowledge to be trained on (2013). The approach is learner-centred and employs instructional strategies that are consistent with trainees' cognitive architecture and the specific goals of the training environment. It is proposed as an alternative to technology-based approaches that offer mostly practice environments with minimal trainees guidance.

According to Vogel-Walcutt et al., the following key elements should be considered when designing a framework to select instructional strategies:

- Instructional guidance should be adaptive to the learners expertise level to avoid unnecessary guidance, but at the same time, provide sufficient instructional support to avoid random problem exploration. The design of training systems will be most optimal when: (a) explicit instructional guidance is provided to novice trainees; and (b) guidance is gradually adapted in line with the development of trainee expertise.
- The selection of instructional strategies should be based on the specific type of knowledge associated with the goals of the training environment (ex. declarative or proce-

dural).

- Instructional design appears most optimal when it is based on an understanding of human cognition.

The instructional strategy selection framework of Vogel-Walcutt et al. is based on a literature review covering 910 unique articles on instructional strategies. The framework is divided by training cycles (pre-training, during-training, post-training), and associates training events, instructional strategies, expertise level, and knowledge types, instructional principles and literature citation sources for the association. Tables 5, 6, 7, 8, and 9 in the long tables appendix contain the 22 instructional strategies. The levels of expertise in the framework vary from novice (N), journeyman (J), to expert (E). The knowledge types used for the framework are (Vogel-Walcutt et al., 2013, p.1491): (a) declarative knowledge (D), which refers to knowledge of basic facts; (b) procedural knowledge (P), which refers to knowledge of steps to complete a task; (c) conceptual knowledge (C), which refers to knowledge of the relationship between elements of information; and (d) integrated knowledge (I), which refers to knowledge that is capable of being applied to novel situations.

Flowcharts

Selection flowcharts are decision guides that decompose a multi-factor problem into a series of small decision steps. The S6000T standard includes flowchart selection as a method for media selection (ASD/AIA, 2021, Chap. 4.7). Flowcharts are relatively easy to use, assuming that a user has prior knowledge of a domain. As a decision support aid, they could be implemented as an interface to any type of selection frameworks. For example, a flowchart could be implemented on top of the International Civil Aviation Organization (International Civil Aviation Organization, 2016) presented in Figure 8. By asking a series of questions to determine the conditions, and taxonomy domains, the flowchart will allow to reduce the number of instructional methods to be selected.

Sequencing

Other methods for selecting among methods of instructions are based on the dependency between sequence of instruction methods. For example, Merrill's First Principles of Instruction are a set of five principles designed to guide the development of effective instructional materials (Merrill, 2002). These principles are based on a constructivist approach to learning and emphasize the importance of providing learners with authentic and meaningful learning experiences. The principles include task-centred learning, activation of prior experience, demonstration of skills, application of skills, and integration of new knowledge into the learner's existing knowledge base. The sequence of instructions should follow this sequence.

Gagne's Nine Events of Instruction is another framework for designing effective instruction (Gagne, 1970). The events are: gain attention, inform learners of the objective, stimulate recall of prior learning, present the content, provide learner guidance, elicit performance, provide feedback, assess performance, and enhance retention and transfer. These events are intended to align with the cognitive processes involved in learning, and to support learners in building new knowledge and skills. The selection of an instructional strategy should follow the learner cognitive processes.

Section Summary

The current section focused on instructional strategies selection models. The taxonomy selection method relies on one or many classification systems to evaluate the consistency of choices between learning objectives, assessments, instruction methods, and other elements such as learner characteristics. Selection by taxonomy and instructional sequencing appear to provide a better foundation for an instructional strategies selection framework than selection flowcharts. However, flowcharts offer a usable interface to facilitate the decision process in selecting strategies, while the conceptual foundation could reside in taxonomies and sequencing approaches. However, given the multi-factors at play in the selection of instructional strategies, taxonomy combination tables might not be enough for the development and maintenance of a knowledge representation for a selection framework. In addition, the combination of taxonomies with instruction sequencing seems to require a formal means to manage the complexity. The next section explores the use of ontology to support instructional strategies selection framework.

A Framework for Instructional Strategies Selection

The previous two sections reviewed (a) key CFITES and S6000T instructional design elements, and (b) instructional strategies selection models. Given the multi-factor characteristics and complexity of instructional strategies, the current section explores the use of ontology (WC3, 2012a) as a formal model for an instructional strategies selection framework.

An ontology is an organization of knowledge into entities such as classes, object properties, individuals, and rules. As a means to organize knowledge about a domain, an ontology can be used to model any theoretical foundation for instructional design, and instructional strategies selection in particular. By identifying and categorizing relevant knowledge components and their relationships, an ontology can help to select instructional strategies that are best suited for the specific relationships between different knowledge components. For example, Vidal-Castro et al. (2012) built a catalogue of instructional design methods using the Ontology Web Language (OWL) and the Semantic Web Rule Language (SWRL). Chimalakonda and Nori (2020) applied ontologies for modelling goals, instructional processes and instructional material. Vu and Tchounikine developed a process for the semi-automatic elaboration of a task-technique knowledge model as an ontology to support teachers for defining learning scenarios in a holistic perspective of the different techniques, types of tasks they address, and the interrelations between techniques and tasks, which may be highly complex (Vu & Tchounikine, 2021). Other applications of ontology in learning technologies include curriculum modelling, descriptions of domain and learning activities, storage of student profiles and performance, and recommendation tools for personalized learning (Rashidi & Dehghanzadeh, 2020).

A Simple Ontology

An ontology is a formal representation of knowledge in a particular domain or subject area, which includes a set of individuals, classes, and properties. This formal and explicit specification of a shared conceptualization of a domain, allows for the classification and organization of knowledge and facilitates communication and understanding between people and machines. There are many ontology language specifications: RDF/XML, OWL/XML, Manchester syntax, Turtle, and the functional syntax. The current task will use the Web Ontology Language (OWL) functional syntax (WC3, 2012b) because of its readability by humans. An ontology can also be expanded with the addition of rules. Table 3 gives basic definitions that will be used to describe the framework.

Table 3. *Definitions of entities (Web Ontology Language - OWL (WC3, 2012b)), and rules (Semantic Web Rule Language SWRL (WC3, 2004)*

Term	**Definition (source: OWL or SWRL)**
Individuals	Objects from a domain (OWL).
Classes	Sets of individuals (OWL).
Object properties	Connect pairs of individuals (OWL).
Axioms	Statements that say what is true in the domain (OWL).
Rules	An implication between an antecedent and a consequent, such that if the conditions specified in the antecedent hold, then the conditions specified in the consequent must also hold (SWRL).

Listing 1 gives an example of a simple ontology with a rule for inferring a grandparent property. Figure 9 contains a set of partial views of the same ontology using the Protégé software (Musen, M.A., 2015; Stanford University, 2015). The object property under the individual :Mary in a yellow background indicates that this property was generated with a reasoner.

Listing 1: *An example of a simple ontology with a rule. In this example, Mary, John, and Paul are individuals, there is a class of person, and a parent object property. The rule can infer a grandparent relationship.*

```
### Declarations (in functional syntax)
Declaration(Class(:Person))
Declaration(ObjectProperty(:grand-parent))
Declaration(ObjectProperty(:parent))
Declaration(NamedIndividual(:John))
Declaration(NamedIndividual(:Mary))
Declaration(NamedIndividual(:Paul))
### Axioms (in functional syntax)
ClassAssertion(:Person :John)
ClassAssertion(:Person :Mary)
ClassAssertion(:Person :Paul)
ObjectPropertyAssertion(:parent :John :Paul)
ObjectPropertyAssertion(:parent :Mary :John)
### Rules (in abstract syntax for readbility).
parent(?x,?y) ^ parent(?y,?z) -> grandparent(?x,?z)
```

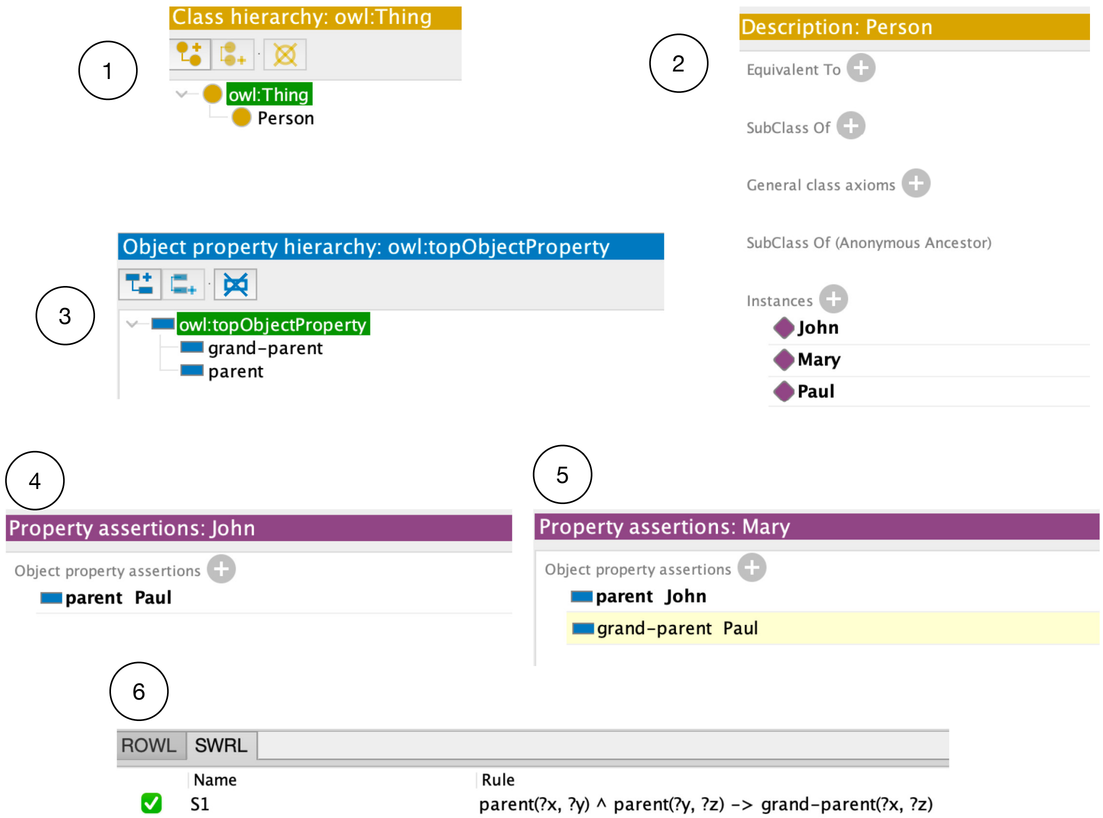

Figure 9. *A collection of partial views of the ontology of Listing 1 using the Protégé software: (1) The class hierarchy; (2) The individual instances of the class Person; (3) The object property hierarchy; (4) The object properties associated to the individual John; (5) The object properties associated to the individual John; and (6) The SWRL rule.*

An Ontology for Vogel-Walcutt et al.

As an iterative step towards implementing a CFITES ontology, the instructional selection framework of Vogel-Walcutt et al. (2013) offers an interesting use case. The framework is briefly described in a previous section, and the ontology consists of converting the information contained in the tables 5 to 9 (see Appendix: Long Tables).

Even though the Vogel-Walcutt framework and CFITES use different taxonomies for learners and knowledge types, the Vogel-Walcutt ontology development process could be informative for future work. In particular, the objective in developing this ontology is to support an instructional designer in selecting instructional strategies consistent with learner characteristics (expertise level) and learning objective knowledge types. Figure 10 shows simple use cases where the instructional designer (a) confirms the learner characteristics, and (b) might need to determine the knowledge type associated with the learning objective if it is not already determined, and (c) reviews the instructional strategies suggested by the ontology engine.

The core classes and object properties to implement an ontology for the Vogel-Walcutt framework are presented in Figure 11. In addition to the main seven classes and

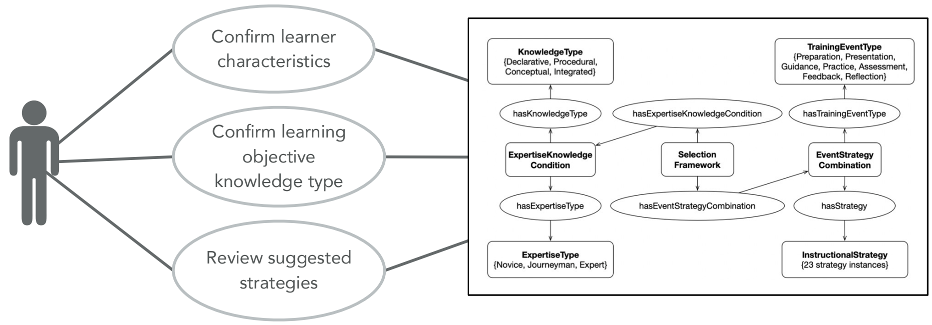

Figure 10. *Three use cases for an instructional designer who would confirm information about learner and learning objective types, and review suggestions extracted from the ontology.*

object properties, the ontology contains 91 declarations and 370 logical axioms. There are a total of 147 individuals (class instances). One SWRL rule allows to consult the combination of training event and instructional strategy given a learner expertise level in the context of a training event. The rule is given in Listing 2. Figure 12 shows an example of visualizing the options using the Protégé software (Musen, M.A., 2015; Stanford University, 2015).

Listing 2: *A rule in the Vogel-Walcutt ontology allows to link learning conditions to instructional strategy in the context of a training event.*

```
ExpertiseKnowledgeCondition(?x) ^
hasExpertiseKnowledgeCondition(?y, ?x) ^
hasEventStrategyCombination(?y, ?z)
    -> canUseEventStrategy(?x, ?z)
```

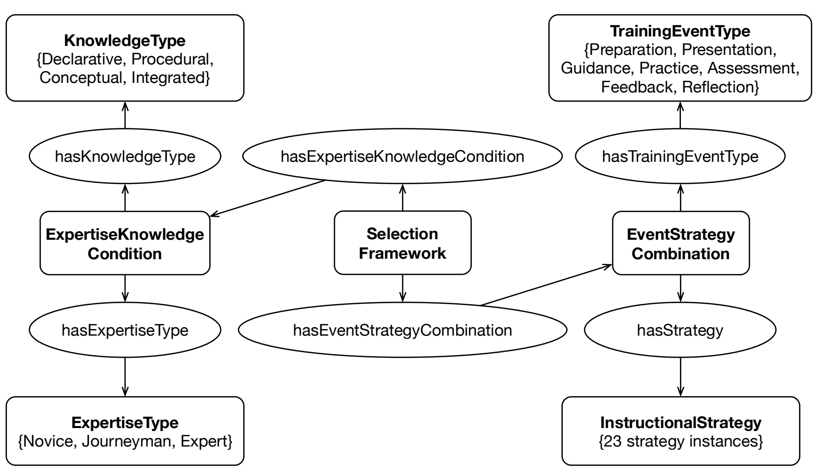

Figure 11. *The core entities for the Vogel-Walcutt ontology consists of seven classes (SelectionFramework, ExpertiseKnowledgeCondition, EventStrategyCombination, KnowledgeType, ExpertiseType, InstructionalStrategy, and TrainingEventType) and seven object properties linking instances of those classes.*

The implementation of the Vogel-Walcutt instructional selection framework as an

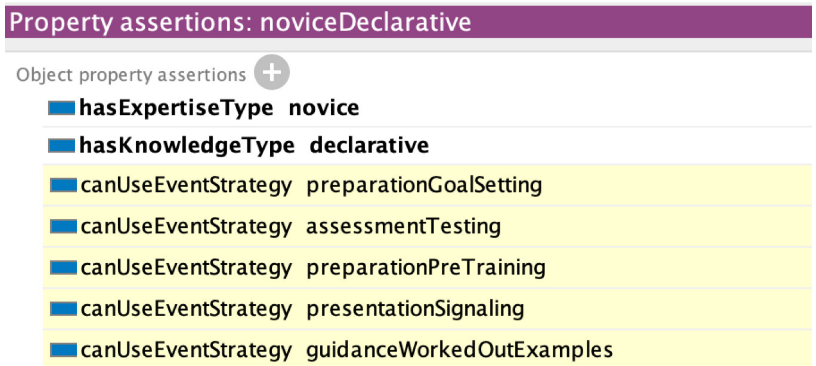

Figure 12. *An example of an inference by the rule in Listing 2 providing instructional strategy options given a learner levels of expertise (novice) and the type pf knowledge to be acquired (declarative). The inferred object property "canUseEventStrategy" have a yellow background and indicate five combinations of training event contexts (preparation, presentation, guidance, and assessment), and instructional method (GoalSetting, Testing, PreTraining, Signalling, and WorkedOutExamples). Definitions of the training methods are given in Tables 5 to 9.*

ontology was relatively straightforward, and covers the use cases of Figure 10. Even though the purpose was not to evaluate the Vogel-Walcutt instructional selection framework value, it is worth mentioning that it is leaning heavily towards novices with even no strategy suggestions for expert needing to learn declarative knowledge.

There were no particular knowledge representation challenges, and the only rule to suggest instructional strategies is simple. The essential of the work was to create axioms for the object properties. The Vogel-Walcutt framework ontology seems to offer a possible model to reproduce for CFITES.

A CFITES Ontology for Instructional Strategies Selection

The review of CFITES and S6000T instructional design elements revealed the many inputs and factors that need to be considered when selecting among alternative instructional strategies. The current section describes an effort to establish a conceptual foundation to support instructional designers in selecting instructional strategies, which for CFITES, is a combination of methods (ex. interactive lecture, case study), media (ex. digital material, instructor) and environment (ex. classroom, online) (DND, 1999, p.12). In addition, the selection must take into account the learners characteristics, assessment instruments, and instructor expertise. The current CFITES ontology for instructional strategies selection is a first step towards handling the complexity of the task. This initial version focuses on using the alignment between teaching points taxonomy categories, and methods taxonomy categories to offer instructional designers a set of method options to consider for a course plan. As such, the current implementation leaves aside considerations related to media, environment, learners characteristics, assessment instruments, and instructor expertise.

The CFITES selection framework ontology has descriptive and normative entities. The descriptive entities include data from the 2023 survey of CAF course plans by Human-Systems Incorporated. The following data fields were integrated in the ontology: course title (n=155), performance objective (n=516), enabling objective (n=1439), teaching points (n=8573), instructional media, environment, sub-environment, key verb, Krathwohl's categorization (cognitive), Krathwohl's categorization (knowledge), and method of instruction simplified. Some of these data fields were concatenated in the ontology, such as 1) enabling objectives and teaching points, making the combination a unique name for teaching points in the ontology, and 2) Krathwohl's categorization (cognitive/process) and Krathwohl's categorization (knowledge), to encode the intended combined taxonomies structure of the revised Bloom's taxonomy (Anderson et al., 2001).

The normative entities in the CFITES selection framework ontology include a set of instructional methods classified under the revised Bloom's taxonomy matrix. These entities do not represent descriptive entities extracted from the HumanSystems survey data, but "in principle" alignment between methods and the categorization of learning objectives.

The CFITES selection framework use cases are presented in Figure 13. The use cases focus on the categorization of teaching points and instructional methods, which enables the ontology to infer additional instructional methods that are not explicitly listed in a course plan.

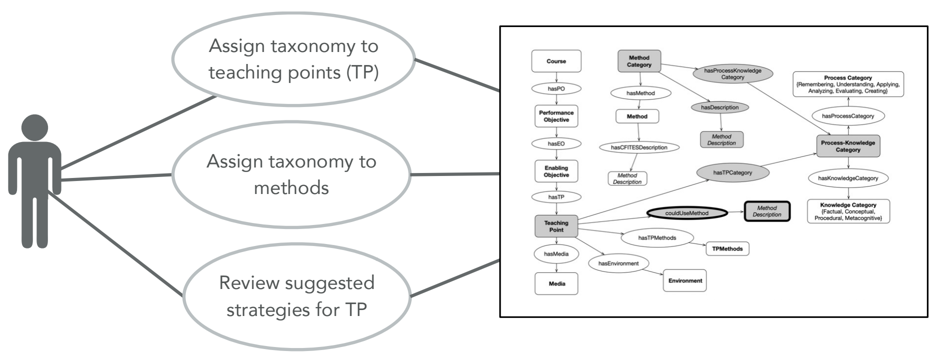

Figure 13. *CFITES selection framework ontology use cases. The framework requires that teaching points and instructional methods are categorized under a common educational taxonomy. For the current ontology, this common taxonomy is the revised Bloom's taxonomy (Anderson et al., 2001). Given category assignments to teaching points and methods, additional methods are suggested to instructional designers for selection consideration. Suggested methods are not explicitly associated to teaching points, but are inferred from the ontology.*

The core classes and object properties to implement the CFITES selection framework is presented in Figure 14. The class and object property instances were generated from the 2023 HumanSystems Incorporated survey data. In addition to these descriptive entities, other entities were added to the ontology to allow method suggestions that were not already associated with course teaching points. The figure shows the main classes, object and data properties. The figure elements that have a grey background and a thicker contours are referenced by the inference rule in Listing 3.

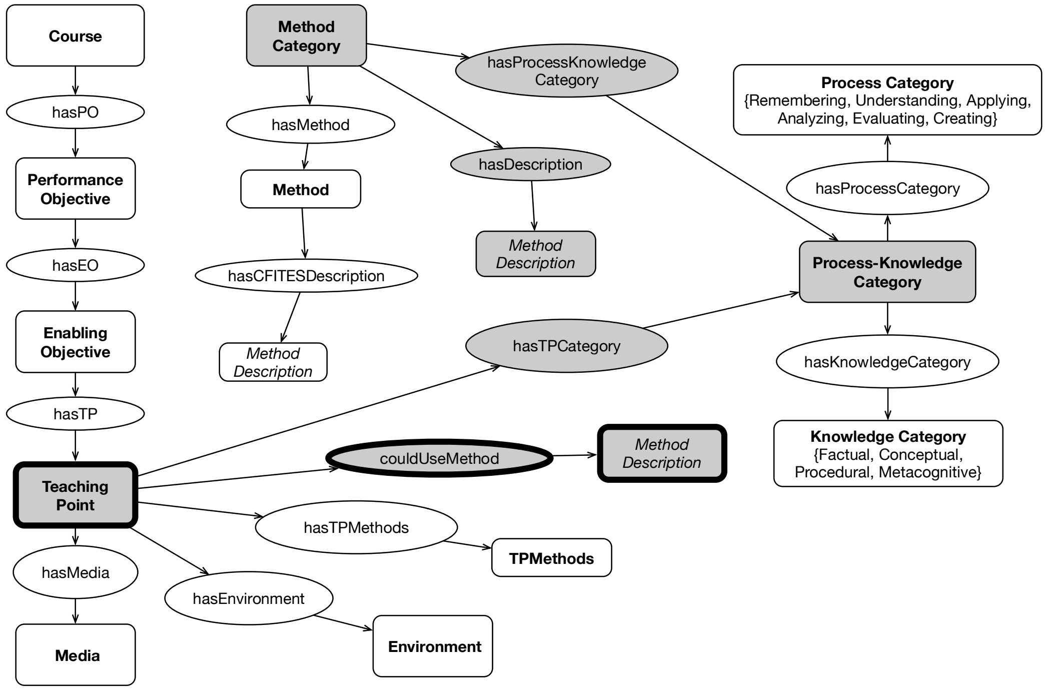

Figure 14. *CFITES methods selection framework ontology. The figure shows the main classes (rectangles), object and data properties (ovals). The ontology contains 98178 axioms with the large majority for encoding data from the HumanSystems survey. The figure elements that have a grey background and a thicker contours are the ontology entities used by the SWRL rule (Listing 3). The thicker contours represent the inferred object property "couldUseMethod".*

Listing 3: *A SWRL ontology rule to infer instructional methods for a teaching point, given category associations to methods, teaching points, and method descriptions.*

```
hasProcessKnowledgeCategory(?method-category, ?kp-category) ^
hasTPCategory(?teaching-point, ?kp-category) ^
hasDescription(?method-category, ?method-description)
    -> couldUseMethod(?teaching-point, ?method-description)
```

Figure 15 gives an example of attributed and inferred (yellow background) object properties when consulting a teaching point entity in the CFITES ontology.

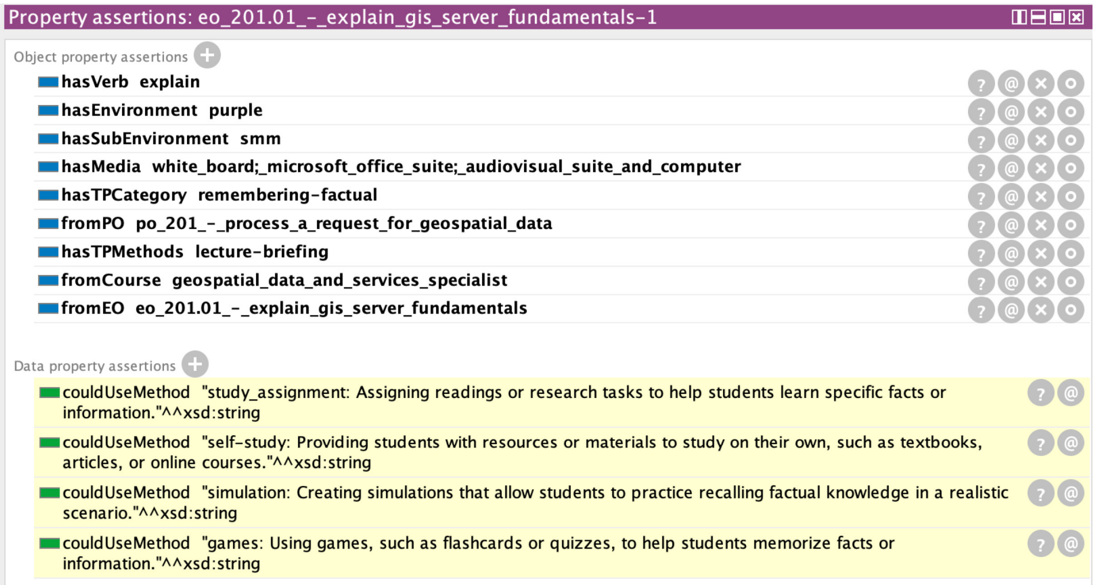

Figure 15. *An example of attributed and inferred (yellow background) object properties when consulting a teaching point entity in the CFITES ontology. The figure shows object properties related to the course structure (fromCourse, fromPO, fromEO), to the main teaching point verb (hasVerb) and its taxonomy classification (hasTPCategory), association to an environment (hasEnvironment) and sub-environment (hasSubEnvironment), media (hasMedia), and methods explicitly associated with the teaching point (hasTPMethods). Suggested methods (couldUseMethod) have a yellow background and are inferred by the ontology using the SWRL rule in Listing 3.*

Section Summary

A literature review shows that an ontology approach is viable to capture instructional design knowledge (Chimalakonda & Nori, 2020; Vidal-Castro et al., 2012) that can be used for various educational applications (Rashidi & Dehghanzadeh, 2020; Vu & Tchounikine, 2021). The development of an ontology for the Vogel-Walcutt et al. (2013) framework validates the feasibility of crossing the representation of learner characteristics, learning sequences, and knowledge types for selecting instructional strategies. The section also presents a first version of a CFITES ontology that encodes 8573 teaching points included in CAF course plans. In support to an instructional designer task of selecting among alternative methods, the CFITES ontology offers an additional set of methods to consider for a course plan.

Conclusion

The current report and its OWL files are deliverable for the statement of work task *to develop a structured framework to support instructional designers in the selection of instructional strategies*. The report first section addresses the task of clarifying key concepts related to the selection of instructional strategies by reviewing the design phase specification from the International Specification for Training Analysis and Design (ASD/AIA, 2021), and the Canadian Forces Individual Training and Education System (CFITES) (DND, 1999, Volume 4). The review indicated that the task of selecting instructional strategies is a complex one that involves many information sources that need to be considered. A second section briefly discussed some selection methods, specifically methods based on taxonomies, flowcharts, and learning task sequencing. The third and last section presented an instructional strategies selection framework using a formal ontology approach. The result of this work provides a first version of a CFITES ontology that encodes 8573 teaching points included in CAF course plans surveyed in 2023 by HumanSystems Incorporated. Using the Protégé software (Musen, M.A., 2015; Stanford University, 2015), the CFITES ontology offers an additional set of instructional methods on the basis of a teaching point classification in the revised Bloom's taxonomy (Anderson et al., 2001), in support of an instructional designer task of selecting among alternative methods.

Limitations and future work

The current work has the following limitations and potential extensions:

- The CFITES ontology is directly dependent on a classification of teaching points into an instructional taxonomy like the revised Bloom's taxonomy. There are no taxonomy additions that could not be used in principle but, it should be applicable to both learning objectives (performance, enabling, teaching points) and methods. This is critical because the foundation for supporting methods selection is a category alignment between objectives and methods. The main issue for future application of the ontology would be to generate taxonomy classification by machine, such as text extraction techniques, to identify main verbs in course plan, and the use of verb categorizations mapping (see (ASD/AIA, 2021, Chapter 3.5)).
- The CFITES ontology does not take into account the combination of environment, media, and method for selecting instructional strategies. The current version only focuses on method. Additional work could use the S6000T extended analysis of media section based on many dimensions of media fidelity (ASD/AIA, 2021, Chapter 4.7).
- The Protégé software is useful for demonstrating the capability of an ontology framework, but it might not be sufficient as an interface for the instructional designer work. However, the current implementation offers a good data specification for a future implementation, and is in line with current technology development on knowledge graphs, and trends towards developing full automation of knowledge modelling (Yun et al., 2021).
- The list of methods used by the CFITES ontology is relatively small, and would benefit from building a digital catalogue of learning methods that could be added to the ontology.
- In principle, major updates to CFITES, such as adopting a competency model, could be handled by an ontology framework, assuming that the competency representations can be formalized.
- Other improvements to a CFITES ontology could include the use of explanations (rationales) for method suggestions, similar to what is included in S6000T.

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Appendix: Long Tables

Table 4. *Twelve dimensions of instructional strategies (Gibbons, 2020).*

Dimensions	Description
Time	Instructional events are defined for specific periods with a beginning, a duration, and an end.
Physical or virtual setting	The setting (physical or virtual) is a determinant of what can be accomplished by a learner.
Social milieu	In the same manner as the physical and virtual setting, the social setting determines the range of social communication possible.
Roles for participants	By assigning roles to individual members of a learning group, new strategy rules are introduced, as well as new instructional goals, and the social unit for which the strategy is devised becomes the group, rather than the individual.
Roles for learning companion	A learning companion is a more knowledgeable coach, teacher, tutor, or peers in a collaborative learning setting.
Goals	The following type of goals need to be distinguished: (a) Instructional goals: the expression of desired learning outcomes; (b) Strategic goals: the plan for attaining instructional goals; (c) Strategic means plan: description of the means to be used to attain the instructional goal.
Activity elements	Conversation topics or objects to be included during the instructional event;
Information elements	Idea elements that the designer feels essential and that may eventually become included in instruction in some form but are of a wider scope than the activity elements;
Interaction guidelines	Pattern of structured or semi-structured communication during a tutoring session.
Communication infrastructure	The means to support communication during an instructional event;
Assessment elements	Means to assess progress during an instructional event;
An algorithm or rule for event sequencing	Defines how events can be scheduled in a sequence that is fixed, algorithmic, or learner-selected.

Table 5. *Instructional strategy selection framework (Pre-training - Preparation). Adapted from (Vogel-Walcutt et al., 2013).*
Expertise Level (N = Novice, J = Journeyman, E = Expert);
Knowledge Type (D = Declarative, P = Procedural, C = Conceptual, I = Integrated).

Strategy	Instructional principle [Expertise] [Knowledge type]
Goal setting	Establish clear and specific training goals based on trainees' current level of knowledge, skills, and abilities. [N] [D,C].
Advance organizers	Provide learners with relevant background information prior to learning in order to facilitate the integration of newly acquired information with prior knowledge. [N] [I]
Pre-training	Define and describe key terms of training material prior to presenting the more complex conceptual relationships between the terms. [N] [D,C]

Table 6. *Instructional strategy selection framework (During-training - Presentation). Adapted from (Vogel-Walcutt et al., 2013).*
Expertise Level (N = Novice, J = Journeyman, E = Expert);
Knowledge Type (D = Declarative, P = Procedural, C = Conceptual, I = Integrated).

Strategy	Instructional principle [Expertise] [Knowledge type]
Multimedia	Present training materials using pictures and words rather than words alone. [N] [C,P,I]
Spatial/temporal contiguity	Integrate words and pictures spatially rather than presenting them spatially separated. Present words and pictures concurrently rather than separated in time. [N] [C,I]
Segmenting or sequencing	Segment or sequence complex material by presenting the material in manageable 'chunks'. [N] [C,I]
Modality	Present words in spoken form rather than text when accompanied with concurrent visuals. [N] [C,I]
Signaling	Emphasize the most important training material by providing visual (e.g., arrows, animations) or auditory cues. [N] [D,C]
Personalization	Present words in conversational rather than formal language during multimedia training. [N] [I]
Animation	Use segmented and realistic (e.g., video-based), animations when training procedural-motor skills. [N,J] [P]
Analogizing and concretizing	Present training material in a context that is familiar to trainees to facilitate the integration of the material with prior knowledge. [N,J] [I]

Table 7. *Instructional strategy selection framework (During-training - Guidance). Adapted from (Vogel-Walcutt et al., 2013).*
Expertise Level (N = Novice, J = Journeyman, E = Expert);
Knowledge Type (D = Declarative, P = Procedural, C = Conceptual, I = Integrated).

Strategy	Instructional principle [Expertise] [Knowledge type]
Worked out examples	Explicitly present and explain to novices all of the steps required for solving a problem rather than requiring them to solve the problems on their own. [N] [D,P]
Faded examples/ completion problems	As trainees develop expertise, begin to require them to solve solution steps to problems on their own rather than providing the steps explicitly. [J] [P,C,I]
Conventional problem solving (minimally-guided instruction)	At the expert level, provide trainees with conventional problem-solving practice rather than explicitly providing any of the solution steps. [E] [C,I]
Cognitive apprenticeship	Guide trainees during real-world training tasks by explicitly modeling appropriate cognitive processing, providing hints and feedback, and assisting when trainees are unable to complete parts of the task on their own. [N,J] [P,C,I]
Immediate feedback	Immediately following errors made during problem solving, provide novice trainees with corrections,hints, or explanations to help them solve the solution step correctly. [N,J] [P,C]
Explanatory feedback	Address trainee errors by explaining the rationale behind correct solutions (i.e., explanatory feedback),rather than only informing trainees whether their solution was right or wrong (i.e., corrective feedback). [N,J] [C,I]
Metacognitive prompting	Provide trainees with prompting that encourages them to reflect on their own understanding of the material and select appropriate learning strategies. [N,J] [C,I]

Table 8. *Instructional strategy selection framework (During-training - Practice).*
Adapted from (Vogel-Walcutt et al., 2013).
Expertise Level (N = Novice, J = Journeyman, E = Expert);
Knowledge Type (D = Declarative, P = Procedural, C = Conceptual, I = Integrated).

Strategy	Instructional principle [Expertise] [Knowledge type]
Deliberate practice	To maximize long-term learning, distribute practice over multiple, short training sessions that are separated in time, rather than massing practice all at once. [N,J] [P,C,I]
Distributed practice	To maximize long-term learning, distribute practice over multiple, short training sessions that are separated in time, rather than massing practice all at once. [N,J] [D,P,C]

Table 9. *Instructional strategy selection framework (Post-training : Assessment, Feedback, Reflection).*
Adapted from (Vogel-Walcutt et al., 2013).
Expertise Level (N = Novice, J = Journeyman, E = Expert);
Knowledge Type (D = Declarative, P = Procedural, C = Conceptual, I = Integrated).

Strategy	Instructional principle [Expertise] [Knowledge type]
Testing	Use assessments as training tools by testing trainees on the material. [N,J] [D,C]
After-action reviews	Provide a summary of trainees' performance following completion of a training task; include corrective and explanatory feedback, as well as suggestions for performance improvement. [N,J,E] [C,I]
Reflective prompting	Prompt trainees to reflect upon their own training outcomes and to consider ways in which they could improve their performance. [N,J,E] [I]

Appendix: CFITES Taxonomy of Suggested Instructional Methods

This appendix contains a description for every method in the CFITES ontology that can be generated as a suggestion for a teaching point. Every method is classified under the revised Bloom's taxonomy with its cognitive/process (remembering, understanding, applying, analyzing, evaluating, creating)) and knowledge (factual, conceptual, procedural, metacognitive) dimensions. The list was automatically generated, then edited after submitting the following request to ChatGPT 3.5 (https://chat.openai.com/), where *method name* is one of the CFITES method (DND, 1999) :

> "Generate a bullet list with examples of using *method name* by combining each category: remembering, understanding, applying, analyzing, evaluating, creating, with the following categories: factual, conceptual, procedural, and metacognitive"

remembering factual

study assignment Assigning readings or research tasks to help students learn specific facts or information.

self-study Providing students with resources or materials to study on their own, such as textbooks, articles, or online courses.

games Using games, such as flashcards or quizzes, to help students memorize facts or information.

simulation Creating simulations that allow students to practice recalling factual knowledge in a realistic scenario.

remembering conceptual

interactive lecture Using a lecture format that includes opportunities for students to ask questions and engage in discussions.

guided discussion Facilitating discussions that encourage students to explore and make connections between different concepts.

case study Presenting students with a real-life scenario that requires them to apply conceptual knowledge to solve a problem.

field trip Taking students on a trip or visit to a place that is relevant to the conceptual knowledge being taught.

remembering procedural

demonstration-performance Providing students with a demonstration of how to perform a task, followed by an opportunity for them to practice the task themselves.

tutorial Providing students with step-by-step instructions for how to perform a task, along with examples and opportunities for practice.

role play Creating scenarios that allow students to practice applying procedural knowledge in a realistic situation.

on job training Providing students with opportunities to practice performing tasks in a real-world setting.

remembering metacognitive

peer learning Encouraging students to work together and learn from each other, which can help them develop metacognitive skills.

behaviour modelling Providing students with examples of effective learning strategies or behaviours, which can help them develop metacognitive skills.

in-basket exercise Presenting students with a set of tasks or problems that require them to use metacognitive skills to prioritize and manage their time effectively.

reflection Providing students with opportunities to reflect on their own learning and thinking processes, which can help them develop metacognitive skills.

understanding conceptual

study assignment Assigning readings or research tasks to help students learn specific facts or information.

self-study Providing students with resources or materials to study on their own, such as textbooks, articles, or online courses.

games Using games, such as flashcards or quizzes, to help students understand factual knowledge.

simulation Creating simulations that allow students to practice understanding factual knowledge in a realistic scenario.

understanding conceptual

interactive lecture Interactive lecture: Using a lecture format that includes opportunities for students to ask questions and engage in discussions.

guided discussion Facilitating discussions that encourage students to explore and make connections between different concepts.

case study Presenting students with a real-life scenario that requires them to apply conceptual knowledge to solve a problem.

field trip Taking students on a trip or visit to a place that is relevant to the conceptual knowledge being taught.

understanding procedural

demonstration-performance Providing students with a demonstration of how to perform a task, followed by an opportunity for them to practice the task themselves.

tutorial Providing students with step-by-step instructions for how to perform a task, along with examples and opportunities for practice.

role play Creating scenarios that allow students to practice applying procedural knowledge in a realistic situation.

on job training Providing students with opportunities to practice performing tasks in a real-world setting.

understanding metacognitive

peer learning Encouraging students to work together and learn from each other, which can help them understand metacognitive concepts.

behaviour modelling Providing students with examples of effective learning strategies or behaviours, which can help them understand metacognitive concepts.

in-basket exercise Presenting students with a set of tasks or problems that require them to use metacognitive skills to prioritize and manage their time effectively.

reflection Providing students with opportunities to reflect on their own learning and thinking processes, which can help them understand metacognitive concepts.

applying factual

case study Presenting students with real-life scenarios that require them to apply their knowledge of facts to solve a problem.

simulation Creating simulations that allow students to apply their factual knowledge in a realistic scenario.

in-basket exercise Presenting students with a set of tasks or problems that require them to apply their factual knowledge to prioritize and manage their time effectively.

applying conceptual

role play Creating scenarios that allow students to apply their conceptual knowledge in a realistic situation.

case study Presenting students with real-life scenarios that require them to apply their knowledge of concepts to solve a problem.

simulation Creating simulations that allow students to apply their conceptual knowledge in a realistic scenario.

applying procedural

on job training Providing students with opportunities to practice performing tasks in a real-world setting.

role play Creating scenarios that allow students to apply their procedural knowledge in a realistic situation.

in-basket exercise Presenting students with a set of tasks or problems that require them to apply their procedural knowledge to prioritize and manage their time effectively.

applying metacognitive

reflection Providing students with opportunities to reflect on their own learning and thinking processes, which can help them apply their metacognitive knowledge to future situations.

case study Presenting students with real-life scenarios that require them to apply their knowledge of metacognitive strategies to solve a problem.

in-basket exercise Presenting students with a set of tasks or problems that require them to use metacognitive skills to prioritize and manage their time effectively.

analyzing factual

case study Presenting students with real-life scenarios that require them to analyze and apply their knowledge of facts to solve a problem.

study assignment Assigning readings or research tasks that require students to analyze and synthesize information from multiple sources.

simulation Creating simulations that require students to analyze and interpret data or information.

analyzing conceptual

guided discussion Facilitating discussions that encourage students to analyze and make connections between different concepts.

case study Presenting students with real-life scenarios that require them to analyze and apply their knowledge of concepts to solve a problem.

field trip Taking students on a trip or visit to a place that is relevant to the conceptual knowledge being analyzed.

analyzing procedural

in-basket exercise Presenting students with a set of tasks or problems that require them to analyze and apply their procedural knowledge to prioritize and manage their time effectively.

case study Presenting students with real-life scenarios that require them to analyze and apply their knowledge of procedures to solve a problem.

role play Creating scenarios that require students to analyze and apply their procedural knowledge in a realistic situation.

analyzing metacognitive

reflection Providing students with opportunities to reflect on their own learning and thinking processes, which can help them analyze and improve their metacognitive skills.

case study Presenting students with real-life scenarios that require them to analyze and apply their knowledge of metacognitive strategies to solve a problem.

behaviour modelling Providing students with examples of effective learning strategies or behaviours, which can help them analyze and improve their own metacognitive skills.

evaluating factual

quiz or test Assessing students' factual knowledge through multiple-choice or short answer questions.

case study Presenting students with real-life scenarios that require them to apply and evaluate their knowledge of facts.

self-study Encouraging students to assess their own understanding and identify areas where they need to improve their factual knowledge.

evaluating conceptual

project Assigning students a project that requires them to apply and evaluate their understanding of concepts in a real-world context.

peer learning Having students work in groups to evaluate and provide feedback on each other's understanding of concepts.

reflection Providing opportunities for students to reflect on their understanding of concepts and identify areas where they need to improve.

evaluating procedural

performance evaluation Assessing students' ability to apply and evaluate their procedural knowledge in a real-world context.

simulation Creating simulations that require students to apply and evaluate their procedural knowledge in a realistic situation.

on job training Providing opportunities for students to apply and evaluate their procedural knowledge in a real work setting.

evaluating metacognitive

self-assessment Encouraging students to assess their own metacognitive skills and identify areas where they need to improve.

peer evaluation Having students provide feedback to each other on their use of metacognitive strategies.

case study Presenting students with real-life scenarios that require them to apply and evaluate their metacognitive skills to solve a problem.

creating factual

study assignment Assigning students to research and report on a particular topic to create new factual knowledge.

project-based learning Assigning students to create a product that requires the synthesis of factual knowledge on a particular topic.

collaborative research Having students work in groups to create new factual knowledge through research and analysis.

creating conceptual

debate Engaging students in a structured debate to create new conceptual knowledge.

design challenge Assigning students a design challenge that requires the creation of a new product or system based on conceptual knowledge.

brainstorming session Encouraging students to generate and share new ideas to create conceptual knowledge.

creating procedural

team-project Assigning students a team project that requires them to develop a new process or procedure based on their procedural knowledge.

game-based learning Using game-based learning to engage students in the creation of procedural knowledge.

role play Engaging students in role-playing exercises to create new procedural knowledge.

creating metacognitive

reflection Encouraging students to reflect on their own thinking and learning processes to create new metacognitive knowledge.

journaling Having students keep a journal to document and reflect on their own metacognitive processes.

peer review Encouraging students to review and provide feedback on each other's thinking and learning processes to create new metacognitive knowledge.

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13a. ABSTRACT (when available in the document, the English version of the abstract must be included here.)

DRDC has identified a requirement to better support DND instructional designers to meet CAF learning needs with a structured framework for the selection of instructional strategies. The report reviews CFITES and S6000T instructional design elements, and common instructional strategies selection models. The report proposes an ontology framework to meet the instructional designer needs. A CFITES ontology using the Protégé software demonstrates how an alignment of taxonomy categories between learning objectives (teaching points) and instructional methods supports the inference of additional instructional methods in the context of a given teaching point. The augmented list of methods allows for an enriched instructional methods selection by instructional designers. The report concludes with a list of current limitations and future work.

13b. RÉSUMÉ (when available in the document, the French version of the abstract must be included here.)

Le RDDC a identifié la nécessité de mieux soutenir les concepteurs de formation du MDN pour répondre aux besoins d'apprentissage des FAC avec un cadre structuré pour la sélection des stratégies d'enseignement. Le rapport examine les éléments de conception pédagogique de CFITES et S6000T, ainsi que les modèles courants de sélection de stratégies d'enseignement. Le rapport propose un cadre d'ontologie pour répondre aux besoins des concepteurs de formation. Une ontologie CFITES utilisant le logiciel Protégé démontre comment une correspondance des catégories taxonomiques pour les objectifs d'apprentissage (points d'enseignement) et les méthodes pédagogiques soutient l'inférence de méthodes suppélentaires dans le contexte d'un point d'enseignement donné. La liste augmentée des méthodes permet aux concepteurs d'instructions de faire une sélection enrichie parmis les méthodes d'enseignement. Le rapport conclut par une liste des limites actuelles et des travaux futurs.