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## RESEARCH ARTICLE

# Examining the Characteristics of Practical Knowledge From Four Public Facebook Communities of Practice in Instructional Design and Technology

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**ABSTRACT** Instructional design and technology (IDT) professionals participate in communities of practice (CoPs) on Facebook to seek pedagogical and educational technology advice for solving instructional design (ID) problems. Much of the IDT literature has focused on formal educational environments and not on nonformal settings outside the classroom and beyond formal education. Further analysis of tacit or practical knowledge exchanged among community members is required to understand the purpose, functions, and organizational knowledge capital in online CoPs. To fill this gap, this study uses natural language processing (NLP) to analyze the practical knowledge of 6,066 anonymized users' posts from four large public IDT CoPs on Facebook from September 2017 to September 2020 after cleaning the dataset. User posts were publicly available and required no password authentication for access, including Instructional Designer (4,717), Designers for Learning (228), Adobe Captivate Users (599), and Articulate Storyline (522). The proposed methodology aims to extract practical knowledge of individual online CoPs in three parts. First, the characteristics of written communication among members are extracted by calculating word and sentence lengths, word frequencies, and contiguous words. Second, the characteristics of members' exchange of practical knowledge are obtained through sentiment identification, entity recognition, and relationships between pedagogical and educational technology entities. Third, the functions of individual online CoPs are developed through topic modeling with latent Dirichlet allocation (LDA) and BERTopic. The findings suggest similarities and differences among IDT CoPs, different resource distribution conventions, and members exchanging pedagogical and educational technology advice. The study highlights the need for pedagogical foundations to support instructional and technical decisions, mechanisms for self-assessment of practical knowledge concerning IDT competencies, community protocols for addressing misconceptions about learning, onboarding materials for new members, and new topic structures to classify practical knowledge. NLP tasks are implemented using Python libraries to support the future development of awareness tools.

**INDEX TERMS** Data mining, instructional design, online learning, communities of practice, social media.

## I. INTRODUCTION

Instructional design and technology (IDT) professionals encounter design problems in most instructional design (ID) projects [1]. Design problems are ill-structured because of

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various degrees of structuredness, complexity, and domain specificity [2]. Structuredness refers to the multiplicity of design problems that require design judgments, solutions, and evaluation criteria from multiple disciplines. ID projects are complex and possess numerous factors or issues that limit professionals' working memory for finding adequate solutions. Regarding domain specificity, ID projects tend

to be situated, embedded, and dependent on the nature of the context or domain. In most cases, IDT professionals deal with ambiguous goal specifications and requirements that require the integration of various solutions. These solutions are not always dichotomous but only better or worse. They may require drawing back from past experiences to determine optimal tasks for completing ID projects.

Online communities of practice (CoPs) allow IDT professionals to access tacit or practical knowledge to seek plausible solutions for ill-structured ID projects. IDT professionals can tap into online CoPs' organizational knowledge capital and overcome the limits of bounded rationality through informed exploration of solutions to problems and analogical reasoning [3]. The concept of bounded rationality refers to the limited information, cognitive functions, and amount of time an individual has for decision-making. Analogical reasoning enables better problem representations by generating new solutions from past problems and partitioning problems into meaningful components and tasks that work together. Additionally, online CoPs provide members with professional development (PD) opportunities to enhance their knowledge, skills, and abilities without geographic and temporal constraints [4]. Online CoPs enable IDT professionals to participate flexibly by seeking information or contributing new knowledge while adhering to shared beliefs, identities, and meanings.

Online CoPs on the Facebook platform have played a pivotal role during the COVID-19 pandemic as IDT professionals pivoted from face-to-face to hybrid and emergency remote teaching (ERT) forms of learning. Online learning requires a careful and iterative course design process. In contrast, ERT involves the rapid transition from in-classroom learning experiences to online environments reliably in a short period of time [5], [6], [7]. Abramenska *et al.* [8] investigated how the Instructional Designer Facebook group facilitated peer-to-peer support for IDT professionals during the COVID-19 pandemic. After performing topic modeling on user posts from March 10, 2020, to June 10, 2020, our findings suggested that IDT professionals voiced their expressed needs in five categories, including Educational Technology Advice, Job-Related, Announcement of PD, General Pedagogical Advice, and COVID-Related Pedagogical Advice. Educational technology and job-related user posts were the most solicited categories by IDT professionals during the pandemic. The Instructional Designer Facebook group lacks mechanisms and tools to search the organizational knowledge effectively for solving IDT problems in their organizational settings. Yu [9] also argued that the pandemic accelerated positive interest in online learning. Teachers can provide individualized student-centered instruction and feedback to improve learning outcomes. In addition, learners across different settings reported an increased acceptance of online learning and highlighted network availability issues, online learning outcomes, and student-instructor interactions [10], [11], [12].

The Facebook social media platform has become one of the most palpable online environments for facilitating information sharing, interaction, and collaboration among individuals [13], [14], [15], [16]. Llorens and Capdeferro [16] noted the strengths and issues with Facebook when used as an online collaborative space. The strengths include the simplicity and speed of creating and administering a group, a high degree of connectivity through chat, messaging, tagging, and the platform's extensibility through custom add-on modules. However, shortcomings involve noise elements (e.g., advertising and self-promotion) and the lack of knowledge discovery mechanisms to tag, filter, and organize the constant stream of information. In a similar online CoP called the eLearning Industry, Leung [17] found similar issues related to the lack of mechanisms to reuse practical knowledge in the online news outlet and the lack of alignment of practical knowledge with competencies in IDT established by professional organizations. The American Talent Development (ATD) [18], International Board of Standards for Training, Performance, and Instruction (IBSTPI) [19], Association for Educational Communications and Technology (AECT) [20], and International Society for Technology in Education (ISTE) [21] have developed competencies to encapsulate the professional benchmarks, responsibilities, and capabilities of IDT professionals in different roles (e.g., training manager, evaluator, instructional designer, and instructional technologist).

Studies in the knowledge management literature examine tacit knowledge extraction from explicit forms of knowledge (e.g., online platforms, documents, and e-mail communication) in professional settings through the SECI model, where knowledge is continuously created through socialization, externalization, combination, and internalization [22]. First, tacit knowledge is generated through a socialization process among individuals, and its tacitness is difficult to codify into explicit knowledge. Second, tacit knowledge is externalized in symbolic language for sharing with others. Third, the combination step involves the application and reorganization of explicit knowledge. Fourth, when explicit knowledge is applied, individuals embody the newly acquired knowledge through action and reflection. The present study aims to extract the tacit knowledge from anonymized users' posts that occur at the externalization stage of the SECI model.

The study identified practical knowledge from four public Facebook groups in IDT. Two online CoPs are related to ID, i.e., Instructional Designer and Designers for Education. The other two groups are related to e-learning development, i.e., Adobe Captivate Users and Articulate Storyline. The Instructional Designer Facebook group is the largest public CoP, with approximately 21,700 members [23]. The purpose of this CoP is to share ideas on instructional systems, design, and technology. The Designers for Learning Facebook group is the second-largest public CoP, with approximately 4,400 members [24]. Although the Designers for Learning does not state its purpose, members generally exchange

information on ID practice, mainly in higher education and K-12 settings. The Adobe Captivate Users Facebook group is a public CoP that targets the technical aspects of e-learning development using the Adobe Captivate e-learning authoring tool [25]. This CoP has approximately 2,600 members, but the purpose is not stated. The Articulate Storyline Facebook group targets the technical aspects of e-learning development using the Articulate Storyline e-learning authoring tool. Similar to Adobe Captivate Users, the Articulate Storyline Facebook group does not state its purpose with approximately 5,800 members [26]. As mentioned above, two common characteristics shared among these Facebook groups are the lack of mechanisms to reuse the accumulated organizational knowledge and the misuse of hashtags that contribute little to organizational knowledge management efforts.

This study proposes applying a methodology to extract practical knowledge in individual online CoPs by generating syntactic and semantic features from user posts with natural language processing (NLP). The syntactic aspect refers to the position of words in a sentence without understanding their context. In contrast, the semantic aspect involves extracting the meaning from context words [27]. The syntactic features include generating the average word and sentence lengths, word frequencies, and n-grams. The syntactic features reveal critical characteristics of members' written communication in articulating ID problems and designing solutions. The semantic features include sentiment analysis, named entity recognition (NER) and their relationships, and topic modeling. The semantic features explore the distribution of affective states from user posts, the exchange of pedagogical and educational technology entities, and the latent topic structures that describe the purpose and functions of online CoPs.

The motivations of the study originated from the lack of quantification efforts in identifying the accumulated practical knowledge and types of practical knowledge exchanged in online CoPs. The tremendous amounts of textual data are also increasing daily without real-time mechanisms to automatically categorize practical knowledge and provide users with advanced filtering options to narrow information on social media. The application of topic modeling, mainly latent Dirichlet allocation (LDA), is widely discussed in the literature and allows the categorization of search results and controls for narrowing information based on the users' topic of interest [28], [29], [30]. LDA is an unsupervised, probabilistic, and text clustering algorithm that allows texts to be categorized into topics. The present study opens new opportunities for creating future awareness tools for classifying practical knowledge by implementing topic modeling techniques to uncover emerging topic structures in online CoPs.

The significance of the study explores the accumulated practical knowledge by understanding the purpose, functions, and emerging topic themes from online CoPs. While content analysis is a standard qualitative methodology, the content analysis methodology fails to analyze big data as a whole unit of analysis due to time constraints and increased human error.

By performing NLP tasks on individual Facebook groups, the study allows for exploring the formation and exchange of practical knowledge among IDT professionals. This study is a foundational effort for taking an inventory of the accumulated practical knowledge by informing researchers, practitioners, and developers with improved organizational schemes on how to organize and curate practical knowledge as an integral part of community engagement. The following research questions were explored:

**RQ1:** What are the text characteristics, most frequent words, and word sequences used in online CoPs?

**RQ2:** What are the characteristics of sentiment, named entities, and relationships among entities in online CoPs?

**RQ3:** What are the latent topic structures in online CoPs?

Present studies examine the PD needs of IDT professionals in academic and corporate settings. Exploring the sources of practical knowledge is required to understand current organizational knowledge capital and gaps in online CoPs where IDT professionals participate informally. The contributions of this research are as follows:

- Fills a gap in the IDT literature about the characteristics of practical knowledge on social media platforms.
- Identifies how IDT professionals participate in online CoPs.
- Explores integrating practical knowledge into formal IDT education and training as an essential part of problem-solving in ID projects.
- Establishes a foundation for future studies that support the development of intelligence and recommendation systems for skill development and detecting misinformation about learning.

The rest of the article is organized as follows. Section II provides a review of the literature and studies on practical knowledge extraction from online resources. Section III describes the proposed research methodology, including a thorough description of the NLP tasks performed. Section IV contains the results of NLP tasks organized by the research question. Section V discusses the results, recommendations for improving online CoPs, implications for research, practice, and development, and limitations. Section VI concludes the article and provides future directions for this work.

## II. LITERATURE REVIEW

The following literature section provides essential concepts that are important to consider for the context of the study. These four concepts relate to how social media supports CoPs, the characteristics and challenges of online CoPs, informal learning, and related studies for extracting practical knowledge using NLP.

### A. CoPs AND SOCIAL MEDIA

Lave and Wenger [31] stated that CoPs are characterized by a shared domain of interest, joint community activities, and a shared domain of practice. CoPs act as knowledge stewarding communities where members can organize and manage a body of knowledge from which they draw professional

learning to improve their practice. CoPs also act as a crowdsourcing mechanism where members generate practical knowledge by converting tacit knowledge, or know-how experiences in the field, into explicit forms (e.g., written texts, videos, and graphics).

Online CoPs have become a powerful knowledge-creation mechanism for geographically distributed organizations and individuals [32], [33], [34]. Social media networking sites (e.g., Facebook, Quora, and Twitter) allow members of CoPs to carry out online conversations that serve three educational functions: transactional, transformative, and transcendent [35], [36]. Several studies have investigated the Facebook social media platform as one of the most convenient ways to participate in online CoPs [37], [38], [39], [40], [41], [42]. Ractham and Firpor [43] argued that Facebook is a strong example of the Groundswell phenomenon where individuals use different tools and CoPs to acquire information goods from multiple sources rather than a single entity. This phenomenon also describes online CoPs as delivery mechanisms for information and access points to collective wisdom [44].

### B. CHARACTERISTICS AND CHALLENGES IN ONLINE CoPs

A literature review by Abedini *et al.* [45] found that member participation in online CoPs is characterized by professional-centeredness, self-directedness, experience-centeredness, problem-centeredness, and lifelong learning principles. When engaging in online CoPs, members can drive their learning independently and possess an intrinsic motivation to learn relevant skills. Driven by intrinsic motivation, members seek autonomy and self-directness by choosing resources and activities that align with personal and professional agendas. Learning in online CoPs occurs when members reflect upon past experiences and attain new knowledge by reshaping newly encountered information into new solutions. Learning in online CoPs is not fixed to a specific phase of life; it is spread out as members engage and disengage with online CoPs throughout their lifetime. In addition, Abedini *et al.* [45] identified the factors that facilitate and hinder community engagement. The facilitating factors of member engagement include competition to learn new skills, freedom to choose content, an interactive learning environment, engagement in practical and relevant learning experiences, and diverse backgrounds. The hindering factors of community engagement are related to the lack of diverse learning experiences, the steepness of learning new technologies, the directness of learning, the burden of professional workloads, the lack of reflection in learning activities, and the lack of prior experiences to support new learning.

The literature also reports the challenges present in CoPs on Facebook. For example, Mai *et al.* [46] found that online CoPs were mainly text-based environments that led to poor participation and inactive membership. Duncan-Howell [47] found that online CoPs were prone to off-topic conversations, poor navigation, and the personal agendas of self-promoters and influencers. Johnson [48] argued that asynchronous

discussions could become inadequate and superficial when they lack coaching and scaffolding. Peeters and Pretorius [49] argued that member participation varies when sharing tacit knowledge in asynchronous environments. Guldberg and Mackness [50] reported that members were overwhelmed with the information presented in online CoPs and suggested developing induction materials and processes to onboard new members. Preece [51] offered usability recommendations to promote collaborative dialogue and participation on social media platforms by improving social interaction, information design, navigation design, and technology access for all community members.

### C. INFORMAL LEARNING IN IDT CoPs

Schwier *et al.* [52] argued that IDT CoPs are born of convenience that allows informal engagement to solve specific project challenges or issues. The authors also investigated the features of IDT CoPs in terms of history and culture, mutuality, plurality, and tacit knowledge. They found that shared history and culture are not prominent features. In contrast, passive participation as a spectator was a critical element aligned with practitioners' agendas and community values. In terms of mutuality, community members develop their protocols for contribution and interaction with others. Community participation is based on the plurality of intermediate relationships with other members (i.e., experts in the field) that provide a wide range of considerations and solutions to learning problems.

Online CoPs in IDT are also knowledge repositories where members draw solutions from online resources and conversations without full participation from others. The shared practical or professional knowledge in online CoPs is the product of transforming practical knowledge into explicit knowledge in informal and serendipitous ways. Practical knowledge includes unique or creative solutions to dealing with demanding clients, job aids or templates for applying criteria to projects, and expert advice to solve complex problems.

In addition, online CoPs offer IDT professionals informal learning opportunities to refine their skills over time. Informal learning is unplanned, unstructured, and incidental learning beyond formal settings and is not bound to a specific place or period [8], [53]. Informal learning is influenced by the presence or absence of intentionality and consciousness of learning in self-directed learning and implicit learning or socialization [54]. In self-directed learning, learners attempt activities that are conscious and intentional. In implicit learning, learners are immersed in a context where they are not consciously trying to understand the subject.

Yanchar and Hawkey [55] characterized informal learning resources as practical, purposive, and inescapable as part of ID practice. Informal learning resources were deemed valid because these allowed practitioners to stay current on professional practices by asking peers for feedback and observing other members' work. Informal learning resources were perceived as significant by gradually deepening practitioners'

skills. IDT professionals were also selective in engaging and avoiding informal learning resources based on their time, energy, and perception of the significant opportunity to learn while helping others. The researchers also found two challenges that practitioners encountered in informal learning resources. The first challenge involved the inability to keep up with the stream of constant information. The second challenge was related to the steep learning curve practitioners needed to overcome to meet project demands.

Boling *et al.* [56] and Nelson and Stolterman [57] investigated the tacit beliefs among IDT professionals in 11 design judgments during design activities. The types of design judgment and how these take place during ID activities are summarized below:

- 1) Framing: Define a space for design activities (e.g., assessing client needs and measuring outcomes).
- 2) Deliberated off-hand: Recall previous successful judgments that allow for adaptation.
- 3) Appreciative: Emphasize value on certain design aspects or stages while backgrounding others.
- 4) Quality: Make decisions about the effectiveness of aesthetic norms and standards of the design.
- 5) Appearance: Evaluate the quality of the entire design product or experience against heuristics and other successful artifacts or experiences.
- 6) Connective: Make connections among design objects to create a cohesive artifact or experience.
- 7) Compositional: Make connections among various design objects central to the artifact or experience.
- 8) Instrumental: Select a tool or method for the design activity.
- 9) Navigational: Consider various alternatives to complete a task successfully.
- 10) Default: Give an automatic response to a triggering circumstance.
- 11) Core: State or ask the reasoning or meaning behind decisions.

#### D. RELATED WORK ON PRACTICAL KNOWLEDGE EXTRACTION

Steiger and Steiger [58] argued that tacit knowledge structures represent the implicit mental models of individuals. Mental models are tacit and integrate ideas, practices, assumptions, beliefs, relationships, facts, and misconceptions individuals use to perceive and interact with others [59]. Tacit knowledge has technical and cognitive dimensions containing mental models, values, beliefs, and perceptions. Tacit cognitive knowledge incorporates implicit mental models and perceptions that allow individuals to understand their surroundings and tasks. Tacit technical knowledge is workers' knowledge and abilities to perform functions that are not easily articulated [60]. Viale and Pozzali [61] argued that different forms of tacit knowledge could be acquired and transmitted in the form of competencies, background knowledge, and implicit cognitive rules, as defined below:

- Tacit knowledge as a competence refers to the skills and abilities acquired through apprenticeships and face-to-face interactions.
- Tacit background knowledge includes the regulations, codes of conduct, and acculturation processes to which individuals adhere, based on their context.
- Tacit knowledge acts as a mechanism for creating new knowledge and assessing the accuracy of the information itself.

As a subset of NLP methodologies, topic modeling is used to identify patterns from textual sources to extract hidden themes and insights. In the education domain, Vijayan [62] performed topic modeling with LDA on abstracts and meta-data across disciplines from Scopus to generate themes highlighting the challenges, solutions, and inequities in education due to the digital divide during the pandemic. The six themes describe the impact of COVID-19 on higher education, the mental health of health care workers, the teaching and learning experiences during the pandemic, the use of educational technology at higher education institutions, the lessons about treatment strategies, and general reflections on the pandemic. Buenaño-Fernandez *et al.* [63] implemented LDA to investigate a large sample of open-ended teacher feedback from course evaluation surveys to extract strategies (e.g., tutorial and experiential learning) that would lead to student retention in university settings.

In biology and informatics, Gurcan and Cagiltay [64] performed topic modeling on bibliometric data from PubMed, Scopus, and Web of Science to discover the developmental stages in bioinformatics studies from 1970 to 2020. The current direction is toward data analysis tools for statistical estimation and prediction of genomic data, ontology, and protein interactions. In the construction domain, Kim and Chi [65] developed models for retrieving critical information about construction accident cases and classifying the nature of the incidents for safety management. The authors of [65] extracted the semantic similarities in accident reports using a rule-based method and machine learning. With a rule-based approach, information is extracted from an established pattern. In contrast, the machine learning algorithm learns the structure and extracts semantic relationships from the text.

While topic modeling is primarily an unsupervised method for identifying latent topic structures from texts, the generated topic structures can also be used practically to classify future or unseen text sources through awareness tools. These awareness tools take the form of knowledge graphs and content recommendation systems that help with the visualization and summarization of large amounts of text. For instance, Badaway *et al.* [66] leveraged topic modeling to initially assign labels to Wikipedia resources that served as the foundation for implementing interactive knowledge graphs. Knowledge graphs allowed for the visualization of the relationships among resources. Shahbazi and Byun [67] used topic modeling as an exploratory strategy to discover the key characteristics of computer science projects on Twitter that built the foundation for a content recommendation

system. The content recommendation system assisted computer science students with quality control and curation of online resources.

### III. PROPOSED METHODOLOGY

This section is organized into three parts. Section A describes user post collection, cleaning procedures, and the environment for NLP tasks. Section B identifies the NLP tasks by the research question, Python libraries, and experimentation details of parameter tuning. Section C provides the evaluation procedures of topic models for obtaining interpretable topics. A summary of the ethical considerations for getting user posts from Facebook groups is discussed in the Appendix.

#### A. DATA COLLECTION, CLEANING, AND ENVIRONMENT

A total of 7,713 posts from September 2017 to September 2020 were obtained from four Facebook public groups, including Instructional Designer, Designers for Learning, Adobe Captivate Users, and Articulate Storyline. The text sources from each public Facebook group were publicly available and required no password authentication to access users' posts. The mobile version of Facebook (mbasic.facebook.com) showed all the posts available in each group without scrolling through each group's feed for other posts. Once user posts were extracted from individual groups, authorship information and any references to authorship in the posts were deleted to protect users' privacy. The study relied on Jupyter notebooks to fully script NLP tasks in Python 3.7.7, including related libraries described in the Units of Analysis section below. Python was selected over R because of its native integration with application programming interfaces (APIs) and extensibility with web development frameworks.

The number of posts was reduced from 7,713 to 6,066 posts by removing posts that had no context (e.g., "hi," "hi there," "hello all," and "good morning professionals") and checking for any duplicate posts. Additionally, promotional links and multimedia assets that contained no context were removed. Self-promotion can be in the form of advertisements from contractors offering e-learning production services, infographics by e-learning shops (e.g., steps to develop educational animation) and white papers from educational technology vendors as marketing tactics to attract potential clients. Only posts containing evidence of seeking advice or a stance on a given topic were considered in the study. Additionally, emojis in user posts were deleted as part of the data cleaning steps for consistent text analysis across all four online CoPs. Table 1 shows the number of scraped user posts for each Facebook group before and after removing posts with no context and promotional links.

#### B. UNITS OF ANALYSIS

##### 1) TEXT CHARACTERISTICS, WORD FREQUENCIES, AND N-GRAMS

In the first research question, lambda functions were implemented to obtain the average word and sentence lengths

**TABLE 1. Number of user posts by Facebook group.**

Facebook Group	Number of User Posts (Before Cleaning)	Number of User Posts (After Cleaning)
Instructional Designer	6,000	4,717
Designers for Learning	348	228
Adobe Captivate Users	641	599
Articulate Storyline	724	522
Total	7,713	6,066

of user posts without filtering out stop words to account for all words, including articles, prepositions, pronouns, and conjunctions. The text characteristics of each Facebook group were summarized in the Profile Report package as an exploratory step [68]. Word frequencies were visualized with the WordCloud package to identify prominent words [69]. The n-gram language model in the Natural Language Toolkit (NLTK) library was implemented to create the probabilities of contiguous words in bigrams, trigrams, and 4-grams [70]. The most frequent 4-grams were reported to illustrate word sequences with the highest probabilities. Word frequencies and n-grams required NLP tasks for cleaning, normalizing, and parsing using NLTK by performing lower casing, tokenization, stop words removal, lemmatization, stemming, and tagging parts-of-speech (POS). Although there is no consensus on using a standard stop words dictionary, removing articles, prepositions, pronouns, and conjunctions from textual data is a typical preprocessing step to remove noise or low-level information and reduce training time and dimensionality from uninformative words [71], [72]. This study implemented the stop words English dictionary, Wordnet Lemmatizer, SnowBall Stemmer, and POS tagger libraries in NLTK.

##### 2) SENTIMENT, NAMED ENTITIES, AND ENTITY RELATIONSHIPS

In the second research question, the TextBlob package was implemented for sentiment analysis to identify positive, neutral, and negative attitudes in the posts [73]. User posts were classified as positive (1), neutral (0), and negative (-1). Although the Vader sentiment analyzer is commonly used for social media texts with an informal tone, TextBlob was a better choice for this study because user posts had a professional tone [74], [75]. In addition, the spaCy package was implemented for NER tasks to identify pedagogical and educational technology entities. In NER tasks, spaCy is a rule-based matcher that identifies named entities in texts and classifies entities into standard categories of people, places, organizations, and geographic locations [76]. Once entities were extracted, subject-object relationships emerged as entity pairs to understand how entities were referenced. These entity pairs comprised the source and target entities linked by edge entities that defined relationships among the entities. The most frequent edge entities were reported in the Findings section to explore the exchange of pedagogical and educational technology entities in each online CoP.

### 3) LATENT TOPIC STRUCTURES WITH LDA AND BERTOPIC

In the third research question, LDA and BERTopic were implemented for unsupervised topic modeling tasks to explore the hidden topic themes in online CoPs. While LDA was the primary topic modeling method for this study, BERTopic was also implemented to explore additional latent topic structures when fitting against a large pretrained sentence transformer model.

In the first topic model, LDA is a generative probabilistic model where text sources are represented by a mixture of hidden topics over the distribution of words [77]. The LDA topic modeling algorithm in the Gensim library generated word representations and probabilities using the bag-of-words (BoW) and Term Frequency-Inverse Document Frequency (TF-IDF) models [78]. In a comparative study of topic modeling algorithms by Albalawi *et al.* [28], LDA is the most popular algorithm that provides useful integrations with NLTK and Gensim Python libraries and allows the development of information retrieval and computational linguistics applications. LDA also provides better accuracy over latent semantic analysis (LSA), nonnegative matrix factorization (NMF), principal component analysis (PCA), and random projection (RP) [28].

Regarding experimentation details, LDA generated two topic models using BoW and TF-IDF. The BoW topic model measured the occurrence of words within the corpus but did not contain information about the order or structure of words. Based on the BoW topic model, the TF-IDF topic model measured the importance of a word based on the occurrences of each word and checked its relevance against the whole corpus. In TF-IDF, a word was considered relevant when it occurred in a few user posts and low if it occurred in many user posts. The topic models mentioned above were created with LDAmulticore to reduce the training time compared to the regular implementation of LDA [78].

LDA required *corpus* and *id2word* parameters. The optional parameters were *chunksize*, *passes*, *n\_topics*, and densities (*alpha* and *beta*) that needed to be precisely tuned to leverage LDAmulticore. In the *corpus* parameter, the tokenized text source was converted to vectors as a sparse matrix of a number of documents and terms. The *id2word* parameter determined the vocabulary size from the corpus. The *chunksize* and *pass* parameters were set to 100 chunks and 20 passes to determine the number of user posts used in training. The *chunksize* and *pass* parameters were implemented consistently in all Facebook groups. In addition, LDA required a specific parameter for determining the exact number of topics the algorithm needed to achieve distinct and coherent topics. The ideal number of topics (*n\_topics*) was performed by running the LDA several times with multiple topic parameters from two (2) to 20 until the elbow method achieved the highest coherence or  $C_v$  value, as described in Table 2. Finally, the hyperparameters *alpha* for document-topic density and *beta* for word-topic density were set to 'auto,' allowing the LDA algorithm to estimate the document-topic and word-topic densities automatically. The *alpha* hyperparameter

controls the mixtures of topics for any given text source. The *beta* hyperparameter controls the distribution of words per topic.

**TABLE 2. LDA semantic coherence values and number of topics parameters.**

Facebook Group	Semantic Coherence Value	Number of Topics Parameter
Instructional Designer	0.481	5
Designers for Learning	0.376	9
Adobe Captivate Users	0.372	7
Articulate Storyline	0.368	7

In the second topic model, BERTopic is a recent topic modeling technique that leverages Bidirectional Encoder Representations from Transformers (BERT) as a class-based TF-IDF (c-TF-IDF) to calculate words' left and right context and generate interpretable topic representations [79], [80]. In c-TF-IDF, text sources are treated as a single class. Then, the frequency of each word was extracted for each class and divided by the total number of words and posts across all classes. BERTopic supports different pretrained models to understand the context of words based on their surroundings that can be used for supervised and unsupervised NLP tasks [81]. The pretrained sentence transformer model (stsb-bert-large) was implemented to identify semantic textual similarity by reducing dimensionality with the Uniform Manifold Approximation and Projection for Dimension Reduction technique (UMAP) and clustering sentence embeddings with the HDBSCAN algorithm. Although stsb-bert-large was deprecated in early 2022 due to low-quality embeddings, the pretrained model was selected at the time of the analyses in late 2021 because it was optimized for semantic similarity tasks with the ability to map features to a dense vector space.

The experimentation details in BERTopic involved fitting the cleaned user posts as the text sources against the pretrained model in English by automatically generating the number of topics (*nr\_topics*) parameter and calculating word probabilities. Although BERTopic can further reduce the generated number of topic parameters with the *reduce\_topics* function, the initial experimentation produced a low number of topics with less semantically coherent topic interpretation. Rather than allowing BERTopic to reduce the *nr\_topics* parameter automatically, the semantic coherence values were calculated to obtain the highest  $C_v$  values to determine the appropriate parameter for each Facebook group, as described in Table 3.

### C. TOPIC MODELING EVALUATION

Chang *et al.* [82] argued that there is no gold standard for evaluating topic models. The semantic coherence values of the topic models generated with LDA and BERTopic were examined through quantitative and qualitative approaches. Semantic coherence refers to relevant words with the highest

**TABLE 3.** BERTopic semantic coherence values and number of topics parameters.

Facebook Group	Semantic Coherence Value	Number of Topics Parameter
Instructional Designer	0.468	5
Designers for Learning	0.503	3
Adobe Captivate Users	0.353	5
Articulate Storyline	0.507	4

probability in a topic that co-occurs within the corpus [83]. In the quantitative approach, the semantic coherence values of topic models were generated by obtaining the highest semantic coherence measures, or  $C_v$  values, during parameter tuning. In the qualitative approach, topic interpretation was based on human judgment and subject matter expertise in IDT. Chang *et al.* [82] proposed evaluating topic model outputs using two methods, including topic and word intrusion methods. Regarding topic intrusion, discovered topics were evaluated to determine whether the topic model's decomposition of the text sources agreed with human judgments. In terms of word intrusion, a topic model was examined by observing the words inserted in a topic model that did not provide semantic coherence or coherent meaning. The pyLDAvis package in Gensim [84] and BERTopic visualization functions [85] were used to assist with evaluating LDA and BERTopic topic models, respectively.

In evaluating topic models using LDA, the topic distributions of BoW produced higher topic probabilities than the TF-IDF topic models. The BoW topic models were easier to interpret and provided more nuanced details into IDT. When evaluating topic models using BERTopic, the topic probabilities were nearly similar to those of the BoW topic models. Nevertheless, topic distributions were more general. In Adobe Captivate Users, for example, E-Learning Workflow was the general topic model with BERTopic. In contrast, the BoW topic models contained the specific components of the e-learning development workflow. The generalized nature of topic models in BERTopic was due to the lack of domain-specific knowledge in the pretrained model that was used for fitting the text sources onto the pretrained model. The use of BERTopic also revealed the black box issue where behaviors of the topic modeling algorithm were not observable. Harrison *et al.* [86] reported a similar problem when running topic modeling with the stsb-bert-large pretrained model on team communication transcripts. Unlike BERTopic, the behaviors of LDA can be customized and explained through parameter tuning except for the automatic parameters for  $\alpha$  and  $\beta$  densities. Even though it was impossible to observe the automated nature of calculating  $\alpha$  and  $\beta$  parameters in LDA, a grid search function could have determined the specific density parameters. However, a grid search function may not be feasible to implement as part of awareness tools in a real-world scenario due to its considerable processing time.

## IV. FINDINGS

This section is organized into three parts. Section A describes the characteristics of user posts, word frequencies, and word probabilities. Section B identifies user posts' sentiment polarity, entities, and entity relationships. Section C lists the topic structures found in each online CoP using LDA and BERTopic.

### A. TEXT CHARACTERISTICS, WORD FREQUENCIES, AND N-GRAMS

#### 1) TEXT CHARACTERISTICS OF USER POSTS

In the Instructional Designer Facebook group, the average word count was 38.75 words, and the average sentence count was 3.14 sentences. The Designers for Learning Facebook group had an average word count of 36.53 words and an average sentence count of 3.20 sentences. In the Adobe Captivate Users Facebook group, the average word count was 44.06 words, and the average sentence count was 3.71 sentences. The Articulate Storyline Facebook group had an average word count of 34.51 words and an average sentence count of 2.63 sentences. The word and sentence length distributions are reported in Fig. 1.

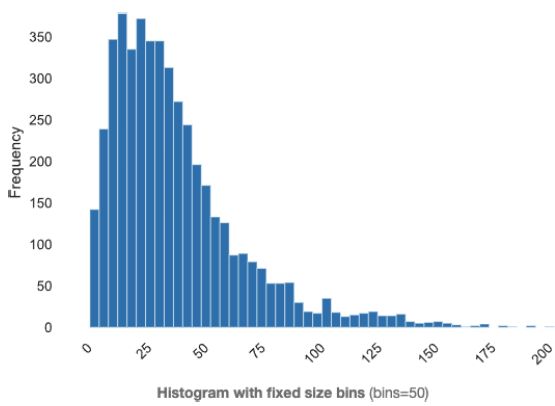
#### 2) WORD FREQUENCIES

After tokenizing and reducing the vocabulary against the stop words dictionary, the most frequent words emerged as unique tokens or the most representative words of each Facebook group. In the Instructional Designer Facebook group, the most frequent words were *id* (774), *course* (770), and *anyone* (681). In the Designers for Learning, the most frequent words were *learning* (51), *anyone* (42), and *course* (34). In the Adobe Captivate Users Facebook group, the most frequent words were *captivate* (254), *video* (155), and *slide* (153). In the Articulate Storyline Facebook group, the most frequent words were *storyline* (185), *video* (155), and *slide* (127). Fig. 2 contains the word cloud visualizations.

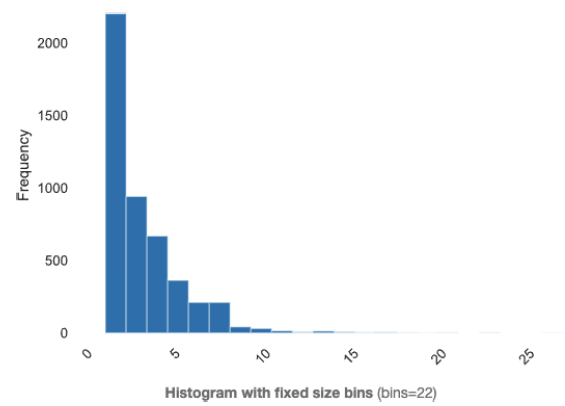
#### 3) N-GRAMS

In the Instructional Designer Facebook group, the most frequent 4-grams referenced following specific discussion posts, remote teaching or learning from home, and hashtags (e.g., #elearningtrends). In the Designers for Learning Facebook group, the most frequent 4-grams described engagement strategies in online learning, training facilitation strategies, webinar events, and asking for specific advice related to educational technologies. In the Adobe Captivate Users Facebook group, the most common 4-grams were related to asking for solutions from new users, developing responsive e-learning, asking for examples, and troubleshooting solutions to common problems. The Articulate Storyline Facebook group had the most frequent 4-grams related to sharing video link tutorials and following up on specific posts. Table 4 summarizes each Facebook group's five most frequent 4-grams and frequencies.

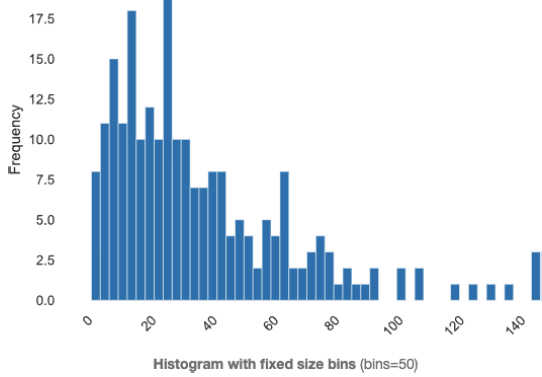




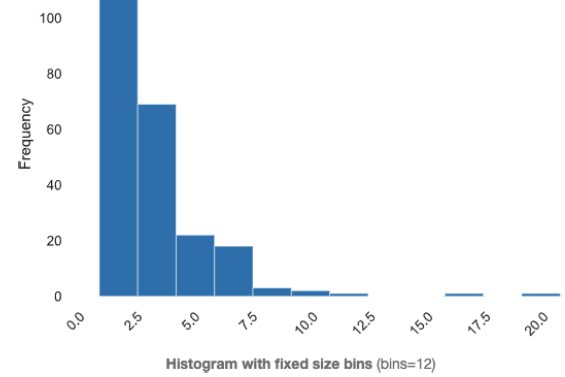
(a) Instructional Designer average word length.



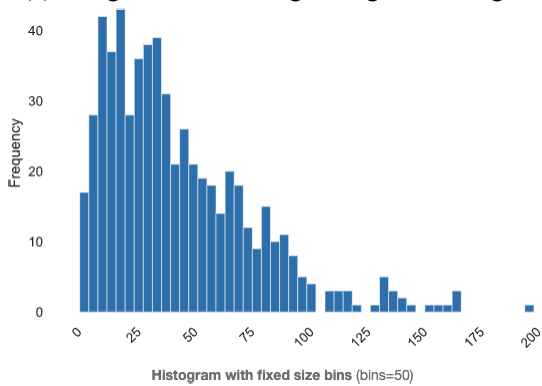
(b) Instructional Designer average sentence length.



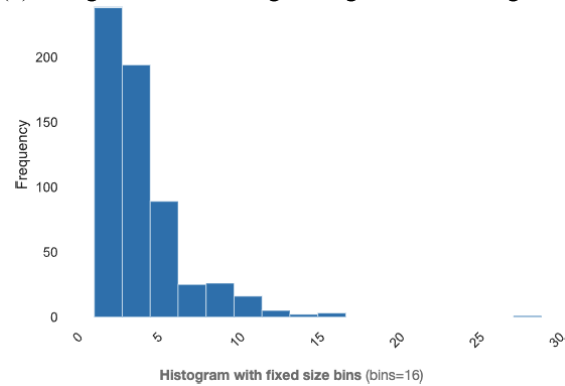
(c) Designers for Learning average word length.



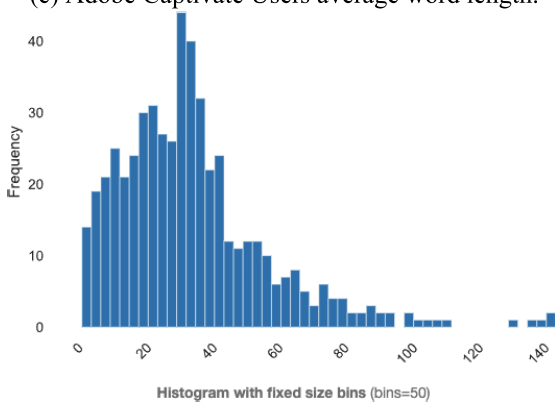
(d) Designers for Learning average sentence length.



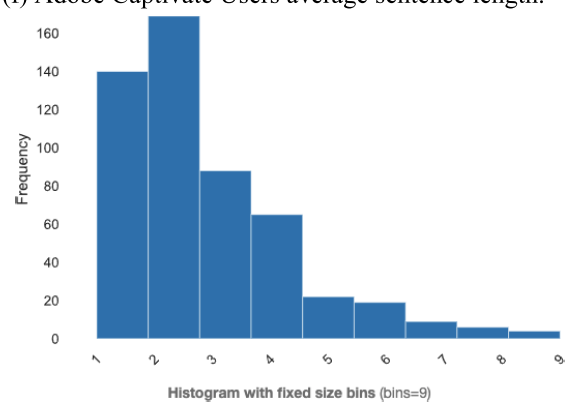
(e) Adobe Captivate Users average word length.



(f) Adobe Captivate Users average sentence length.



(g) Articulate Storyline average word length.



(h) Articulate Storyline average sentence length.

FIGURE 1. Distribution of word and sentence lengths.



**TABLE 4. Most frequent 4-grams and frequencies.**

Facebook Group	4-Gram	Frequency
Instructional Designer	( <i>u, learningpark, learn, right</i> )	9
	( <i>learningpark, learn, right, way</i> )	9
	( <i>follow, u, learningpark, learn</i> )	9
	( <i>learningfromhome, onlineteaching, onlineeducation, teachersofinstagram</i> )	7
	( <i>learningeveryday, lifelonglearning, keeplearning, neverstoplearning</i> )	7
Designers for Learning	( <i>learning, designer, showcasing, best</i> )	4
	( <i>facilitate, engaging, online, course</i> )	4
	( <i>online, course, hope, see</i> )	4
	( <i>best, use, social, learning</i> )	4
	( <i>might, relevant, anyone, looking</i> )	4
Adobe Captivate Users	( <i>hi, im, new, group</i> )	3
	( <i>im, using, drag, drop</i> )	2
	( <i>one, whole, quiz, project</i> )	2
	( <i>adobe, captivate, 2019, update</i> )	2
Articulate Storyline	( <i>responsive, mode, csv, format</i> )	2
	( <i>storyline, tip, link, het</i> )	20
	( <i>ill, show, step, step</i> )	20
	( <i>tip, link, het, first</i> )	20
	( <i>link, het, first, comment</i> )	20
	( <i>see, video, first, comment</i> )	20

**TABLE 5. Sentiment distribution of user posts.**

Facebook Group	Positive	Neutral	Negative	Total
Instructional Designer	3,298	1,011	408	4,717
Designers for Learning	163	52	13	228
Adobe Captivate Users	358	165	76	599
Articulate Storyline	294	149	79	522

SharePoint (3), and Canvas (1). Fig. 3 shows the distributions of the most frequent entities.

**3) ENTITY RELATIONSHIPS**

After performing entity recognition in each group, prominent relationships between entities emerged when community members used specific words. In the Instructional Designer Facebook group, 1,908 entity relationships were identified. Community members used words (e.g., *thanks, thank, want*) to exchange suggestions and solicit help related to e-learning development (e.g., storyboarding, development hourly cost), ID graduate programs, online workshops, PD, and job opportunities.

In the Designers for Learning Facebook group, 173 entity relationships were identified. Community members used words (e.g., *thanks, want, see*) to share online workshops and resources to support teaching practices. Additionally, the entity relationships suggested that members use the group to seek feedback from others (e.g., a member’s custom e-learning course, online ID portfolio) and advice for

selecting educational technology tools (e.g., Scratch for game development).

In the Adobe Captivate Users Facebook group, 342 entity relationships were identified. Community members used words (e.g., *thanks, thank, help*) to seek technical solutions to e-learning development using Adobe Captivate. Community members in this group were particularly interested in asking questions about media production, 360 immersive videos, e-learning interactions (e.g., drop-down menus, image sliders, quiz items), accessible e-learning, and operating system specifications for the authoring tool.

In the Articulate Storyline Facebook group, 286 entity relationships were identified. Community members used words (e.g., *thanks, thank, link*) to share instructional video tutorials and exchange tips on using Articulate Storyline. These tips and tricks involved video and quiz triggers using JavaScript and variables in the standalone version of the tool and integration with the web-based e-learning authoring tool (i.e., Articulate Rise). Table 6 summarizes each Facebook group’s ten most frequent entity relationships and frequencies.

**C. LATENT TOPIC STRUCTURES WITH LDA AND BERTOPIC**

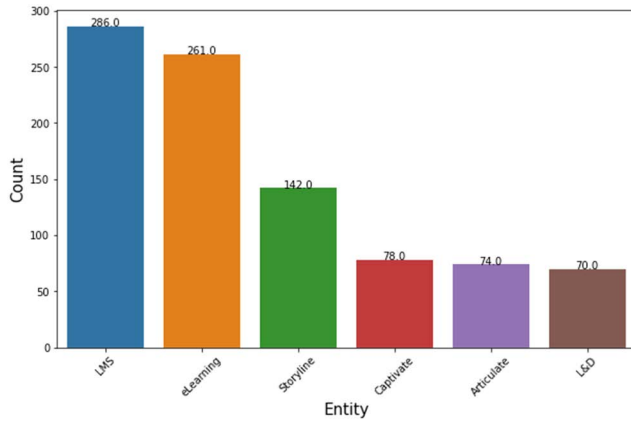
The BoW topic models had better topic interpretation based on subject matter interpretation and higher probabilities of topic distributions than TF-IDF topic models. BoW topic models generated the majority of the topics with a higher degree of specificity in IDT. Nevertheless, the topic models using BERTopic developed fewer topics that were more general, with little detail in pedagogy and educational technology. The topic models generated by BERTopic are a great example of how domain-specific models are needed to create better topic representations. Table 7 summarizes the emerging topic patterns for each Facebook group using the BoW and sentence transformer topic models.

**V. DISCUSSION**

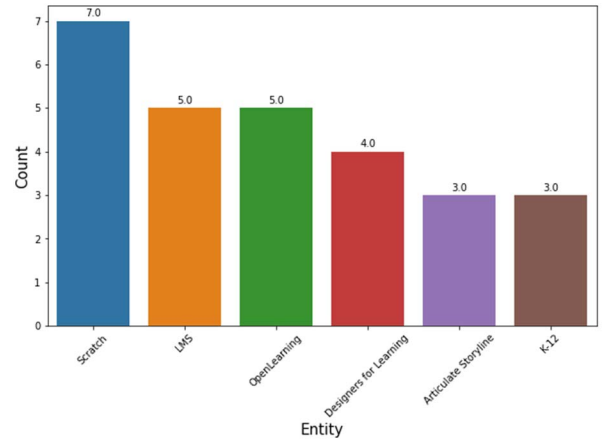
This study examined 6,066 user posts from four CoPs in IDT on the Facebook social media platform from September 2017 to September 2020 to better understand the characteristics and emerging topic themes in practical knowledge. This study offers several findings that provide valuable information for researchers and practitioners in the IDT field. The study also suggests development considerations for machine learning operations (MLOps) that allow for the future development of complex, scalable, and robust NLP tools to enhance community members’ ability to browse and filter practical knowledge in asynchronous online environments. A discussion of the findings, implications, and limitations are summarized below.

**A. GENERAL, UNIQUE, AND SHARED CHARACTERISTICS AMONG IDT CoPs**

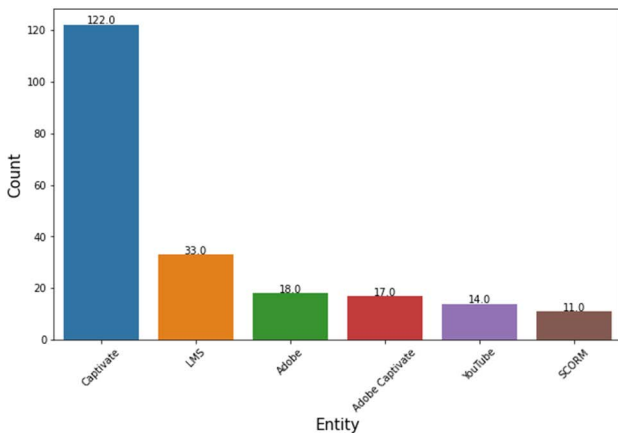
As a social media platform, Facebook groups facilitated the exchange of practical knowledge among IDT professionals through opportunities for informal PD and just-in-time



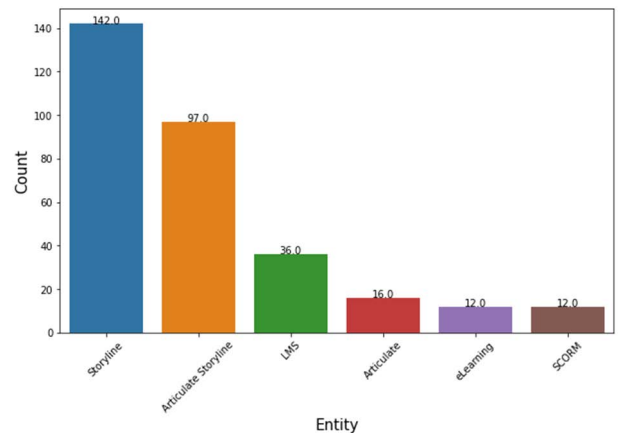
(a) Most frequent entities in Instructional Designer.



(b) Most frequent entities in Designers for Learning.



(c) Most frequent entities in Adobe Captivate Users.



(d) Most frequent entities in Articulate Storyline.

**FIGURE 3. Most frequent entities.**

interventions. The findings showed general characteristics regarding members’ written communication and sentiment. As a general characteristic, community members in the four Facebook groups used four sentences or less and 45 words or less to seek pedagogical and technical advice. In the Instructional Designer and Designers for Learning Facebook groups, these online CoPs had almost similar sentiment distributions from 70%–72% for positive sentiment, 22% for neutral sentiment, and 6%–8% for negative sentiment. In the Adobe Captivate Users and Articulate Storyline Facebook groups, these online CoPs also had almost similar sentiment distributions from 56%–60% for positive sentiment, 28%–29% for neutral sentiment, and 12%–15% for negative sentiment.

The findings suggested unique and shared characteristics that revealed the purpose behind online CoPs in IDT. Based on the topic structures, the unique features of the Instructional Designer Facebook group were related to asking peers to review ID portfolios and soliciting resources for educational animation development. The unique characteristics of the Designers for Learning Facebook group were associated with the development of serious games for learning, online game development, and educational technology tools. The shared

characteristics of the Instructional Designer and Designers for Learning Facebook groups were in the areas of ID graduate programs, job postings, event announcements, and general resources for online course development and online training in higher education and private settings, respectively.

When comparing the topic models, the Adobe Captivate Users Facebook group’s unique characteristics were mobile development, e-learning course integration in LMS platforms, and e-learning development workflow. In contrast, the unique characteristics of the Articulate Storyline Facebook group pertained to the integration of JavaScript with Articulate Storyline outputs. Because of the similar purpose behind the e-learning authoring tools, it was not surprising to observe shared characteristics in the technical aspects of the software related to manipulating slide properties, quizzes, virtual reality, and multimedia components.

**B. INTENTIONALITY BEHIND COMMUNITY MEMBERS’ POSTS**

The findings suggested an active exchange among community members in all Facebook groups by stating appreciation when members received answers from others. The results

**TABLE 6. Most frequent entity relationships and frequencies.**

Facebook Group	Recognized Entity	Frequency
Instructional Designer	thanks	263
	thank	153
	want	56
	use	54
	advance	50
	known	48
	appreciated	46
	think	43
	help	41
	tia	40
Designers for Learning	thanks	105
	want	5
	see	4
	make	4
	appreciated	3
	thank	3
	wanted	3
	know	3
	help	3
	learn	3
Adobe Captivate Users	thanks	37
	thank	19
	help	17
	ideas	11
	suggestion	10
	need	10
	captivate	10
	know	9
	get	9
	want	8
Articulate Storyline	thanks	26
	see	23
	link	20
	help	13
	thank	12
	want	12
	thx	11
	use	10
	add	8
	create	8

align with Evans *et al.*'s intentionality and consciousness of self-directed learning, where community members sought solutions independently [54]. The findings also showed the cognitive dimension of CoPs' organizational knowledge capital as members pursued collective goals with established norms and behaviors [60]. In the Instructional Designer and Designers for Learning Facebook groups, the intentionality and consciousness of self-redirected learning occurred when members requested advice about e-learning development processes, learner engagement strategies, multimedia development, ID graduate programs, and ID jobs. In the Adobe Captivate and Articulate Storyline Facebook groups, members had conscious efforts in seeking help with the technical aspects of e-learning authoring tools.

Furthermore, each online CoP had different conventions for distributing informal learning resources. The Instructional Designer Facebook group relied heavily on hashtags to allocate resources for e-learning development and courseware integration with LMS platforms. Additionally, the Instructional Designer Facebook group members followed specific

user posts deemed valuable. Based on the entities extracted, this online CoP attracted IDT professionals from a wide array of work settings, mainly in L&D settings in the private sector. In the Designers for Learning Facebook group, members discussed learner engagement strategies, gamified learning, and free PD opportunities. Although the distribution of resources was not present in the Adobe Captivate Facebook group, members relied heavily on others to solve technical questions related to the Adobe Captivate software. Additionally, new members in the Adobe Captivate Facebook group tended to introduce themselves to the group before requesting advice. In the last Facebook group, members of the Articulate Storyline relied on videos that community administrators shared, and members asked questions about the location of the resources in the online CoP. Community administrators also tended to misspell definite articles (i.e., *het* instead of *the*), as seen in Table 4.

**C. TYPES OF PRACTICAL KNOWLEDGE**

The exchange of practical knowledge was observed as members offered solutions to others through design judgments. In the Instructional Designer and Designers for Learning Facebook groups, members framed and deliberated off-hand design judgments as they inquired about converting face-to-face training to an online format while keeping learners engaged. Additionally, members exhibited appearance, compositional, connective, and quality design judgments when reviewing ID portfolios and sample e-learning courses requested by other members. In the Adobe Captivate Users and Articulate Storyline Facebook groups, members showed default design judgments as they solved technical issues about manipulating various properties for quizzes, slides, and multimedia.

Seeking advice related to educational technology was prevalent in online CoPs. In examining the frequencies of all extracted entities, however, pedagogical entities were less frequent than educational technology entities. For instance, the less frequent pedagogical entities in the Instructional Designer Facebook group were ISD, learning styles, and e-learning design. The less frequent pedagogical entities in the Designers for Learning Facebook group were UDL, ADDIE, and Learning Pyramid. The learning styles myth suggests that learning can be acquired in distinctive ways through visual, auditory, and kinesthetic channels. The learning pyramid myth indicates that different learning activities are associated with memory retention rates. The learning pyramid is the product of misusing Dale's research on continuity of learning through experience, where learning occurs on a concrete to abstract continuum using audiovisual media options [87].

Although pedagogical entities related to learning styles and learning pyramid were present to a lesser degree in the Instructional Designer Facebook group, members either debunked or spread these learning myths. Spreading these learning myths showed the lack of community protocols to provide corrective actions or clarifications. In the Adobe

TABLE 7. Emerging topic patterns.

Facebook Group	Topic	Bag-of-Words Topic Model	Sentence Transformers Topic Model
Instructional Designer	Topic 1	ID Programs	Educational Animation
	Topic 2	E-Learning Development	E-Learning Training Resources
	Topic 3	E-Learning Engagement Practices	ID Jobs
	Topic 4	E-Learning Software	ID Experience
	Topic 5	Simulation Development	ID Portfolio Development
Designers for Learning	Topic 1	Video Development	Free Resources and Events
	Topic 2	Online Course Development	Online Game Development
	Topic 3	Online Training Development	ID Jobs
	Topic 4	Video Development	
	Topic 5	Research EdTech Tools	
	Topic 6	Coding and Game Design	
	Topic 7	ID Profession	
	Topic 8	Serious Games	
	Topic 9	ID Programs	
Adobe Captivate Users	Topic 1	E-Learning Output	E-Learning Workflow
	Topic 2	Quiz Tracking	Adobe Captivate for New Users
	Topic 3	Video Development	Virtual Reality
	Topic 4	Slide Questions	Version Questions
	Topic 5	Mobile Development	Integration with CMS/LMS
	Topic 6	Slide Questions	
Articulate Storyline	Topic 1	Object Triggers	Slide Questions
	Topic 2	Slide Questions	Integration with JavaScript
	Topic 3	Layer Troubleshooting	Virtual Reality
	Topic 4	Quiz Tracking	Quiz Tracking
	Topic 5	Slide Questions	
	Topic 6	E-Learning Development	
	Topic 7	Video Development	

Captivate Users and Articulate Storyline Facebook groups, pedagogical entities were absent because these online CoPs were used for troubleshooting software issues. However, cognitive load theory, cognitive theory of multimedia learning, and Section 508 for accessibility are critical pedagogical concepts and frameworks for e-learning development.

#### D. THE NEED FOR PEDAGOGICAL FOUNDATIONS

Even though pedagogical entities were less frequent in the Instructional Designer and Designers for Learning groups and nonexistent in the e-learning development software Facebook groups, the real-world applications of pedagogical concepts are critical to the IDT profession. Without pedagogical foundations, IDT professionals risk designing online learning experiences with a heavy emphasis on technology delivery mechanisms without proper technology integration considerations and perpetuating the misconceptions of the IDT role, primarily for e-learning materials development and technology support. The focus on e-learning materials production has also been reported in Leung [17], where a large online CoP in IDT, called the eLearning Industry, prioritized e-learning development over pedagogical concepts in online articles written by IDT professionals. Recent research has also highlighted the need for information hubs to ensure continuity of learning during times of crisis [88], [89], [90]. Information hubs, or COVID-19 response online resources, do not currently exist in these online CoPs. Pedagogical resources should be integrated into online CoPs to

support IDT professionals' abilities to design online and hybrid learning experiences and properly incorporate educational technology.

The real-world applications of pedagogical concepts have implications when designing compelling online and blended learning experiences in various settings. Although this study highlights the need for pedagogical foundations in online CoPs, it does not intend to list all frameworks, concepts, and theories to guide the design of online and blended learning that lead to positive outcomes for learners and instructors. An example of applying pedagogical concepts to ID projects is explained in a book chapter on Managing ID Projects in Higher Education [91]. IDT professionals in higher education perform five types of ID projects that involve pedagogical concepts to guide decision-making as follows:

- 1) Course Development: Collaborating with faculty and staff to develop new courses, redesign existing courses, and enrich in-person courses with educational technology with quality assurance (e.g., UDL, Bloom's Taxonomy, Community of Inquiry, Backward Design).
- 2) Institutional Learning Initiatives: Leading or supporting pedagogical approaches (e.g., microlearning, service learning, gamed-based learning) and technology initiatives (e.g., proctoring platforms, content curation, video conferencing).
- 3) Workshops: Aligning and evaluating the impact of educational technology through technology integration frameworks (e.g., Technology Acceptance Model

(TAM); Replacement, Amplification, and Transformation (RAT); Substitution, Augmentation, Modification, and Redefinition (SAMR); Technology Integration Matrix (TIM)).

- 4) Quality Assurance: Implementation of course development and quality assurance procedures (e.g., Quality Matters Higher Education rubric).
- 5) Support: Supporting stakeholders regarding educational technology, pedagogy, and accessibility.

Additionally, project management is critical for handling ID projects by leveraging interpersonal, technical, and administrative skills. Even though pedagogical concepts are essential in higher education, these concepts are still applicable in different professional settings. Several IDT Open Educational Resources (OERs) can be found on OER Commons [92]. IDT CoPs may choose to curate resources that build the necessary pedagogical foundations, especially for newly minted IDT professionals.

## E. IMPLICATIONS

The findings of the study have several implications for research, practice, and MLOps.

### 1) IMPLICATIONS FOR RESEARCH

Erden *et al.* [93] argued that research on the collective quality of practical knowledge is required to understand organizations' knowledge creation capabilities. The authors also suggested that the collective quality of practical knowledge can be examined on four levels: Group as Assemblages, Collective Action, Phronesis, and Collective Improvisation. Online CoPs are newly formed in the first level, where members share no collective history or understanding. In the second level, collective action is defined by shared memory and knowledge for solving problems and adopting group-based routines as an integral part of the community culture. In the third level, phronesis refers to the collective actions that online CoPs take to advance goals guided by shared culture and values. Additionally, the collective quality of practical knowledge emerges in the third level, where members articulate solutions to familiar problems. In level four, collective improvisation is the highest level of practical knowledge, where online CoPs respond quickly to unpredictable situations.

Based on the observed entity relationships, 4-grams, and topic models, the collective quality of practical knowledge in the online CoPs of interest operated at the second level, where community members actively exchanged pedagogical and educational technology advice as part of the cultural routine. Although topic models can be used to assert the overall quality of practical knowledge in online CoPs, it is crucial to understand that online CoPs can operate at the third level of phronesis or the fourth level of collective improvisation, where members can improvise solutions to unfamiliar challenges. As part of the Instructional Designer Facebook group's culture, for example, the ID Portfolio Development topic model involves providing feedback on

portfolios that are inherently diverse in creativity based on professional backgrounds and goals for applying to specific jobs. In another instance, the Designers for Learning Facebook group may also operate at the fourth level of collective improvisation when encountering unfamiliar topics regarding new research on educational technology and game design tools. Last, the Adobe Captivate Users and Articulate Storyline Facebook groups operated at the second level of collective action when solving common technical issues of the e-learning software. In addition, e-learning development software CoPs can perform at higher levels when encountering new challenges and opportunities in updated software versions.

Further research is required to understand how members of online CoPs engage at level three of phronesis and level four of collective improvisation through discourse analysis, sequential pattern analysis, or process mining. Research on how topic models evolve can also demonstrate how community priorities and goals shift. The evolution of topic models can provide insights into online CoPs' abilities to respond to unpredictable circumstances.

### 2) IMPLICATIONS FOR PRACTICE

Professional organizations, IDT education and training providers, leaders of online CoPs, and e-learning development software companies can be informed through the study about how community members participate when seeking pedagogical and educational technology solutions.

Professional organizations can identify topic patterns in practical knowledge online CoPs when IDT professionals exchange pedagogical and educational technology advice. Professional organizations can also benefit from the findings by examining their frameworks against the discovered entities and topic models. The results of the study highlight the need to research the extent to which competencies and standards in IDT align with practical knowledge present in online CoPs. Thus, further investigating the alignment between online CoPs' practical knowledge and competencies identifies the gaps and opportunities for targeted PD opportunities. A further investigation is needed to understand how IDT professionals apply newly acquired practical knowledge in different settings (e.g., K-12, higher education, and private settings) and how it is internalized into their professional practice.

IDT education and training providers can identify formal and informal learning opportunities that enhance the pedagogical foundations of IDT students and professionals. IDT faculty are informed of types and topic patterns in practical knowledge that can be incorporated into IDT programs and internships. IDT students can leverage the accumulated practical knowledge in online CoPs to seek solutions to academic coursework and receive informal student portfolio reviews. Although the extracted educational technology entities were more prevalent than pedagogical concepts, informal learning opportunities can enhance the pedagogical foundations of IDT professionals by exploring research and implementation trends in

higher education, K-12, and private settings. In higher education, the 2022 Educause Horizon Report describes redefining instructional modalities that affect how institutions develop new courses two years after the COVID-19 pandemic [94]. IDT professionals in K-12 settings can learn about the trends in the USA through the Condition of Education 2022 report by the National Center for Education Statistics [95]. IDT professionals in private settings can benefit from exploring workplace reports by the ATD [96].

Community leaders of Instructional Designers and Designers for Learning Facebook groups can better understand the emerging topic structures in online CoPs by devising mechanisms for better knowledge sharing and discoverability within the technological limits of the Facebook platform. While Facebook groups facilitate the exchange of practical knowledge in an asynchronous environment, three recommendations are necessary to sustain online CoPs by creating mechanisms for reusing knowledge, onboarding new members, and adopting a culture of accountability through professional competencies. The first recommendation is to develop better mechanisms for reusing existing knowledge to make knowledge more discoverable by members. Rather than using hashtags to distribute content, the topic structures found in this study can be used to design content structures that classify cognitive and technical practical knowledge. By developing a new set of hashtags that organizes practical knowledge, such hashtags can be used to filter specific functions of the online CoP and types of practical knowledge as follows:

- 1) Instructional strategies and theories.
- 2) E-learning workflows for face-to-face to online and blended formats.
- 3) Educational technology tips.
- 4) ID jobs and career advice.
- 5) Feedback on online and blended learning experiences and portfolios.
- 6) PD resources and events.

The second recommendation is to create specific onboarding for new members by stating the online CoP's purpose, protocols for sharing knowledge, and the types of practical knowledge available. The third recommendation is to adopt a culture of accountability in which leaders and members of online CoPs fact-check information and discourage misinformation by adopting professional competencies that allow IDT professionals to self-assess their practice.

Software companies can design better support mechanisms that address users' most challenging technical aspects of e-learning development in their respective CoPs on Facebook and support websites. The Adobe Captivate support website currently organizes troubleshooting discussions in 15 categories with general and in-depth aspects of the software. Nevertheless, the support website lacks additional in-depth topic categories and issues (e.g., slide manipulation and response templates for mobile) that users encounter on the Facebook group [97]. The Articulate Storyline support website does not provide users with topic categories to organize

software-related issues. Instead, users rely on threaded discussions to find solutions on the Articulate Storyline support website [98]. Although it is unknown whether the e-learning development software companies endorse their respective Facebook groups, online CoPs and support websites lack search mechanisms for allowing members to seek technical solutions independently. Moreover, these companies benefit from the findings by integrating the topic categories with consistent hashtags in both online CoPs and support websites.

### 3) IMPLICATIONS FOR MLOPS

The study implemented NLP tasks in an unsupervised manner to discover the patterns in practical knowledge in online CoPs. The study established a critical foundation for understanding member interactions and exchanging practical knowledge. The study also provided lessons for MLOPs about producing machine learning (ML) models as awareness tools to provide insights into the patterns of the accumulated practical knowledge. MLOPs are a set of practices where ML models are brought into production to increase quality, management, monitoring, and automation in large-scale production environments. Furthermore, developing awareness tools can be guided by understanding the factors that impact positive outcomes in online learning. In a meta-analysis of online learning studies from 1998 to 2021, Yu [99] found that behavioral intention, instruction, engagement, interaction, motivation, self-efficacy, performance, satisfaction, and self-regulation were critical factors in online learning. Shaik *et al.* [100] argued that implementing NLP has implications for improving learning processes in online environments in five categories: understanding the end user without human intervention, adapting learning environments, automating repetitive tasks, personalized guidance and motivation, and monitoring learner progress.

The Python code used in the NLP tasks supports the development of ML models as dashboard components that can help online CoPs in engagement, satisfaction, and self-regulation. ML models can assist members and leaders in overcoming the issue of knowledge discoverability at the member and leadership levels. For example, a member dashboard can contain four components and their respective Python libraries to visualize word frequencies with WordCloud, classify user posts by topic categories with LDA, organize pedagogical and educational technology entities with spaCy, and classify entities by topic categories with spaCy and LDA. At the leadership level, an administrative dashboard provides a high-level view of the online CoP by integrating five components to identify topic patterns in user posts, summarize word frequencies, identify sentiment and assign topic categories with TextBlob and LDA, count pedagogical and educational technology entities in topic categories, and count user posts in the form of word frequencies with lambda functions.

In higher education, the Python code also supports the future development of awareness tools in LMS platforms for IDT education. The accumulated practical knowledge from online CoPs and past online IDT courses assists



students in seeking potential solutions to ID problems. Recent research on ML models in LMS platforms has focused on predictive tasks with continuous or numerical features, such as predicting student performance, providing resource recommendations, developing learner profiles, and automating feedback based on student performance [101], [102], [103], [104], [105], [106], [107], [108]. However, the integration of accumulated practical knowledge from formal and informal sources using NLP attributes has not been developed in LMS platforms. Integrating practical knowledge sources in LMS platforms can provide IDT students with real-world solutions and prevent them from accessing multiple information sources to solve ID projects during coursework.

Huyen [109] argued that ML models must align with the objectives that ultimately lead to positive outcomes. Additionally, ML models must be reliable, scalable, maintainable, and adaptable to operate efficiently at scale. Integrating ML models on social media platforms can positively impact the discoverability of practical knowledge while promoting engagement, satisfaction, and self-regulation. In higher education, integrating ML models in LMS platforms can provide IDT students with the ability to solve ID projects by accessing the accumulated practical knowledge in online CoPs and discussion boards from past online IDT courses while promoting self-directed learning. In the proposed methodology, the NLP tasks provided reliable word frequencies, entities, sentiment analysis, and topic structures by implementing the respective stop words dictionary, lists of features for identifying entities and sentiment, and appropriate semantic coherence scores for topic modeling. Although the NLP tasks were performed locally, the NLP tasks may present scalability issues in a real-world context when processing a large corpus from social media sources. For example, the text processing of the large corpus in the Instructional Designer Facebook group was the most time-consuming aspect because of the rule-based nature of word frequencies and entity matching against a dictionary of words during the POS tagging process and the list of entity categories for classifying entities, respectively. Even though the topic modeling component was an easy task, parameter tuning for obtaining semantically coherent topics required a significant processing time. Concerning maintainability, the Python code used in NLP tasks is reproducible in testing and production environments. Nevertheless, optimization techniques are needed to reduce errors and latency between the hosting server of the ML models and users' dashboards.

While the proposed approach used three years of public data for training purposes, future experimentation and testing are required to examine the quality of produced topic models on new text sources, types of processing (i.e., batch or on-demand processing), data cleaning of self-promotion and spam, and storing analytical insights in cloud services. As ML models degrade due to the growth of practical knowledge, updating entity dictionaries is necessary for tracking the performance of ML models when new entities are created. Monitoring the semantic coherence scores in

ML models is another critical task when semantic scores fall below a given threshold, which leads to low-quality interpretable topic structures. Regarding the types of processing, batch and on-demand processing are two options available for processing text sources. On-demand processing via cloud services is the ideal solution, but further analyses of cost and usability requirements are needed to determine the best processing choice. Although the study relied on the manual identification of posts related to self-promotion and advertisements, the NLP tasks need to implement additional code to correct grammatical mistakes and delete irrelevant user posts to ensure the reliable generation of topic structures. The last indispensable features are scaling text processing capabilities and adjusting the cloud's storage capacities of analytical insights.

Before ML models are deployed in cloud services, the NLP tasks implemented in the study require further optimization techniques to increase robustness. Omar *et al.* [110] argued that NLP is susceptible to adversarial attacks that lead to corrupted predictions. In their literature review of the robustness of NLP, the authors stated that robustness analysis tools, robustness metrics, and defense mechanisms are required for creating robust NLP pipelines after deployment in the real world. Concerning robustness analysis tools, NLP tasks require further robustness analyses to mitigate adversarial attacks that may occur during deployment, including the CheckList by Ribeiro *et al.* [111], Robustness Gym by Goel *et al.* [112], and WildNLP by Rychalska *et al.* [113]. Robustness metrics are also necessary to measure the robustness of the proposed method by obtaining three metrics, including attack success rate, error rate, and interval bound propagation (IBP) bound tightness, to understand the level of normal accuracy and training accuracy during word substitution attacks. Finally, the NLP tasks require a defense mechanism through data augmentation when processing input text sources in a real-world scenario. In data augmentation, input words are masked to defend against word substitution and character-level attacks.

## F. LIMITATIONS

The present study was not without limitations. Community members posted links to resource documents, blogs, video tutorials, and research papers that were not analyzed because the textual data were outside the Facebook platform. A significant amount of practical knowledge was contained in these external resources. Nevertheless, external resources were not analyzed due to additional data cleaning mechanisms required to extract text from documents and obtain video transcriptions.

## VI. CONCLUSION AND FUTURE WORK

The study provided a systematic approach to examining tacit or practical knowledge from four CoPs when IDT professionals attempted to solve design problems asynchronously on the Facebook social media platform. By examining the written communication in each online CoP, the study

quantified the organizational knowledge capital, types of practical knowledge, and hidden topic patterns. The study documented the frequency and exchange of pedagogical and educational technology entities. This study also uncovered an active exchange of cognitive and technical dimensions of tacit knowledge. Tacit cognitive knowledge was present in the Instructional Designer and Designers for Learning Facebook groups about implementing instructional and assessment strategies, making career suggestions, presenting effective e-learning production workflows, and evaluating ID portfolios. Tacit technical knowledge was observed in the Adobe Captivate Users and Articulate Storyline Facebook groups regarding manipulating e-learning development software and integrating online courseware in LMS platforms. The findings provided recommendations for organizing the accumulated practical knowledge that allows community members to seek design solutions independently. Though active member participation occurs in online CoPs, community leaders must devise protocols for correcting misconceptions about learning and aligning their current organizational practical knowledge to professional benchmarks to enable self-evaluation of members' tacit cognitive knowledge. The findings provide opportunities for targeted PD in the learning sciences to enhance the pedagogical foundations of IDT professionals. Community leaders should include pedagogical resources to support IDT professionals' PD needs and decision-making of educational technology tools. It is also imperative for online CoPs to become information hubs to support instructional decisions during unprecedented circumstances that require a rapid shift from in-person learning to online, blended, and hybrid-flex forms of learning. The study established a foundational step for the future development of awareness tools to facilitate community members' exchange of design solutions for ID projects.

The future directions of the study involve the following:

- Investigating user posts by sentiment to discover the challenging aspects of ID projects from the practitioner's perspective.
- Examining practical knowledge to understand the collective quality of practical knowledge and evolution of topic models in online CoPs.
- Creating a comprehensive entity dictionary from online CoPs to investigate practical knowledge in IDT CoPs on different platforms.
- Testing the development of APIs to support native and third-party integration of awareness tools to assist online CoP leaders and members with knowledge discoverability of practical knowledge.

## APPENDIX

Even though web scraping is still a relatively new and emerging practice, Krotow and Silva [114] argued that ethical issues are associated with the automatic extraction of information. According to the authors [114], web scraping entails five ethical considerations: individual privacy and rights of research

participants, discrimination and bias, organization privacy, diminishing organizational value, and impact on decision-making. Even though web scraping involves ethical hurdles to academic researchers and Terms of Service (TOS) explicitly prohibits web scraping and crawling of their platforms, Mancosu and Vegetti [115] noted that scraping public information from online platforms may be safe for researchers because research on social media serves the public interest. Additionally, Catanese *et al.* [116] argued that TOS is designed to perverse the status quo by enforcing behavioral and technical limitations to web scraping.

Technology plays a critical role in sustaining knowledge creation and sharing. Nevertheless, it can result in negative consequences when comparing online CoPs because of the lack of anonymity and privacy that lead to unintended identification of users when searching for authorship of posts on Facebook. For this reason, any identifiable information (i.e., links to public posts and authorship) was deleted to ensure the anonymity and privacy of users. Text sources are not publicly available to prevent plagiarism and protect online CoPs' organizational knowledge [117].

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