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Metacognition in Learning

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Meet the editor

Nosisi Nellie Feza is a Full Professor in the Faculty of Humanities in the Central University of Technology. She is currently a Dean of Humanities at the Central University of Technology. She obtained a PhD in Mathematics Education from the State University of New York at Buffalo, New York as a Fulbright scholar. She received a Diversity Scholar Award from the National Center for Institutional Diversity in Michigan in 2009. In 2016 she received a Distinguished Researcher Award in mathematics education from Venus International Foundation in Chennai, India. Her research interests are early childhood mathematics stimulation, teacher development, and cultural influences in learning mathematics in students of African descent.

Contents

Preface

Metacognition and learning have a positive association because "thinking about thinking and knowing about knowing" are empowering processes for successful learning. Knowing how your brain captures information and how your thinking processes work provides you with pedagogical tools for mediating your own learning. Successful teaching can only be determined by learners' interpretation of knowledge provided and how it is received. Learning is an important process for cognitive growth, hence this book brings diverse strategies of developing metacognitive skills at different levels of learning. The contributions come from different backgrounds (economically and geographically) and different academic fields.

Literature on metacognition clearly indicates the strength of metacognitive skills in developing independent responsible learners. Such learners become creative learners who are not limited by provided instruction but go beyond, questioning and challenging provided knowledge. With such a calibre of learners, more inventors, creators of ideas, and problem solvers will emerge. Our contribution in this book provides diverse strategies at all levels of learning in different fields to promote successful learning experiences.

Educators at different levels of education should read and use this book as it provides strategies for developing and nurturing metacognitive skills. It also exposes readers to internal abilities that students have that can be developed further. The book is divided into two sections: (1) Strategies to nurture metacognition, and (2) Intrinsic metacognition enablers.

Under the first section which is "Strategies to nurture metacognition", there are five chapters.

Chapter 1 "Listener Background in L2 Speech Evaluation" discusses strategies used in training listeners of second language students of English to eliminate their biases against L2 speech. Literature articulates how accents, pronunciations, and other linguistic factors of speakers of L2 are judged and used against them in the learning processes. Hence this chapter promotes the training of listeners first with the aim of eliminating their biases for successful oral presentation and engagement of L2 speakers also developing their metacognitive skills on listening.

Chapter 2 "Teaching with and for Metacognition in Disciplinary Discussions" deliberates on the strategic observation and reflection of the SOAR teaching framework's influence in teaching with and for metacognition. The framework is argued to enhance teaching as well as improve learning. The chapter presents detailed components of the framework using classroom-based strategies as well as scenarios to unpack how the framework operates and its benefits for developing metacognition.

Chapter 3 "Mathematics Dictionary: Enhancing Students' Geometrical Vocabulary and Terminology" explores how dictionary and polygon pieces encouraged inquiry-based learning that later support learning of geometry and develop independent learning strategies for students. The findings indicate that students moved from being passive to actively participating, and independent information seeking learners.

Chapter 4 "Using Problem-Solving as a Method for the Development of Self-Regulation of Learning with Adolescents: An Experience Report" presents an analysis of the strategy used in mediating adolescents compared to problem solving with the aim of discovering a method that develops independent learning. The chapter employs Robert Sternberg's theory of problem solving together with Barry Zimmerman's concept of self-regulation. The findings reveal that problem solving has the potential to develop independent learning skills.

Chapter 5 "Drawings as Diagnostic Cues for Metacomprehension Judgment" discusses the accuracy of metacognitive monitoring for improved learning through drawings. It also discusses the procedures used to identify the cues. Literature argues for the importance of metacognitive monitoring and regulation of behaviour. Metacognitive monitoring is described as an activity that allows an individual to understand his/her own abilities to regulate behaviour for successful learning. Therefore, monitoring metacognition enhances one's ability to acquire new knowledge. Research reveals that cues enhance accuracy in metacognitive monitoring. However, highly diagnostic cues have not been determined, hence this chapter's discussion and exploration of drawings as cues.

The second section of this book is about "intrinsic metacognition enablers" and is composed of five chapters.

Chapter 1 "Self-Regulation in Early Years of Learning Mathematics: Grade R Observed Self-Efficacy Skills Shared and Aligned" empirically demonstrates how the Piagetian perspective on autonomy cited from Kamii and DeClark innate to young children carries in itself self-regulating skills that could be nurtured into metacognition. Maintaining this autonomy and extending it will create young learners who are continuously curious to learn and therefore seek ways of making sure they attain new ideas in new settings.

Chapter 2 "Generating Internal Motivation through Mobile Application Technology" investigates how mobile technology can be utilized to enhance intrinsic motivation and improve student's performance. Technology has become an everyday tool, even in developing countries, smart /mobile phones are prevalent. This chapter examines how these mobile devices can enhance both motivation and performance since students' curiosity is skewed towards their mobile devices. The findings of this exploration reveal increased motivation and performance amongst students.

Chapter 3 "Multilateral Relationship between Information Literacy, Self-Concept and Metacognitive Ability" reports an investigation of a number of competencies such as: information literacy, metacognitive abilities, and the self-concept. The importance of these capabilities has been highlighted by the literature as competencies that nurture self-esteem and self-regulation. Hence this chapter focuses on triangulating these three proficiencies, addressing literature limitations.

Chapter 4 "Redcay's STEM-oscope Model: Connecting STEM Education, Social Robots, and Metacognition" utilises STEM challenges to investigate links between STEM and social robots with metacognition. This qualitative exploration is situated within the literature that argues that STEM education is associated with metacognition. The literature asserts that STEM challenges stimulate students' curiosity, and metacognitive thinking, hence the association. The findings show that metacognitive thinking is associated with solving STEM problems.

Chapter 5 "Understanding in Action an Analysis of Its Levels and Qualities" examines the multiple roles of understanding by unfolding the levels and quality of understanding. Research argues that understanding includes in-depth knowledge that can be used to solve and create new problems. Understanding goes beyond what is taught, enabling challenging thoughts and asking difficult questions to see if the knowledge possessed can stretch beyond lived experiences.

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Section 1

Strategies to Enhance Metacognition

Chapter 1

Listener Background in L2 Speech Evaluation

Mohammadreza Dalman and Okim Kang

Abstract

Listeners are integral parts of second language (L2) oral performance assessment. However, evaluation of listeners is susceptible to listener background variables and biases. These variables and preexisting biases distort native speaker (NS) listeners' perceptions of non-native speakers' (NNSs) speech performance and contribute errors into their oral performance assessment. Among listener background variables, listeners' first language status, the amount of exposure to different English varieties, listeners' educational background, prior language teaching experience, NNSs' linguistic stereotyping, and listener attitude have been investigated in the literature and assumed to exert sizable amount of variation in speakers' oral proficiency true scores. To minimize listeners' bias in the assessment context, listeners are provided with intensive training programs in which they are trained how to rate NNSs' speech more objectively utilizing scoring rubrics. To mediate listeners' bias in social contexts, the literature has provided strands of evidence in favor of structured intergroup contact programs, which are inoculations particularly devised to improve NSs' attitude, thereby making them more receptive to NNSs' English varieties. To enhance L2 listeners' self-efficacy and foster their autonomy, L2 instructors are encouraged to emphasize explicit instruction of listening strategies.

Keywords: listener background, listener bias, listener training, listening strategies, self-efficacy, assessment

1. Introduction

Despite recent advances made in the application of automatic speech recognition (ASR) technology in second language (L2) pronunciation, the evaluation of L2 speakers' oral performance is extensively carried out through the judgment of human raters. This is the case whether the evaluation is narrowly focused on pronunciation accuracy and speech intelligibility or more broadly on communication success. The human rater judgments of L2 speakers' oral performance have consequential impacts on L2 speakers due to the fact that they form the bases upon which critical decisions are made regarding L2 speakers' education and employment. However, human raters are vulnerable to be impacted by listeners' bias. Listeners who harbor negative expectations toward a certain group of speakers due to their social group affiliations, nationality, and un-prestigious accent have the proclivity to assess accented speech more negatively [1–3]. The bias formed mainly by listeners' background factors, such as listeners' predispositions, attitudes, expectations, and stereotypes, compromises the validity of oral proficiency assessment and unrightfully contributes to the speakers' oral proficiency score variance. Thus, the results of the assessments may not make valid contributions to L2 speech research and teaching due to such inaccurate assessment. Given the fact that the insertion of the listener-related variables, also referred to as "trait-irrelevant" variables, would obscure the speakers' true speaking ability, the main objective of oral proficiency assessment and second language research is to mitigate the potency of the extraneous factors so that the obtained score rightfully reflects the true ability of the speakers [4].

The current chapter is a desktop review aimed at examining existing research that have investigated a wide range of listener background factors, which are at play in speakers' score variation and oral proficiency discrepancies. This review would inform future researchers of the presence of the listener-related variables and help them devise some effective strategies to lessen, if not to eradicate, their intervening effects. The factors specifically accentuated in this desktop review include listener first language status, effect of exposure to different varieties of English, listener educational background and linguistic knowledge, effects of prior language teaching and tutoring experience, linguistic stereotyping, and listener attitude. We will then discuss rater training in the assessment contexts and structured contact activities which are used as remedies for minimizing the effects of listeners' bias, as well as L2 listening strategy instruction and self-efficacy, followed by implications for L2 pronunciation research and pedagogy as well as recommendations for future directions.

2. Listener background

2.1 Listener first language status

The literature on the effect of listeners' first language status on rating NNSs' oral performances has yielded mixed results. On the one hand, some studies reported that NNSs tend to be more stringent in their assessments than NSs [5–7]. This severity could be justified in the light of the fact that "NNSs may reflect their personal L2 learning struggles, leading them to attribute examinees' errors to a lack of language learning effort on the part of the test takers" ([3], p. 5). On the other hand, some other studies reported contradictory findings in which NSs were more severe listeners than NNSs [8]. Yet the results of some studies reported similar trends of stringency for NNS and NS listeners [9, 10].

Bent and Bradlow [11] noted the fact that some listeners might be more tolerant of accented speech than others based on the concept of "interlanguage speech intelligibility benefit." This occurs when listeners are well-attuned to the speakers' rhythm of speech due to the phonological similarities that exist between the listeners and speakers' L1. For example, Major et al. [12] argued that Chinese and Japanese listeners had a relatively decent understanding of Spanish-accented English due to the shared prosodic features that existed among Chinese, Japanese, and Spanish. Other studies reported that Japanese L1 listeners found Japanese L1 speakers of English were more intelligible than native English listeners found them to be [13], and also Indian and South African listeners were able to comprehend listening passages recorded by their own shared L1 speakers, respectively [14].

2.2 Effects of exposure to different varieties of English

A growing body of literature on the effect of prior interaction with L2 varieties lends favorable support to the fact that L2 speech perception is, to a large extent, influenced by the degree of familiarity with and exposure to L2 accented varieties.

In this regard, Derwing and Munro [15] reported that those listeners who self-reported to have frequent exposure to foreign accent had higher intelligibility scores and were more successful in language identification compared with their counterparts who self-reported to have more sporadic interaction with foreign accent. The result of this study comports with Gass and Varonis [16] assertion that those listeners who have prior exposure to accented varieties of English are favorably biased toward ratings of NNSs' speech. Likewise, Kennedy and Trofimovich [17] argued that the NSs with more frequent exposure to L2 speech had a more accurate transcription of NNSs' speech. In another study, Carey et al. [18] investigating the effect of listeners' familiarity with speakers' interlanguage on their assessment of speakers' pronunciation added that those listeners who had extensive prior exposure to the L2 accented variety of the speakers tended to rate their pronunciation higher than those who reported having little or no familiarity with that particular L2 accent.

The findings of various studies further indicate that the listeners who are less familiar with particular L2 varieties tend to perceive the speakers of those specific L2 varieties more accented, which would consequently impair their comprehension [1, 19, 20]. In this regard, Adank et al. [21] hypothesized that listeners' familiarity with a particular accented English positively correlated with comprehensibility. To test the hypothesis, they had the recordings of two British English speakers varying in accent (Southern Standard versus Glaswegian) rated by two groups of British listeners both of whom familiar with Southern Standard accent but only one of them familiar with Glaswegian accent. The results indicated that familiarity with accent facilitated comprehension. Taken as a whole, the frequency with which one encounters and processes a foreign accent determines the ease with which they comprehend the speakers of that particular L2 variety. This phenomenon could be explained in the light of the fact that the listeners who have prolonged exposure to a particular L2 accent register the sound system prototypes of the accented variety and they refer to them while perceptually decoding the speech signal [22, 18]. Therefore, they would comprehend the accented speech effortlessly.

2.3 Listener educational background and linguistic knowledge

Current research is equivocal on the effect of listeners' linguistic knowledge and educational accomplishment on the assessment of L2 performance. The findings of the study conducted by Kang et al. [3] did not reveal any significant relation between the degree of educational accomplishment and linguistic knowledge on listeners' holistic ratings of L2 proficiency. Also, listeners varying in degrees of educational accomplishment did not differ in rating severity; nevertheless, those listeners who were extremely severe or lenient in their assessments, regardless of their educational background, became more moderate after they received training and became familiar with assessment criteria. In another study, Kang and Rubin [2] reported that listeners' education in linguistics and TESOL conferred a higher degree of NNS perception comprehensibility on the listeners. However, the results of Kang's [1] study failed to establish a significant relationship between listeners' prior formal training in language and linguistics and their ratings of NNSs' speech. Given the contradictory results in the literature, no definitive conclusion can be drawn on the effect of listeners' formal training in linguistics and their patterns of NNSs' speech rating.

2.4 Effects of prior language teaching and tutoring experience

Listeners' teaching and tutoring experience can be associated with the ratings of NNSs' speech. In Kang's [1] study, the undergraduate listeners who had the experience of teaching and tutoring in languages tended to be less severe listeners. Such results are consistent with those of Hsieh [23]. In her study, the effects of listeners' teaching experience status on the ratings of ITAs' oral proficiency, comprehensibility, and accentedness are investigated. Hsieh reported that English as a second language (ESL) teachers were more lenient in their ratings of ITAs' oral proficiency, comprehensibility, and accentedness than American undergraduates with no teaching experience. However, in a more recent study, Kang et al. [3] did not find a statistically significant relationship between listeners' amount of teaching experience and their holistic ratings as well as their rating severity of L2 proficiency. Thus, although listeners who possess language teaching experience are assumed to be more lenient than their counterparts with no experience in teaching, this leniency is not consistent across the board.

2.5 Non-native speaker linguistic stereotyping

Prior research on US undergraduates' perceptions of NNSs' oral proficiency has established the validity of linguistic stereotyping [2]. As set forth by Lambert et al. [24], linguistic stereotyping is a phenomenon through which a short sample of L2 variety attributable to low-prestige groups arouses a cascade of demeaning evaluative judgments of speakers. They elicited NSs' perceptual judgments in regard to NNSs' productions according to a speech evaluation instrument developed by their research team. This pioneering study showed that NSs tended to pass negative judgment in relation to intellect, superiority, and friendliness when they heard accented speech. Rubin and Smith [25] postulated that one of the factors that moderated the proclivity of undergraduates' engagement in linguistic stereotyping was the amount of exposure they had with international instructors. This means that those undergraduates who have more cross-cultural experiences tend to be less critical and more tolerant of L2 accented varieties. In contrast, the undergraduates who harbor negative expectations toward speakers belonging to a particular social group would not be able to provide an impartial judgment of an L2 speaker's oral performance.

Another source of bias associated with listeners is reverse linguistic stereotyping (RLS), which is the converse of linguistic stereotyping [2]. In RLS, speakers' nonlinguistic cues can affect NS listeners' perceptions of the speaker. Such cues could include pictures of the speaker and knowledge about their ethnicity, race, gender, or social class. Thus, when listeners are misinformed that they are listening to an NNS, they tend to rate the speaker highly accented and less comprehensible [2, 26]. This problem is compounded if speakers represent members of stigmatized social groups and speak with a stigmatized accent, as it is the case with those NNSs who speak Spanish-accented English. The members of this community tend to be rated less favorably on the indices of status and solidarity by NSs [2]. In Kang et al. [3] study, RLS emerged as one of the listener-related variables which significantly predicted naïve listeners' deviation from expert scores, implying that those who had the propensity to become engaged in RLS were more likely to be influenced by subjective impressions and provide less accurate ratings. Overall, listeners' perception can be influenced by a variety of nonlinguistic or paralinguistic aspects of an utterance.

2.6 Listener attitude

The effects of listeners' expectations on the perception of L2 speech have been researched through listeners' attitudes in perceptual encoding of information. Using matched guise technique [25] and verbal guise technique [27], studies have revealed that listeners' attitude toward speakers' perceived social groups will not only impact the listeners' ratings of the speakers' degree of accentedness but also their perceptions of the speakers "nonlinguistic characteristics," such as intelligence and language competence ([28], p. 570). Rubin [29] investigated students' perception toward non-native speakers. The guises (a picture of an Asian ITA and that of an American TA) were used to form participants' perceptions of the speech files and to mislead them in terms of the speaker's ethnicity. His finding reported that L1 English listeners had the proclivity to rate the speaker of the lecture more accented when the lecture was accompanied by the picture of an Asian woman than the same speaker of the lecture when it was accompanied by the picture of a Caucasian woman. Also, Brown's [30] study on American college students' attitude toward non-native instructors confirmed that listeners' preexisting knowledge of the speakers' country of origin significantly influenced their judgments of the speakers' language competence.

In addition to encoding a distorted perception of accent and language competence, the listeners who hold attitudinal biases toward a group of L2 speakers tend to have a less accurate perception of individual sounds in the speech signal transmitted by the L2 speakers. An illustrative example is the case of Cantonese L2 speakers of English who are stereotyped to have an unreleased word-final stop production. In this regard, Hu and Lindemann [31] investigated whether this existing stereotype would impair Cantonese perceptions of English word-final stops. To test their hypothesis, they selected a group of Cantonese participants and presented them with recordings of some sentences each one of which included an underlined keyword featuring a final stop. After each recording, the participants listened to three versions of the keyword that varied in the pronunciation of the final stop, and they were required to decide which one of the versions they listened to in the sentence. In one version, the final stop was totally unreleased, in another one the final stop had a released burst, and in the third version the released burst of the final stop was followed by an aspiration. The listeners who were told that the sentence was recorded by an American L1 speaker had the propensity to choose the aspirated version, and those who were told that the sentence was recorded by a Cantonese L1 speaker had the tendency to choose the unreleased version. The results of this study confirmed the hypothesis that the preconception notions held toward the speakers of a language have a direct bearing on how listeners perceive the phonemes produced by speakers of the language.

An area which is comparably under-researched in the literature is the role of listeners' bias in perceived comprehensibility and intelligibility. Smith and Nelson [32] theoretically defined comprehensibility as understanding the overall message of an utterance and intelligibility as the accuracy with which the individual words are understood in an utterance. In a similar vein, Munro and Derwing [33] conceptualized comprehensibility as the relative ease with which an utterance is understood by the listeners, measured subjectively through scalar ratings, and intelligibility as word recognition, measured objectively through transcription tasks and cloze tests. Integral to the conceptualizations of the two speech constructs is the fact that they are regarded as the inherent characteristics of speech and the speaker is blamed for any breakdown in communication due to an incomprehensible speech. This misconception is reflected in van Wijngaarden's [34] argument stating that "the intelligibility of speech is known to be lower if the speaker is non-native instead of native for the given language" (p. 103).

However, among the few scholars who pioneered appreciating the role of listener bias in the perception of speech comprehensibility and intelligibility is Munro [35] who stressed that the measurement of L2 speech is a function of three interrelated factors, namely, the characteristics of the speech per se, listener-related factors, and contextual factors. An active line of research has hitherto supported

Munro's argument and lent credence to the role of listeners' attitudinal biases. For example, Kang and Rubin's [2] RLS study revealed that the listeners presented with the picture of an Asian scored lower in the listening comprehension test than those who were presented with the picture of a Caucasian. They attributed this phenomenon to the listeners' biased perception stemming from their prior experience such as their negative experience with international teaching assistants. In another study, Wolff [36] reported that in his experiment involving Nembe and Kalabari speakers, two languages of Eastern Niger delta, Nembe speakers reported to have found more linguistic similarity between their language and Kalabari and had a more complete perception of Kalabari speakers, whereas the opposite was reported by Kalabari speakers. Lindemann and Subtirelu [28] associated this discrepancy in perception with the "asymmetrical attitude" held by the listeners toward different language groups (p. 577). Therefore, it can be concluded that listeners' predispositions make significant contributions to what listeners perceive and the attitudinal biases held by listeners toward the speakers of a particular social group, especially a low prestigious one, would impair their perceptual encoding of the speech signal produced by the speakers from that stigmatized social group.

3. Listener training

3.1 Listener training in the assessment contexts

Given the effect of listener background factors on the assessment of L2 performance, it is of utmost importance to mitigate the variance of these trait-irrelevant variables. One way to curb the magnitude of the bias exerted by the listeners' background is training listeners. Training listeners would reduce, if not eradicate, the error inserted by the aforementioned listener variables. For example, some scholars recommended listener training for minimizing the effect of accent familiarity as a factor leading to listener bias [37–39]. On the importance of listener training, Cumming [40] maintained that trained listeners are less likely to be deviated by background variables, as they gravitate more toward trait-relevant variables, such as language use, content, and rhetorical organization. Regarding the effect of listener background and training on rating reliability, Shohamy et al.'s [41] study indicated that regardless of the professional background of the listeners, whether they be English teachers or lay persons, and their training status, whether they be trained or native, all groups of listeners achieved high inter-listener reliability in rating writing samples; however, inter-listener reliability was higher among trained listeners. In a more recent study, Kang et al. [3] researched the effect of listener training on reducing the amount of divergence between novice and trained listeners. The results of that study indicated that for the novice listeners who underwent training, the impact of trait-irrelevant listener variables reduced by 75% for oral proficiency holistic rating and by 50% for comprehensibility rating. As a result of listener training, the listeners who were previously scattered on each extreme of rating continuum converged, meaning that the distance between the listeners who tended to be extremely severe or lenient prior to the training reduced and they became more moderate.

3.2 Structured contact activities to mediate listeners' bias in social contexts

Another approach to listener training, which is more concerned with preparing NS listeners for accomplishing successful intercultural communication with NNSs, rather than calibrating their ratings of NNSs' speech, is structured intergroup contact. As a consequence of globalization, there is more urgent need for people from different fields of science to communicate with interlocutors from diverse linguistic and cultural backgrounds. Thus, it is critical to devise an intervention that fosters a successful communication between NSs (ingroup) and NNSs (outgroup). A slew of research in the field of social psychology has provided support for structuring intergroup contact for reducing NSs' existing prejudices. Intergroup contact involves interaction between members of two groups (ingroup and outgroup) who do not seem to share similar identities, beliefs, and religions [42]. Intergroup contact is based on the assumption that contact across groups minimizes the alienation and promotes positive attitude toward members of outgroup. For an intergroup contact to be effective, the following five conditions should be met. First, within the contact situation, groups should have (or inculcated that they have) equal status. Second, groups should have shared objectives or common goals that make contact activities goal oriented. Third, there should be a sense of cooperation, rather than a competition between the groups for fulfilling the common goals. Fourth, there should be someone in the position of power who sanctions and regulates the contact situation. Fifth, the dynamic of the contact situation should be conducive to intergroup intimacy and encourage the members of ingroup to establish rapport with the members of outgroup. The violation of each one of the principles has been alleged to reduce the efficacy of intergroup contact [42, 43].

Pettigrew [43] maintained that the alteration of negative attitude through intergroup contact is a function of four interconnected processes, namely, learning about the outgroup, changing behavior, generating affective ties, and ingroup reappraisal. The first process is deemed to be most critical due to the fact that prejudice reduction is a direct consequence of correcting negative attitude harbored by the ingroup which occurs as a result of new learning about the outgroup. It is also important to note that the dynamics of contact situation acts as a catalyst for the attitude reform. Any alteration in the ingroup members' attitude should be preceded by a change in their behavior which is a response to the expectations of the situation. For example, if expectations of the situation call for accepting outgroup members, in response to those expectations, ingroup members modify their behaviors and, as a result, their attitude changes [43]. Although anxiety might be overwhelming in the initial encounters of the groups, as intergroup contact continues and a sense of intimacy augments between the two groups, this negative emotion would deplete and be gradually replaced with a sense of empathy for the members of outgroup. This friendship between the groups provides a fertile ground for improving positive attitude toward the outgroup as a whole. Finally, as a result of having more contact with members of the outgroup, ingroup members would revisit their established norms and customs, as they find them to be too restrictive and instead develop a perspective which is more universal. In other words, not only do ingroup members change their attitudes and become more accepting of the outgroup, but they also perceive that the norms they have set and ardently supported are not the only legitimate ones to manage the world [43].

Kang et al. [44] investigated the effect of a brief intergroup contact on American undergraduates' perception of international teaching assistants' (ITAs) teaching competence and speech performance. At the heart of this contact intervention, undergraduates engaged in doing some cooperative activities (solving puzzles) with ITAs. Comparing the results of undergraduates' ratings in the pretest and the posttest indicated that undergraduates rated ITAs' speech performance and teaching competence more highly in the posttest. Interestingly, those undergraduates who had the aversion to participate in the intervention owing to their prior negative experiences with ITAs underwent a more remarkable change in attitude toward ITAs' speech performance and teaching competence. The results of this study are significant in that despite the short duration of the intervention, it brought about dramatic changes in undergraduates' attitude. The authors attributed this accomplishment to their strict adherence to the principles of optimal intergroup contact established by Allport.

In a similar study, Staples et al. [45] developed a structured contact program to investigate its effect on US undergraduate students' (USUGs) perception of ITAs' comprehensibility, accentedness, and instructional competence. In this study, USUGs met with ITAs once a week for an hour over a span of 8 weeks. Similar to the previous study, USUGs are involved in doing collaborative activities with ITAs aiming at accomplishing common goals. The results of the study revealed that as a result of participating in the structured contact program, USUGs' attitudes toward and perceptions of ITAs improved and they were manifested in their three outcome ratings. Both of these two studies provide evidence in support of reducing NS's preconception biases of ITAs' language ability through the successful application of an intergroup contact program.

3.3 L2 listening strategy instruction and self-efficacy

As an effective approach to enhancing L2 listeners' self-efficacy and rendering them more efficient listeners both in classroom and real-life settings, L2 researchers and practitioners have emphasized equipping L2 listeners with an array of listening strategies. Given the fact that those listening strategies do not develop spontaneously, educators advocate developing carefully designed interventions to incorporate those strategies and instruct them to L2 listeners.

Broadly defined as "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" ([46], p. 3), self-efficacy is regarded to determine what tasks individuals choose to perform, how willing they are to face challenges, and the level of persistence they devote to accomplishing them. The relationship between L2 listening self-efficacy and L2 listening performance has been explored in the literature. Chen [47] reported that self-efficacy beliefs among Taiwanese university students predicted their listening performance and its magnitude was larger than other variables, such as listening anxiety. In a similar study, Mills et al. [48] found a positive correlation between self-efficacy for listening and listening proficiency in their study, and both of these two constructs were inversely correlated with listening anxiety.

Self-efficacy in listening, however, can be enhanced through explicit instruction of listening strategies focusing on scaffolding of learning and learner reflection [49]. Strategies taught within this framework would be based upon listeners' needs and are specific to the task and the situation within which the task is performed. This type of strategy instruction accompanied by instructors' immediate feedback on the efficacy of the strategy employed would increase listeners' sense of control and draw their attention to the relationship between the strategy just used and the observable outcomes ensued [49]. In Graham's [50] study listeners were encouraged to jot down and keep diaries of the listening strategies they employed in accomplishing assigned tasks. The researchers then perused the strategies used and rectified those less efficient ones and encouraged the listeners to use new strategies. This model of intervention improved listeners' self-efficacy and helped them gain more control over the tasks they performed.

Another listening strategy reported to have salubrious effect on L2 listeners' self-efficacy is verbalization. According to this model, first employed by Schunk and Rice [51], listeners think aloud the strategies they plan to use prior to performing tasks after they have been modeled by their teachers. Verbalization not only draws the attention of the listeners to the strategies and facilitates the encoding of upcoming information, but it also provides an opportunity for the listeners to have the veracity of their selected strategies confirmed by their teachers. Thus, if there is a mismatch between the strategies verbalized by the listeners with those modeled by their teachers, the teacher can intervene and rectify those mismatches. Taken as a whole, self-efficacy and listening performance are both amenable to improvement which can be achieved through judicious selection and instruction of effective listening strategies. What is more, it is assumed that L2 listeners with stronger self-efficacy would be more willing to run the risk of exposing themselves to real-life interactions involving NSs and would be more tolerant of the harsh criticisms of NSs.

4. Implications and future research directions

There are some important implications that researchers and educators can draw from the findings of the existing research investigated in this desktop review. First, researchers should be informed of the fact that NSs' judgments of NNSs' speech performance involve a varying degree of listener bias. Any research that involves subjective judgments of NS listeners should control such confounding variables and curtail their intervening effects. Second, intelligibility is as much a function of listeners' effort as that of speakers, meaning that the intelligibility of speech is not solely determined by speakers but by listeners. In measuring the intelligibility of an L2 speech variety, listeners play an active role. A speech sample might be highly intelligible for a particular group of listeners but less intelligible for another group. Communication is a two-way street. Sharing responsibility between both speakers and listeners would be the first step to take for successful communication. Finally, acknowledging the active role of listeners in determining L2 speech intelligibility challenges the research instruments prevalently used in research for measuring speech intelligibility. The stimuli used in intelligibility-based research are recorded speeches that do not provide an opportunity for listeners to employ effective communication strategies and to negotiate meaning with speakers [28]. Thus, intelligibility remains to be determined still solely by speakers. Future research should take the initiative to utilize interactive stimuli in which intelligibility is more realistically measured as a joint effort between a listener and a speaker as it is what is expected to happen in real-life interactions.

Given the importance attached to listeners as active contributors to speech intelligibility and communication success between NSs and NNSs, L2 pronunciation educators would require to dedicate a substantial amount of their instruction to introducing and practicing successful communication strategies such as how to paraphrase, do circumlocution, and use nonlinguistic signals. Additionally, in lieu of setting NS pronunciation norms and encouraging L2 learners to approximate their pronunciations to those norms, educators should emphasize the pronunciation features which contribute more to speech intelligibility and prioritize them over those less critical features in their instruction [28]. As of yet, research on the efficacy of this type of instruction is scarce. Future research will be needed to determine to what extent this type of instruction promotes the communication between NS and NNS.

It is also important to note that those L2 learners who experience varying degrees of bias in their encounter with NSs tend to report having lower self-efficacy expectations, which would, as a consequence, impair their self-estimate of their language abilities. Self-efficacy expectations would predict one's performance beyond their true abilities. Those L2 learners with lowered self-efficacy expectations would be less willing to initiate and maintain interaction with NSs both in classroom and real-life settings. This reluctance on the part of L2 learners would exacerbate the existing bias toward them by NS. To mitigate the bias, if not eliminate it, educators can devise interventions which would foster L2 learners' self-efficacy through strategy instruction and other methods such as providing them with supportive mentors. By fortifying L2 learners' self-efficacy, they would be more encouraged to participate in interactions involving NSs. As a result of more interaction, the intensity of bias held by NSs toward that particular group of NNSs decreases.

With respect to listener background variables, researchers should be cognizant of the fact that some listener-related variables such as listeners' first language status and the amount of their exposure to accented varieties of English are more influential to listeners' perceptions of NNSs' speech than other variables (e.g., listeners' linguistic knowledge and their prior teaching experience). Thus, those variables warrant more attention in selecting listeners for rating NNSs' speech, as they might exert more potent influence and compromise the reliability of the assessment. On the other hand, as pointed out by Kang et al. [3], the effects of the latter variables are more contextually determined and should be considered regarding the type of assessment being administered. For example, if the purpose of speech assessment is evaluating the nuances of pronunciation, listeners' linguistic knowledge and their educational background should be considered for selecting listeners as raters. Additionally, the way that the prior studies have operationalized listener variables needs to be rectified. For example, Kang et al. [3] operationally defined listeners' linguistic sophistication as a function of three factors: (a) the number of foreign languages they spoke, (b) the number of years they studied foreign languages, and (c) the number of linguistic courses they had taken. However, this definition needs to be improved given that with the spread of globalization and emergence of English as an international language (EIL), the concept of foreign language is becoming ambiguous. Thus, future research should take initiatives to address these limitations marked in the prior studies.

5. Conclusion

The current chapter, which was a desktop review, sought to provide an overview of various listener background variables that would influence oral performance ratings. Although the effects of these listener-related variables have been underemphasized in assessing the oral performance of L2 learners, researchers should take their influence into account and endeavor to make the potential contributions of these trait-irrelevant variables as negligible as possible. Listener training is assumed to mediate these extraneous variables. Through training, listeners are equipped with the necessary skills required to rate speech performances of L2 speakers more objectively using predetermined criteria. The effect of listener bias on the evaluation of L2 speech has also been researched in social contexts. As reported in the previous literature, the listeners who harbor negative attitudinal perspectives toward the speakers of a particular social group, especially a stigmatized one, have the proclivity to encode a distorted perception of their speech and more often than not find the speakers unintelligible. Structured intergroup contact, for example, can be a program devised to address the listeners' negative attitudes and reduce their bias. Explicit instruction of L2 listening strategies can also be effective in strengthening L2 listeners' self-efficacy and make them more motivated to embrace the challenges involved in participating in social interactions with NSs and encourage them to regard this as an opportunity to fortify their nascent oral skills. However, research on the listener role in communication is still in its infancy, and future studies should address this issue more comprehensively.

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Chapter 2

Teaching with and for Metacognition in Disciplinary Discussions

Susan O'Hara, Robert Pritchard and Debi Pitta

Abstract

Teaching metacognitively, which involves teaching *with* metacognition and teaching *for* metacognition, is critical for learners of any age. *With* enables teachers to gain awareness about and control over how they think and teach, and to monitor, evaluate, and adjust their instructional practices in accordance with specific students, goals and contexts. *For* enables teachers to design instruction that will develop and activate their students' metacognition, enabling them to be aware of what they know and do not know, and take action to address flaws or gaps in what they know. Our research findings, based on empirical studies conducted in a variety of educational settings, have identified effective instructional practices for teaching metacognitively. This chapter focuses on practices that support the metacognition of learners engaged in disciplinary discussions. This emphasis addresses a significant void in the research literature which more commonly targets metacognition in learning generally or applied specifically to reading and writing.

Keywords: teaching with metacognition, teaching for metacognition, teaching frame, disciplinary discussions, instructional practices

1. Introduction

Teaching metacognitively, which involves teaching with metacognition and teaching for metacognition, is critical for learners of any age. Teaching with metacognition enables teachers to gain awareness about and control over how they think and teach by planning, monitoring, evaluating, and adjusting their instructional goals and teaching strategies in accordance with their students' needs and the sociocultural context. Teaching for metacognition enables teachers to design instruction that will develop and activate their students' metacognition, enabling students to be aware of what they know and do not know by engaging in reflective processes, and to take action to address flaws or gaps in what they know by employing self-regulation strategies.

Given the essential role that teaching metacognitively plays in the professional growth of teachers and the academic development of students, a need exists for a tool to support teaching with and for metacognition. Our research findings, based on empirical studies conducted in a variety of educational settings [1–4], have identified such a tool: The SOAR Teaching Frames for Literacy. This chapter focuses on the SOAR Teaching Frame for Disciplinary Discussions and instructional practices that support the metacognition of learners engaged in academic conversations, e.g., face-to-face interactions, online dialogues, and written conversations. This emphasis addresses a significant void in the research literature which more commonly targets metacognition in learning generally or applied specifically to reading and writing.

2. What is SOAR?

SOAR, which stands for strategic observation and reflection, is not a curriculum or a set of instructional strategies. SOAR is the lens teachers look through as they plan, teach, reflect upon, and elevate their teaching practice by engaging in cycles of strategic observation and reflection. SOAR has emerged from more than a decade of systematic research and development designed to identify the essential practices that teachers can use to drive learning across disciplines. More specifically, we identified research-based essential practices for disciplinary discussions through analyses of data from Delphi panel studies of expert consensus on disciplinary literacy instruction across content areas [4–7], video observations of classroom instruction [1], existing instructional practice protocols with established reliability and predictive validity [2, 8–10], and an extensive review of the research literature on effective language and literacy instruction [11–15]. One High-Impact Practice emerged as having significant potential to enhance students' ability to engage in student-to-student academic discourse. We call this practice disciplinary discussions.

Our research also suggests that this essential High-Impact Practice does not operate in isolation. Instead, effective teachers enact a set of dynamic instructional moves during instruction in support of the High-Impact Practice. We labeled this set of three instructional moves Cross-Cutting Practices.

Facilitating acquisition of academic language: this practice focuses on structuring, strengthening, and supporting the acquisition and use of the academic language needed to participate in disciplinary discussions [13, 16–18].

Fostering metacognition for disciplinary learning: this practice focuses on the degree to which a teacher visibly enacts and deconstructs metacognitive processes and strategies that foster students' metacognitive knowledge and their ability to engage in academic discourse [19, 20].

Monitoring and guiding disciplinary learning: this practice focuses on how effectively a teacher monitors and guides disciplinary learning as well as adjusts and supports disciplinary discussions to meet the current needs of all students in the classroom [21, 22].

Finally, in preparation for enactment of High-Impact and Cross-Cutting Practices, teachers employ a Foundational Practice.

Designing instruction for disciplinary thinking and understanding: this practice focuses on the design of lessons and learning tasks to promote disciplinary discussions and support the High-Impact Practice. This practice also focuses on how the teacher establishes high expectations and fosters in all students the willingness to participate in intellectually rigorous tasks that require academic discourse [21, 23–26].

To illustrate the interconnectedness of the practices, we organized them into a Teaching Frame consisting of the High-Impact Practice supported by the Cross-Cutting and Foundational Practices (see **Figure 1**). The frame is designed to help instructors understand and implement the High-Impact Practice that drives student learning, while simultaneously enacting a set of dynamic instructional moves in support of the High-Impact Practice and taking the foundational planning steps needed to do this well. This Teaching Frame provides a common language around

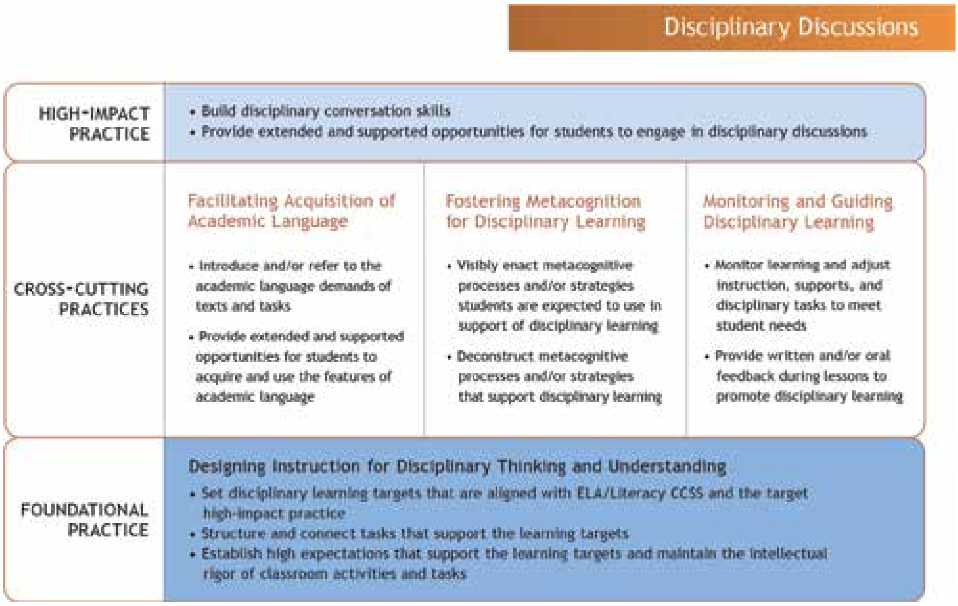

Figure 1.
SOAR teaching frame.

instruction at a grain size that allows instructors from kindergarten to higher education to meaningfully plan and reflect individually or collaboratively.

3. Using SOAR to teach with metacognition

By using a SOAR Teaching Frame —in this case, the SOAR Teaching Frame for Disciplinary Discussions—as a lens to plan, teach, and reflect upon their instructional practice, teachers are by definition teaching with metacognition. That is, they are gaining awareness about and control over how they think and teach by using the High-Impact, Cross-Cutting, and Foundational Practices to plan, monitor, evaluate, and adjust their instructional goals and teaching strategies. To support teachers through this process we have developed an implementation rubric that is aligned with each practice in the disciplinary discussions teaching frame. **Table 1** contains the section of the rubric that is aligned with the High-Impact Practice.

Moving along the rubric from "no implementation" to "full implementation" enables a teacher in the planning stage to focus specifically on what she needs to include in her lesson. For instance, if her students are still developing the conversation skills necessary to engage in disciplinary discussions (Element 1), the implementation rubric will help the teacher recognize the need to introduce and refer to those skills as well as provide support for students to use them in tasks and activities. Then, when the lesson is over and the teacher is reflecting on how successful it was, the rubric can help her recognize what worked and what did not work. For instance, she may realize that the supports she used enabled some students to use the conversation skills to engage in a discussion, but other students clearly needed something more. This insight will help the teacher adjust her instruction during the next lesson.

We are currently using the SOAR Teaching Frames in professional learning programs for teachers, coaches, and instructional leaders in partner schools and school districts across the United States. We have also brought the SOAR model and

	No implementation			Full implementation
ELEMENT 1: Build disciplinary conversation skills	Teacher does not introduce or refer to disciplinary conversation skills.	Teacher introduces and/or refers to disciplinary conversation skills, but does not provide support for students to use them during tasks and activities.	Teacher introduces and/or refers to disciplinary conversation skills and provides support to enable most students to use them during tasks and activities.	Teacher introduces and/or refers to disciplinary conversation skills and provides support to enable all students to use them during tasks and activities with diverse partners.
ELEMENT 2: Provide extended and supported opportunities for students to engage in disciplinary discussions	Teacher does not provide opportunities for disciplinary discussions.	Teacher provides limited and/or unsupported opportunities for students to engage in disciplinary discussions. Routines for disciplinary discussions are not evident, or students are not required to use them during tasks and activities.	Teacher provides supported opportunities for students to participate in disciplinary discussions. Routines for disciplinary discussions are evident, and teacher provides support to enable most students to use them during tasks and activities.	Teacher provides extended and supported opportunities for students to participate in disciplinary discussions. Routines for disciplinary discussions are evident, and teacher provides support to enable all students to use them during tasks and activities.

Table 1.
Implementation rubric: disciplinary discussions.

materials to Teacher Preparation Programs and New Teacher Induction Programs. Based on these experiences we have identified stages of awareness and action that instructors typically go through when using SOAR to teach with metacognition (see **Figure 2**).

The first stage represents someone who is not familiar with SOAR and therefore is unable to use it as a lens to plan, teach, and reflect. The second stage depicts someone who has been introduced to SOAR but who is still learning how to use a teaching frame and the instructional practices that support the metacognition of learners engaged in disciplinary discussions. Teachers at this stage of the continuum tend to equate SOAR with the use of certain instructional strategies (e.g., Layering Text, What Makes You Sat That?) rather than a specific High-Impact, Cross-Cutting or Foundational Practice. Teachers at the third stage of the continuum have developed a deeper understanding of SOAR as evidenced by their ability to use a High-Impact, Cross-Cutting or Foundational Practice as a lens to plan, teach and reflect, but because their focus is at the practice level, the metacognitive impact of the planning-reflecting process is limited. Finally, teachers at the last stage have developed an understanding of how all of the practices of the SOAR Teaching Frame work together and can be used as a lens to plan, monitor, evaluate, and adjust their instructional goals and teaching strategies in accordance with their students' needs and the sociocultural context. Using SOAR in this way to teach with metacognition has the greatest impact on the academic development of students.

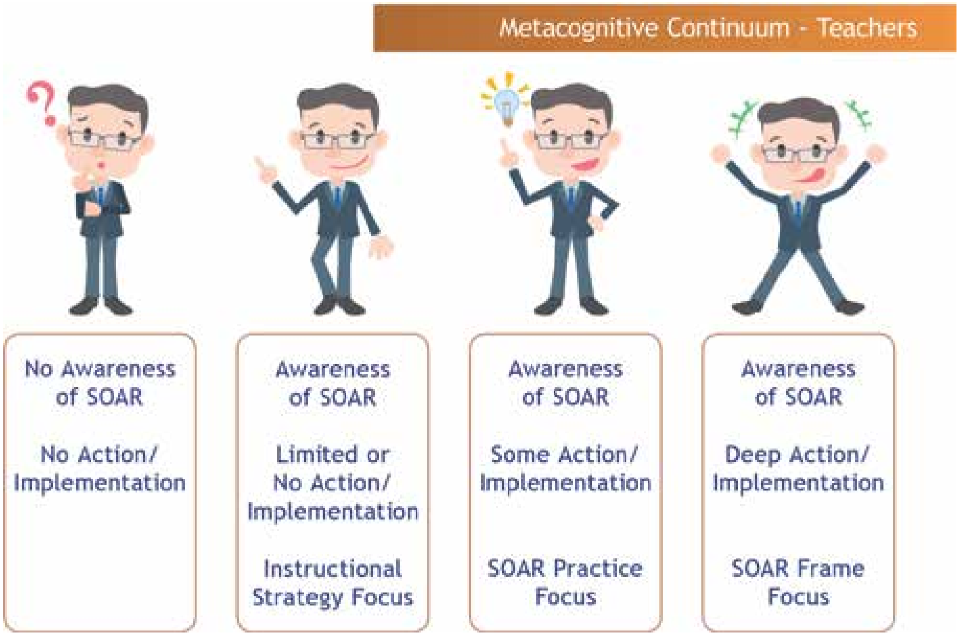

Figure 2.
Metacognitive continuum—teachers.

4. Using SOAR to teach for metacognition

Our research and professional development experiences over the past decade have convinced us that many teachers struggle to acquire and apply the conceptual understanding and skills necessary to develop students' metacognitive knowledge; in other words, the ability to teach for metacognition. One reason for this is that reflecting on and improving performance on a task is easier when the task requires physical action, e.g., hitting a golf ball. You can watch a video of yourself engaged in this task or listen to feedback from a coach who observed you. Cognitive tasks, on the other hand, are invisible and cannot be directly observed, making it harder for students to reflect on their performance and take action to correct it when necessary. So, the instructional challenge most teachers face is how to help students improve their performance on tasks that are dependent upon invisible cognitive progresses. Our research indicates that SOAR can support teachers in this endeavor [3, 27].

As we explained in the preceding section, the Disciplinary Discussions Teaching Frame as a whole—High-Impact, Cross-Cutting, and Foundational Practices—provides the lens that enables instructors to teach with metacognition. Using SOAR to teach for metacognition requires a narrower focus: the Cross-Cutting Practice of Fostering Metacognition for Disciplinary Learning. This practice's emphasis on visibly enacting and deconstructing metacognitive processes and strategies enables teachers to design instruction that will develop and activate their students' metacognition. Students will become aware of what they know and do not know by engaging in reflective processes, and they will be able to take action to address flaws or gaps in what they know by employing self-regulation strategies.

Consistently engaging students in reflective processes and explicitly teaching metacognitive strategies are at the heart of teaching for metacognition. But as is the case with any learning, not all students progress at the same pace. We have identified stages of awareness and action that learners typically go through as they develop their metacognitive abilities (see **Figure 3**).

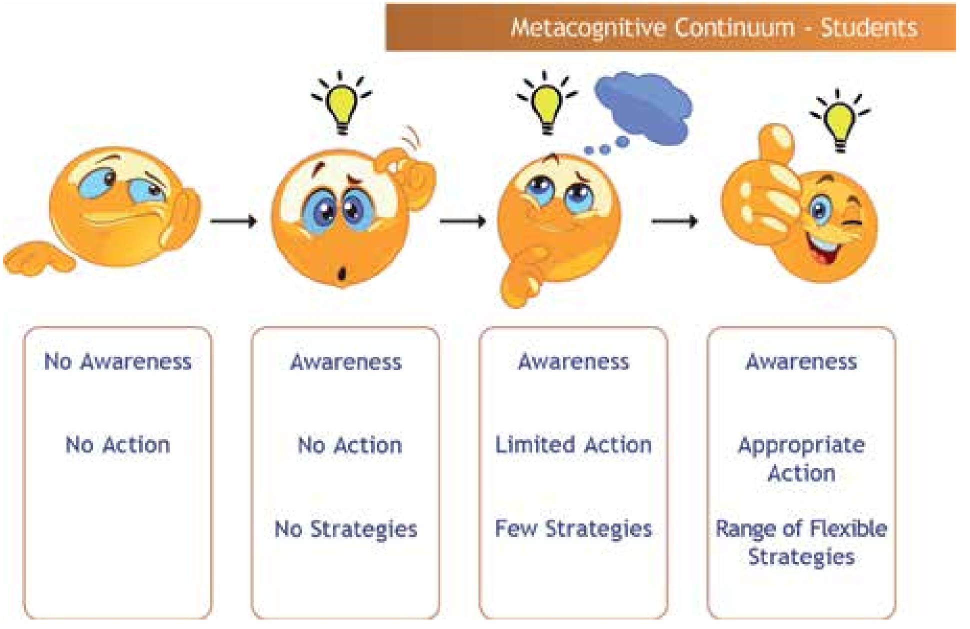

Figure 3.
Metacognitive continuum—students.

The first stage represents a student who does not reflect on his learning and is therefore unaware of how well or poorly he is doing on the assigned task. And because awareness triggers action, he cannot take action to correct any problems that may arise. For instance, think of a student who does not recognize, and therefore mispronounces, many words as he attempts to read a story aloud. But because he does not realize he is mispronouncing them he does not stop to correct himself. This student was unaware that he was not reading the words correctly, so he did not/could not take any action, i.e., use reading strategies to address the problem.

The second stage depicts a student who is reflective, that is, he is aware that he is experiencing problems with an assigned task. However, this student is unable to take any action to address the problem because he has not been taught strategies to use in this situation. Imagine a reader who, unlike one at the first stage of the continuum, is aware that he does not recognize the words he is reading. However, this reader is unable to take action because he has not been taught reading strategies to use when this occurs, e.g., use phonics to sound out unknown words.

Students at the third stage of the continuum have developed a deeper understanding of metacognition as evidenced by their ability to use strategies when problems arise. The challenge these students experience is that they have a limited range of strategies to use, so they struggle if the one or two strategies that they have ownership of do not prove to be successful. For instance, a reader at the third stage realizes that he has trouble recognizing and pronouncing certain words, but he has only been taught (or has only learned) to use phonics to sound out unknown words and, when that does not work, he asks the teacher for help. Students at this stage are certainly progressing metacognitively, but they are not yet at the level where they can apply a range of strategies flexibly and independently.

Finally, students at the last stage have become aware of what they know and do not know by engaging in reflective processes, and they are able to take action to address flaws or gaps in what they know by employing a variety of self-regulation strategies flexibly and independently. A reader at this stage, who encounters words he does not recognize and is unable to pronounce, is able to try a range of strategies.

For instance, he is confident of his ability to use phonics to sound out words, but he knows that is not the best strategy to use with polysyllabic words. So, when he encounters "photosynthesis" he breaks the word into parts using the morphological skills his reading teacher taught him.

5. Teaching for metacognition in disciplinary discussions

Through our research and work with educators in schools we have identified key stages that represent what teachers need to do when teaching for metacognition in disciplinary discussions. These five stages begin with helping students understand what metacognition is and progress through student reflection on their thinking, understanding metacognitive strategies, and then applying them independently. **Figure 4** outlines these five stages. Below we provide an explanation of each stage, a scenario to illustrate what this might look like in instruction, and some strategies teachers can use to implement these ideas in their teaching.

5.1 Introducing metacognition

Teaching for metacognition in disciplinary discussions must begin with an explicit explanation of what we mean by metacognition. In our experience "thinking about thinking" is too abstract and vague a definition to resonate with most students. Our work with instructors and learners across the grade level spectrum has led us to this: metacognition is awareness of what you know and do not know, and the action you take to address flaws or gaps in what you know. The following scenario demonstrates how a teacher who has worked with us introduces the concept to his students and provides a model that others can adapt for their settings.

Scenario for introducing metacognition: Mr. Carter is introducing metacognition to his young students. He says, "I have a really big word I want us to know and understand. It is metacognition. Say it with me, friends. Metacognition. Has anyone ever heard that word before? A few of you. I am going to write it on the whiteboard. Let's clap it out. Met-a-cog-ni-tion. Excellent. It has five syllables.

One part of metacognition is being aware of what you know and what you don't know. An example would be us learning our high frequency words. We each have our stack of words. When we can read them automatically, we move them out of our stack. We know that we know those words. The words that are left in our stack are the words we don't know well. So, I am aware of which words I know and which words I don't know. That is one part of metacognition. I am going to draw a lightbulb here to represent us being aware of what we know and don't know.

The other part of metacognition is knowing what action to take to learn what you don't know. Let's think about the high frequency words we still need to learn. What can we do to learn them? What action can we take? Talk to a neighbor and see what ideas you can come up with." Students share out some ideas like practicing more and looking for the words when they read. "Very good. Those are all actions you can take. I am going to draw the brain driving a car to represent the action we are taking to learn what we don't know.

So, metacognition is being aware of what you know and don't know and then taking action to learn. This anchor chart (see **Figure 5**) will help us as we continue to work on our metacognition. Turn to your neighbor and explain what metacognition is."

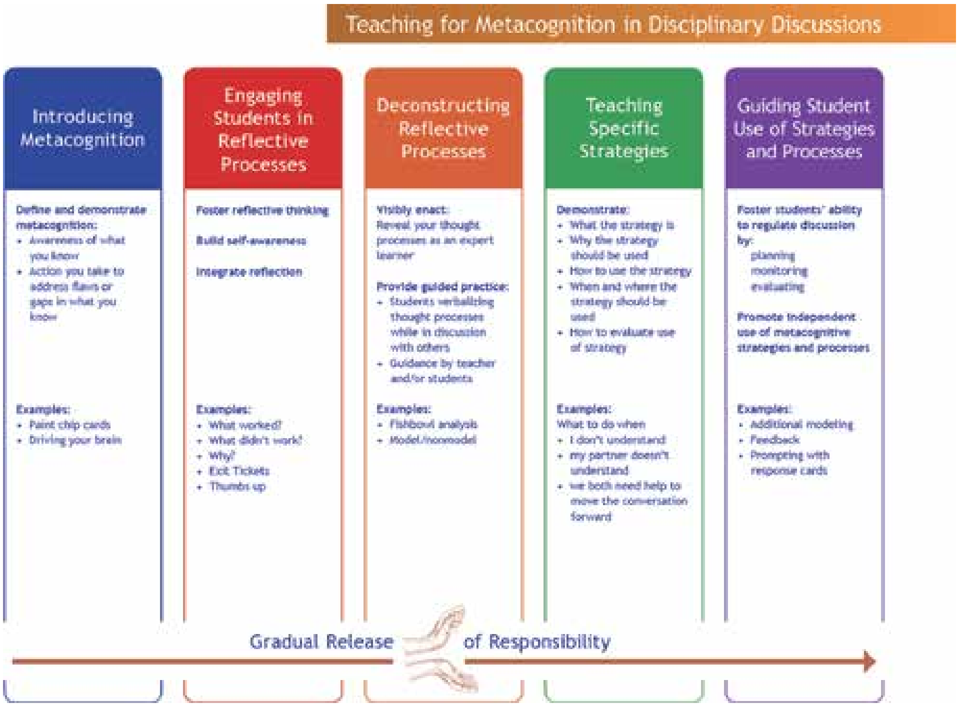

Figure 4.
Stages in teaching for metacognition.

In addition to an anchor chart a teacher can demonstrate metacognition using paint chip cards with different gradations. (See **Figure 6**.) The lighter colors would represent little or no understanding or knowledge while the darker colors would represent stronger understanding or knowledge. Once students are aware of their level of understanding or knowledge, they take action to "drive their brain" to gain more. This visual can also be used for older students.

5.2 Engaging students in reflective processes

Engaging students in reflective processes is the next step in developing students' metacognitive knowledge of how they learn—their knowledge of themselves as learners, of strategies, and of tasks. It builds the **awareness** aspect of metacognition without which there can be no strategic **action**. Asking questions such as "What worked in your discussion?," "Did you deepen your understanding of the topic?," and "What could you do differently in your next discussion?" fosters reflective thinking and helps build self-awareness. When teachers consistently and systematically integrate reflection into their teaching, it permeates the curriculum and gets built into their daily teaching activities. The teacher in the following scenario has done this successfully with her class.

Scenario of engaging students in reflective processes: Ms. Peck has already introduced her students to metacognition. She is now working on having them be more reflective about their discussions in order to improve upon them. Students have just completed a discussion with their partners. She distributes a reflection sheet that has these prompts: What worked? What didn't work? And why?

"You are all getting so much better in your discussions. Today I want us to think more deeply about our discussions and how each of you did. The first prompt is 'What worked?' Think about what worked in your discussion with your partner. Some things to consider might be: Did you both take turns? Did you both share your ideas? Did you ask each other clarifying questions?

The next prompts ask, 'What didn't work?' and 'Why?' Think about your discussion. Did it stall? Did you stay on topic? Did you fortify your discussion? Did you help each other get better? So, with your partner, discuss each of these prompts to reflect on how your discussion went."

At this stage in teaching for metacognition, there are more strategies to help students become engaged in self-awareness. One strategy is a metacognitive "Do Now" which is given to students at the beginning of class. It is a list of actions related to the task they will be doing (in this case engaging in a discussion), and students mark which ones they will attempt to improve upon during their discussion. (See **Figure 7**.) At the end of the lesson, students return to their Do Now and reflect on how they improved in those areas.

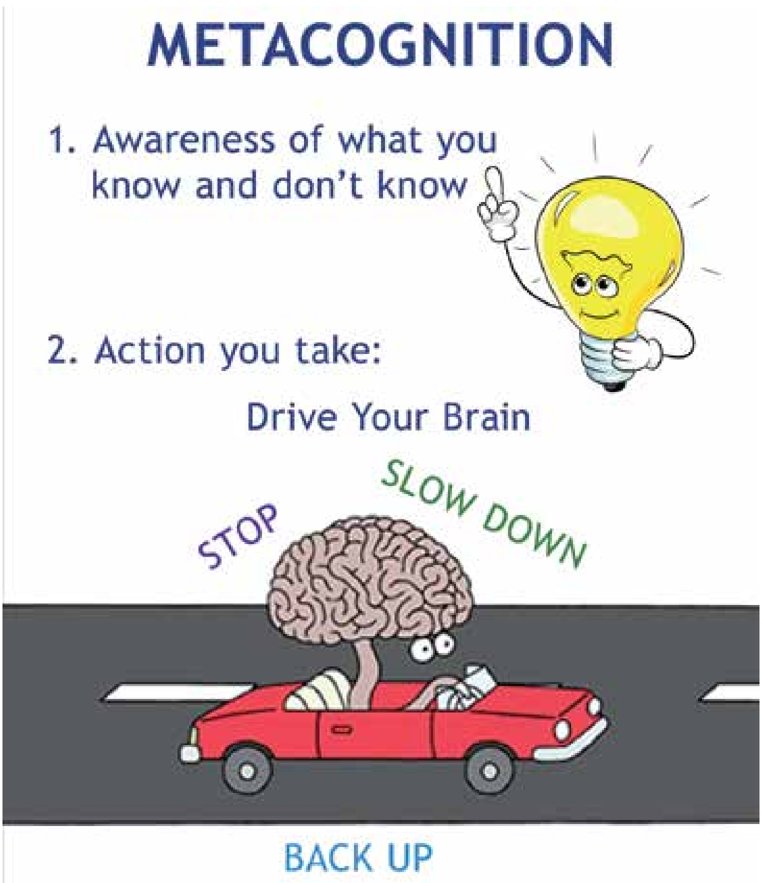

Figure 5.
Metacognition anchor chart.

A strategy that moves students to a deeper level of reflection is a strategy checklist. (See **Figure 8**.) The first column is a list of discussion strategies followed by an additional 3–5 columns that students check to indicate if they used each strategy at

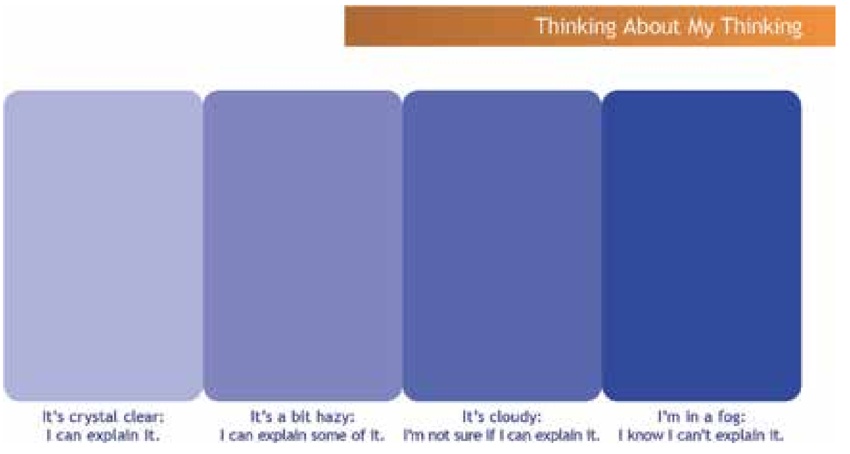

Figure 6.
Paint chip cards.

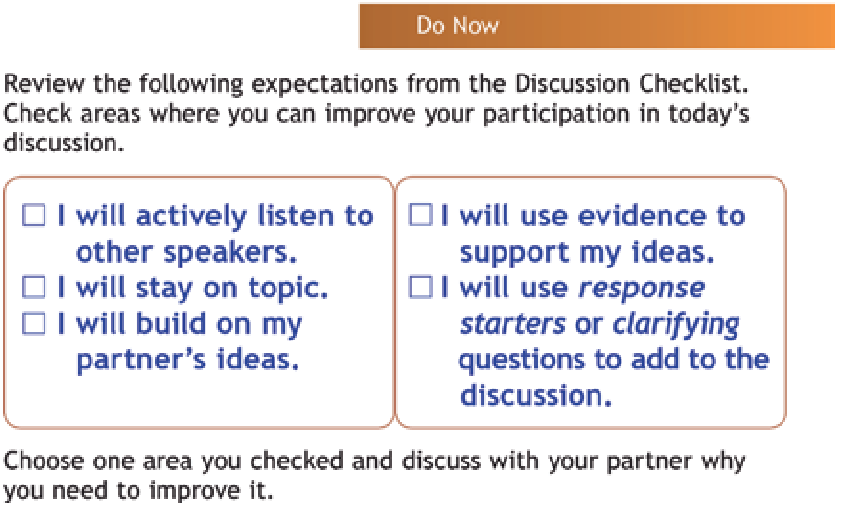

Figure 7.
Do now.

different points in the lesson. A different checklist could ask students to indicate whether "I did it well," "I need to work on this skill," or "I need help in using this strategy." Students complete this checklist at the end of the discussion.

5.3 Deconstructing reflective processes

Modeling your own thinking, i.e., revealing the thought processes of an expert learner, is an essential element of effective teaching because it helps students develop their own metacognitive abilities. However, not everything teachers label as modeling is consistent with this stage in teaching for metacognition. For instance, using a think aloud to verbalize the procedural steps of a learning task is not the same as visibly enacting and deconstructing the underlying thought processes required to complete the task. It is the latter that provides learners with the scaffolded support they need to develop their metacognitive abilities and ultimately become more independently learners. The scenario that follows illustrates how a

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Discussion Strategy Checklist

When I didn't understand … this is what I did.	1st Time	2nd Time	3rd Time	4th Time	5th Time
Raised my hand					
Waited for teacher to call on me					
Told the teacher I didn't understand					
Asked a question to help me understand					
Stopped trying to understand					
Disrupted the lesson					
Other					

Figure 8.
Discussion strategy checklist.

teacher can help students verbalize their thought processes while engaged in discussion with others.

Scenario for deconstructing reflective processes: Mr. Vu is working with his students on strengthening their reflective processes regarding discussions. "Turn to your partner and explain how our self-reflection has strengthened your discussions." Students then share out how it has helped them be aware of what they are doing well and the gaps that they need to strengthen. "Today, I want to demonstrate some things you can do to continue to strengthen your discussion and co-construct your knowledge with your partner. I am going to be partner A and all of you are going to be partner B. (See **Figure 9**.) We are going to discuss our article: 'Species at Risk.' The prompt is 'Discuss the reasons the Monarch butterfly has decreased its population. I'll start.'"

Teacher: "One reason that the monarch butterfly population is dropping is due to climate change. Now what can you, partner B, say to me. Joaquin?"

Class (represented by Joaquin): "I could say another reason is pesticides."

Teacher: "That is a correct. You could state another reason. Is there something else partner B could say? Yes, Isabelle."

Class (represented by Isabelle): "I could ask you to elaborate."

Teacher: "Yes, we can discuss climate change more, so we make sure we both understand it before we move on to the next reason. This helps deepens our discussion. So, I will respond to Isabelle. 'I think that weather is always changing. We are having bigger storms and hotter temperatures. The monarch butterfly migrates from Mexico to the upper United States, over 3000 miles.' Now, do you think I should ask you, partner B, a question? … Yes, now I can say 'What was another reason the monarchs are decreasing?' Yes, Joaquin."

Class (represented by Joaquin): "Pesticides is another reason they are decreasing in numbers."

Teacher: "I don't remember reading that in the article, so I am going to ask Joaquin, 'Can you show me where it says that in the text?'"

Class (represented by Joaquin): "Right here it says, 'These include habitat loss and pesticides.'"

Teacher: "I need to figure this out. The article says habitat loss and pesticides, so I want to see if we can figure out these two things. I am going to ask you, partner B, a question to help me understand this more. 'What do you think it means by habitat loss?' How can you respond? Georgia."

Class (represented by Georgia): "In science we studied that a habitat is where animals live. So, where the monarchs live is being destroyed or isn't around anymore."

Teacher: "Good job, Georgia. Can you follow up with a question to me?"

Class (represented by Georgia): "Do you agree with me?"

Teacher: "That works, Georgia. I can also paraphrase what you just said. 'So, you think that monarchs are decreasing because their habitat has changed.' I am going to check with Georgia to see if I am correct. She is nodding so I am going to add a question. 'So, do you think the pesticides have affected the habitat?'"

Class (represented by Georgia): "Yes. Were there any other reasons mentioned in the article?"

Teacher: "Good job checking to see if we have discussed all the reasons, Georgia. I am going to see if we can summarize the reasons. 'I think that is all of them. Can we summarize what we just discussed?'"

Class (represented by Georgia): "Throughout the discussion we made decisions about how to deepen our understanding through our discussion."

Figure 9.
Modeling.

In this scenario, the teacher utilized a model as a way for her students to "see and hear" what a good conversation sounded like. Another strategy we have found to be effective is using a non-model, i.e., a poorly constructed conversation. The teacher provides students with a non-model and asks them to work in pairs to improve it. Initially, the teacher works with the entire class and a projected conversation, asking them first to improve one aspect of the discussion. She then asks them to focus on another aspect of the conversation before increasing the rigor of the task by having them work independently with a partner.

A similar strategy is the fishbowl where 2–4 students sit in the middle of the classroom and engage in a discussion while the remaining students sit in a circle observing them. Based upon what the teacher has observed in previous classroom discussions, she assigns specific things the observers should be looking for while the fishbowl is going on. For example, the teacher might ask different sets of students to listen for certain discussion skills (e.g., clarifying an idea, adding on to an idea, providing evidence for an idea) while others listen for norms of interaction (e.g., looking at the speaker, taking turns, being respectful). When the discussion is over, the teacher and students debrief what students notice during the activity. The teacher uses this opportunity to specifically point out the talk moves students made to enrich the discussion.

5.4 Teaching specific strategies

A great deal of research indicates that the explicit teaching of strategies to students will improve student learning and help them become more independent learners [28–30]. Our work with the SOAR Disciplinary Discussions Teaching Frame has also demonstrated that introducing and demonstrating specific metacognitive strategies students can use when engaged in discussions significantly improves their ability to recognize and address breakdowns that occur and ultimately keep the discussion (and learning) on track [3, 27]. The key to the successful teaching of strategies is explicitly demonstrating what the strategy is, how to use it, and when and why to use it. In the scenario that follows the teacher is introducing one of our research-based discussion strategies to her students.

Scenario for teaching specific strategies: as a class routine, Ms. O'Rourke has her students reflect on their discussions. She now wants to teach them a strategy she thinks will strengthen their discussions further. "You have really improved with your discussions because you have been reflective about what you are doing well to deepen your discussions and about those areas that need improvement. Nonetheless, I have noticed that there are times when your discussions seem to stall or shut down, so I want to teach you some strategies to help. What seems to happen is one of you stops talking because you do not know what else to say or you are confused about the topic. Let us review how we have defined metacognition. Turn to your partner and discuss what metacognition is and give an example when you have acted metacognitively."

After students have had a chance to discuss, Ms. O'Rourke has them share. Then she says: "So, as you stated, you first need to be aware that your discussion has stalled and that you do not understand what to do. Once you are aware, you need to take some action to get the discussion moving again. I have a reference chart here on the white board for us to discuss. (See **Table 2**.) One thing you can do is reread the prompt. This gives you an opportunity to refocus your thinking and come up with some ideas to add to the discussion and move it along. It also gives you a moment to clarify the prompt if necessary. Another strategy is you can summarize what you and your partner have said so far. By summarizing the discussion, you are 'retracing' the discussion to see where it broke down. You might find that a question or comment took your discussion off topic which caused it to stall. The third strategy is to ask your partner for help to get back on track. You could say, 'I can't think of anything else to say. Can you ask me a question or make a comment to get us moving again?' Or you could say, 'I am not sure if I'm on the right track with our discussion. Can you help me get back on track?'

I really want you to be thoughtful in your discussions and use these strategies if you get stuck. When you have completed your discussion, I am going to ask you and your partner to process your use of these strategies: Did you reread the prompt, summarize the discussion, and/or ask your partner to help?"

It is important for teachers to monitor student discussions to be able to determine what strategies need to be demonstrated and why, when, and how to use them. In the scenario above, Ms. O'Rourke demonstrated for her students what they could do when one partner (partner A) realizes their discussion became stalled because he is not understanding.

Another possibility for why the discussion breaks down and students are not going deeper to co-construct their knowledge can be because partner A realizes that partner B is not understanding. The third possibility is that both partner A and partner B realize the discussion has stalled and they need help to move forward. In both of these cases, the teacher would demonstrate what she has seen in the discussions and explain and model the steps (see **Table 3**) that could be taken to deepen the discussion.

5.5 Guiding student use of strategies and processes

To use strategies independently, students need metacognitive knowledge about their own abilities and attitudes, what strategies are effective and available, and the particular type of activity they need to do. Carefully designed guided practice, with a gradual release of responsibility built into the instructional sequence, enables students to develop this knowledge and the confidence they need before applying them in independent practice. At this stage learners also need timely, constructive feedback to determine how effectively they are learning and applying the discussion skills. The final scenario describes how a teacher in the SOAR project monitors and guides his students as they use the processes and strategies they have been learning.

Scenario for guiding student use of strategies and processes: Mr. Lu has introduced metacognition, engaged his students in the reflective process, deconstructed the reflective process, and taught metacognitive processes and strategies to his class. As a result, he feels they are being more metacognitive in their discussions. He is now monitoring and guiding his students in using those processes and strategies automatically. "You all have grown so much in working with your partners to co-construct your learning through your discussions. I see you using the metacognitive strategies we have discussed. Today, while you are having your discussion, I will be walking around listening to how you are using those strategies to regulate your discussions. I might ask you a question or set down a discussion prompt card (see **Figure 10**) as a reminder of what you could be doing to strengthen your discussion. Let us look at the cards so you are familiar with them. This one says, 'Summarize your ideas.' Which problem does that refer to? Yes, 'I don't understand.' This one says, 'Paraphrase your partner's ideas.' Yes, that matches 'My partner doesn't understand.' This one says, 'Retrace the discussion.' Yes, that is, for 'We need help to move forward.'"

If... or when....	Then I can
I don't understand	Reread the prompt to refocus my thinking. Summarize my ideas to clarify my thinking. Ask my partner for help to get back on track.

Table 2.
Metacognitive strategies A.

If... or when....	Then I can
My partner doesn't understand	Paraphrase my partner's ideas to help her refocus her thinking. Ask a question to prompt my partner to reconsider her thinking. Explain my thinking to move my partner beyond her misunderstanding.
We both need help to move the conversation forward	Clarify why the discussion has stalled to figure out how to move forward. Retrace the discussion to identify where the breakdown occurred. Explain why we are stuck and ask for help to enable us to move forward.

Table 3.
Metacognitive strategies B.

Getting students to monitor and guide their own discussion can be challenging. A unique strategy to help students do this is with the use of technology. Pairs of students can video tape themselves having a discussion using an iPad, Chromebook, or phone. Ask a pair if they would allow the class to view their video as a model. Take this opportunity for students to share the strategies they saw the students in the video use appropriately as well as any suggestions for improvements. Have the rest of the class watch their own videos and provide a checklist or graphic organizer for students to record what they did well and the areas they could improve upon. Debrief as a class. Finally, have students record another discussion with the goal of incorporating those strategies they need to improve.

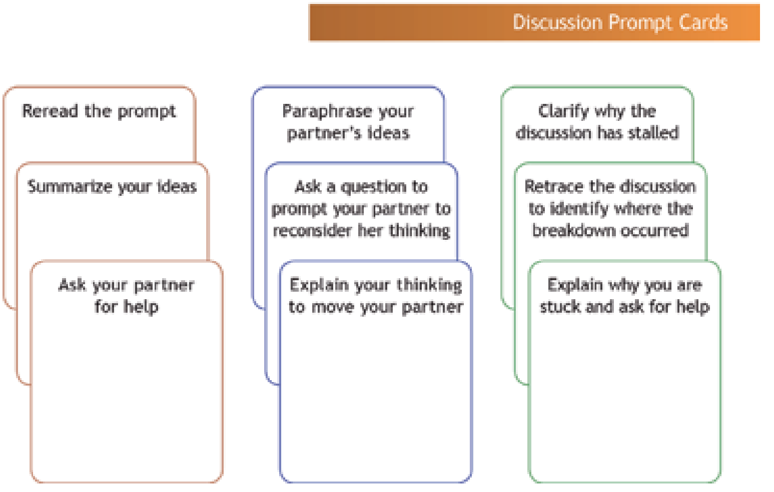

Figure 10.
Discussion prompt cards.

6. Conclusion

Instructional practices that help students develop a reflective and strategic approach to learning, i.e., teaching for metacognition, need to be embedded across the curriculum and throughout the school day. Accomplishing this goal requires instructors to think metacognitively about their teaching and to use instructional practices strategically, i.e., teaching with metacognition. In this chapter we have explained these concepts as well as how the SOAR Teaching Frame for Disciplinary Discussions can be used to support them.

In addition, we have introduced a framework called the stages of teaching for metacognition in disciplinary discussions. This framework, as well as the research-based instructional strategies and classroom scenarios that support it, can be used to help students develop a range of metacognitive strategies for remaining actively engaged in disciplinary discussions. It also provides insight into the stages of the framework by illustrating the dynamic and interdependent ways in which they work together to drive both teacher growth and student learning.

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Chapter 3

Mathematics Dictionary: Enhancing Students' Geometrical Vocabulary and Terminology

Shakespear Maliketi Chiphambo

Abstract

Students' understanding of geometric vocabulary and terminology is still an area of concern when teaching and learning geometry. The chapter addresses the benefits of integrating mathematics dictionary and polygon pieces into the teaching and learning in order for students to be proficient in geometry. However, there is little evidence in the literature regarding teachers' integration of mathematics dictionary and polygon pieces in the teaching and learning of geometry with an aim to support students' geometrical vocabulary and terminology. Consequently, the aim of the chapter is to provide an overview of how the integration of mathematics dictionary into the teaching and learning can be promoted. Also it provides the empirical and theoretical evidence of how mathematics dictionary influences students' understandings of geometrical vocabulary and terminology. The uses of mathematics dictionary and polygon pieces modify how learners learn, from passive to hands-on, and promote visualisation, respectively. The chapter recommends that mathematics teachers integrate mathematics dictionary and polygon pieces into the teaching and learning of geometry to all students to promote independent learning.

Keywords: geometry, terminology, dictionary, integration, self-depended

1. Introduction

This chapter presents theoretically and empirically how the integration of mathematics dictionary during mathematics instruction needs to be made a reality. The emphasis of the chapter is to demystify the myth that dictionaries are for language lessons. Hence, it is for all mathematics teachers to integrate mathematics dictionaries into their lessons. At a deeper level, the chapter highlights how to integrate mathematics dictionary into the instruction of geometry to promote critical thinking and the skill of information seeking.

However, there is an existing research on the benefits of integrating mathematics dictionary into mathematics instruction [1, 2]; however, most teachers do not bother themselves integrating the dictionary into their lessons. Most teachers stick to the same traditional methods of teaching where no resources are used to enhance students' geometrical understanding that promotes critical thinking [3].

There is an increase concern that most students underperform in geometry due to vocabulary and terminology that are not well established, but teachers still give it little attention [4].

One of the most important highlights in research is that dictionaries develop in students the use of vocabulary and terminology with their true or multiple meanings [2]. The chapter uses both theoretical and empirical evidence to demonstrate how mathematics dictionary can influence students' understanding of geometrical vocabulary and terminology which is a challenge in geometry mostly. Research shows that the reason why most students fail geometry is due to lack of well-grounded knowledge on geometrical vocabulary and terminology and its abstractness [5]. Misunderstandings and alternative conceptions which are a result of lack of proper geometrical terminology are addressed when mathematics dictionary is integrated into the lesson. However, with the integration of mathematics dictionary in the lesson students are made to be focussed, this leads to enrichment and enhancement of the mathematical success of students now and in the future [2]. Students become focused since they get empowered with mathematical vocabulary and terminology which are the essential elements for understanding geometrical concepts. The integration of mathematics dictionary into the lesson also promotes the skill of information seeking which enhances self-dependent learning.

Research has noted that one of the factors that act as a barrier to learning of mathematics by deaf or hard-of-hearing students is difficulties with language [6]. On the other hand, [7–9] argue that mathematics language and vocabulary also pose challenges to all students. The challenges are different from ordinary reading situations for the reason that they are more of mathematical terminological challenges. In support of the recent statement [10], a research study found out that the highest percentage of errors students committed emanated from the use of technical words in mathematics. According to [11–13], the improvement of mathematical vocabulary enhances students' mathematical proficiency.

However, research reveals that mathematical proficiency rests on a constant growth and balance of sophisticated components of critical element skills such as concepts, procedures, algorithms, computation, problem solving and language [14].

In order to explore the influence of mathematics dictionary on students' learning of geometry, the study was underpinned by [15] a model of geometric thinking. The model is described as follows:

Level 0 of geometry thinking: visualisation. At this level, polygons are judged according to their visual characteristics where students may, for example, judge a square as not being a parallelogram.

Level 1 of geometry thinking: analysis. At this level, students through reflection and testing of geometric shapes' characteristics gradually develop and then they use the identified characteristics to define the given shapes.

Level 2 of geometry thinking: abstraction. At this level, the learner has an ability to order figures and interpret them one from another using properties that are arranged chronologically.

Level 3 of geometry thinking: formal deduction. At this level a learner is considered to be at an advanced level of making meaning out of the given figures. For instance, the learner can prove situations with valid reasons.

Level 4 of geometry thinking: rigour. At this level, students have the ability to compare systems based on diverse axioms and can study geometric concepts abstractly (p. 311).

Clements and Battista [16] suggest that beyond the levels of van Hiele, there is a pre-recognition level (level 0) of geometry thinking. The argument is that students who cannot differentiate a shape from a cluster of shapes should be considered not yet operating at the visual level of van Hiele's theory but to be considered at the pre-recognition level [16]. This contribution adds up the levels of geometric thinking to five.

Van Hiele [15] proposes that to allow the sequential transition of students' ability of geometric thinking from one level to the next, teaching and learning must be guided by the five-phase structure, namely:

Phase 1: Inquiry phase. In this phase, resources lead students to discover and realise definite features of geometric figures.

Phase 2: Direct orientation. In this phase, activities are presented in such a way that their features appear steadily to the students, i.e., through brainteasers that disclose symmetrical sections.

Phase 3: Explication. The terms are introduced, and students are encouraged to use them in their discussion and written geometry exercises.

Phase 4: Free orientation. The teacher presents a variety of activities to be done using different approaches, and this instils in students capabilities to become more skilled in what they already know.

Phase 5: Integration. Students are given opportunities to summarise what they have acquired during instruction, possibly by creating their personal activities.

2. The integration of mathematics dictionary into teaching and learning for students' geometric proficiency

2.1 Methodology

The main research study was informed by the mixed method paradigm defined by [17] as the unification of quantitative and qualitative data analysis. The mixed method approach has been utilised for the following reasons:

i. To ensure that the outcomes are instructive, comprehensive, composed and convectional [18]

ii. For triangulation which is aimed at validation, deepening and widening the understanding of the viewpoint being studied [19]

The emphasis is that the mixed method approach gives a wide range of opportunities to analyse the collected data.

The cohorts of 56 eighth grade volunteers wrote the diagnostic test with an aim:

i. To find more on students' alternative conceptions and misunderstandings regarding geometric concepts

ii. To capture and explore the students' conceptual understanding of geometry before employing the intervention

iii. To help in designing appropriate intervention strategy that focuses on addressing the identified alternative conceptions among eighth grade students in learning geometry

2.2 Diagnostic and post-test content

Both the diagnostic and post-test questions 1.1–1.5 each with its three sub-questions were aligned to different levels of the van Hiele theory of geometric thinking as presented below.

Seven questions, 1.1(i), 1.2(i), 1.3(i) and (iii), 1.4(i) and (iii) and 1.5(i), were aligned to level 0 visualisation of the van Hiele theory. The questions at level 0 visualisation provided students with opportunities to use visual skills to determine the properties of triangles and also allowed them to recognise various triangles based on their unique properties.

Question 1.3(ii) considered to be at level 1 analysis of the van Hiele theory of geometric thinking focused on students' ability to identify a geometric shape's properties given all the symbols to describe it.

Six questions, 1.1(ii) and (iii), 1.2(ii) and (iii) and 1.4 (ii) and 1.5(ii) pitched at level 2 abstraction of the van Hiele theory of geometric thinking, required students to solve problems where properties of figures and interrelationships were significant [20].

Question 1.5(iii) was set at level 3 formal deduction of the van Hiele theory for students to think logically in order to provide the properties of the given triangle. The question at this level was set to assess whether how well the learner could give sufficient conditions of a triangle without the use of polygon pieces and mathematics dictionary. For details of the diagnostic and post-test content, refer to Appendix 1.

2.3 Intervention and results

After the diagnostic test was marked, purposeful sampling of nine students was employed according to individual students' performance: three with a high percentage, three with an average percentage and three with a below average percentage. Purposeful sampling was done to target a small number of individuals in order to maximise opportunities for eliciting more in-depth data [21] about the influence of mathematics dictionary in the teaching and learning of geometry, which was the spectacle under study [22]. **Figure 1** below presents how the selected nine students performed in both tests (diagnostic and post-test).

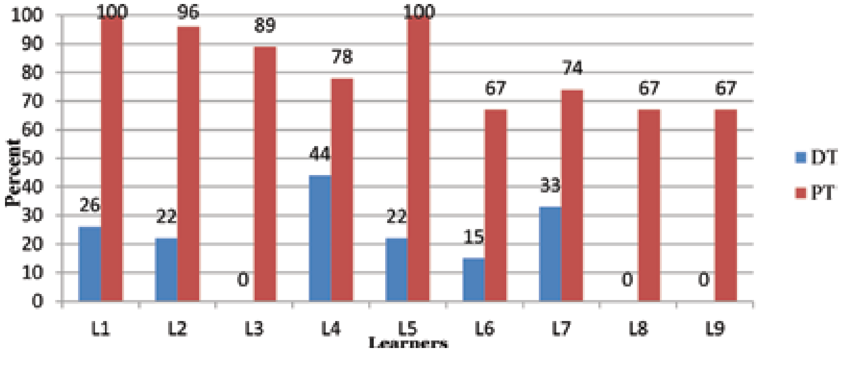

Figure 1.
The comparison of diagnostic test and the post-tests results. DT, diagnostic test; PT, post-test; L, learner.

Figure 1 shows that in the diagnostic test, all nine students involved in the research scored marks that were below 50%. However, after being engaged in the intervention activities that made use mathematics dictionary, all the students scored above 60% in the post-test.

The results of the diagnostic test helped in the designing of the nine intervention tasks which were aimed at addressing the alternative conceptions and misunderstandings that students demonstrated in geometry. In each of the planned intervention activities, students were supposed to answer each one of the questions after measuring and comparing angles and sides of the given triangles using cut polygon pieces of the same triangle.

However, to be engaged in the activities, students were to use A4 paper where triangle ABC was drawn; alongside the A4 paper, the two copies of triangles ABC were provided to every learner. **Figure 2** clarifies how the process of using the original triangle and its copies was done.

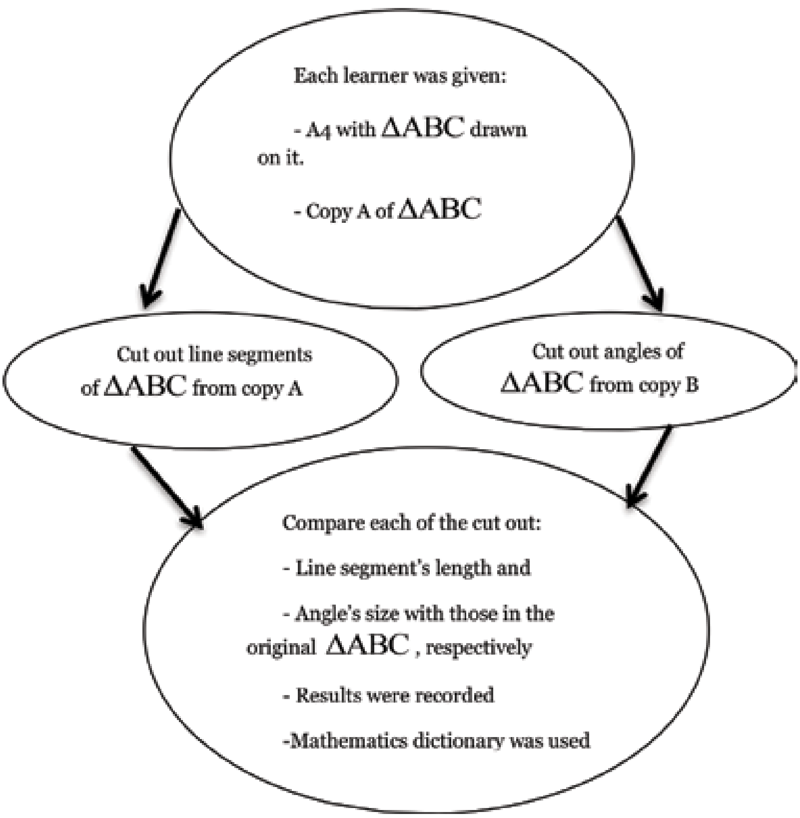

Figure 2.
The process of how the learners cut out polygon pieces during the intervention process.

In order to do the intervention activities as planned, students were supposed to answer each and every question after measuring and comparing angles and sides of the given triangles using the cutout polygon pieces. Mathematics dictionary was made available for the students to use during the process to support with vocabulary, spellings and terminology. After the intervention activities, all the nine students had to write a post-test. **Table 1** shows how students improved their responses in the post-test as compared to the diagnostic test.

Learner code	Question number	Diagnostic test students' responses	Post-test students' responses
L1	1.1(ii)	AB, parallel; AC, horizontal; BC, horizontal	The lines are not equal
L1	1.4(i)	Equal triangle	Equilateral triangle
L2	1.3(iii)	The name of a triangle is DEF	Isosceles triangle
L2	1.4(iii)	XY is bigger than YZ and XZ is bigger than XY	XY is equal to YZ and XZ
L3	1.1(ii)	It is small side and A bigger side AC small bigger from A to another A deduce about size	$\hat{A}$ is smaller than $\hat{C}$
L4	1.1(iii)	A and B are equal and C is less than A and B	It is a scalene triangle
L4	1.2(iii)	Triangular prism	It is a scalene triangle
L4	1.5(i)	It is an equilateral triangle because all sides are equal	Isosceles triangle
L5	1.1(i)	$\hat{A}$ is longer than $\hat{C}$ A is bigger than C	$\hat{A}$ is smaller than $\hat{C}$
L5	1.2(iii)	2 dimensional shapes	Scalene triangle
L5	1.3(iii)	2 dimensional shapes	It is a scalene triangle
L5	1.4(i)	2D shape	Equilateral triangle
L5	1.5(i)	2D shape	Isosceles triangle
L5	1.5(ii)	They were not equal, and they are used to make a shape	They are equal in size
L6	1.1(iii)	AB are associated, AC are the convection and BC are associated	It is the scalene triangle
L6	1.4(i)	It is triangular	It is the equilateral triangle
L7	14(i)	It is an equal triangle	Equilateral triangle
L8	1.4(i)	Triangular	Equilateral triangle
L9	1.3(iii)	D is 4 cm and F is 3 cm	Two angles are equal
L9	1.4(i)	Rectangle	Equilateral Δ

Table 1.
Students' responses to questions in both diagnostic test and post-test.

Table 1 shows how the use of mathematics dictionary enhanced students' comprehension of geometric concepts in the post-test as compared to the diagnostic test responses. To cite few examples, L1 and L7 when responding to questions 1.4(i) in a diagnostic test incorrectly answered, equal triangle, but after being engaged in the intervention activities that integrated mathematics dictionary the response was now correct, equilateral triangle.

After the intervention activities, all nine students were involved in a semi-structure interview just to find out their views on the use of mathematics dictionary in learning geometry; below are some few direct quotations:

L3: *I like the programme that made use of mathematics dictionary because it helped me to understand mathematics concepts that I did not understand before.*

L4: *Yes, sir, I got a clear picture because now I clearly understand the concepts of triangles and their properties.*

L7: *I have learnt that: in a scalene triangle all side are not equal, in an isosceles two opposite side are equal and there are two angles equal, an equilateral, all the angles are equal in size the same as the sides, they are equal in length and also how to spell correctly the names of triangles*.

L8: *I did not understand the properties of an obtuse angled triangle. Even the slashes that are used to show that two opposite sides of an isosceles triangle are equal. I did not know the meaning of such slashes, but now after your programme it is clear to me, the dictionary and shape cutting helped me a lot.*

The four students cited above echo the sentiments that the use of mathematics dictionary in the learning of geometry has empowered them to understand some of the concepts that were a problem to them as they moved throughout the grades. They have emphasised that the definitions, symbols and properties of different triangles were also addressed in the process of engaging with the dictionary, issues that were identified by [10] as challenges for deaf students only.

The citation by L8 shows how the integration of mathematics dictionary and polygon piece into their learning helped them to experience hands-on learning and

Question number in both DT and PT	van Hiele's levels of geometric thinking for each of the questions	Students' codes	Did students achieve questions in the DT at a given van Hiele level of geometric thinking?	Did students achieve questions in the PT at a given van Hiele level of geometric thinking?
1.1 (i) (ii) (iii)	Level 0	L: 3, 4, 5, 6 and 8	No	Yes
	Level 2	L: 1, 3, 6, 7 and 9	No	Yes
	Level 2	L: 1, 2, 3, 4, 5, 6, 7 and 8	No	Yes
1.2 (i) (ii) (iii)	Level 0	L: 1, 3, 4, 5, 6, 7 and 8	No	Yes
	Level 2	L: 2, 3, 4, 5, 6, 7 and 8	No	Yes
	Level 2	L: 1, 3, 5, 6, 7 and 9	No	Yes
1.3(i) (ii) (iii)	Levels 0 and 3	L: 2, 5, 8 and 9	No	Yes
	Level 1	L: 2, 3, 7, 8 and 9	No	Yes
	Level 0	L: 1, 3, 5, 6 and 9	No	Yes
1.4(i) (ii) (iii)	Level 0	L: 3, 5, 6, 7, 8 and 9	No	Yes
	Levels 2 and 3	L: 1, 2, 3, 5, 6, 8 and 9	No	Yes
	Level 0	L: 1, 2, 3, 6, 8 and 9	No	Yes
1.5(i) (ii) (iii)	Level 0	L: 1, 2, 3, 4 and 5	No	Yes
	Level 2	L: 1, 2, 3, 5, 8 and 9	No	Yes
	Levels 0 and 3	L: 1, 2, 3, 5, 6, 7 and 8	No	Yes

Table 2.
A summary of the students' responses to diagnostic test and post-test.

visualisation of geometric concepts before the answer was established. However, it is apparent that students gained other skills in the process of using dictionary and cutting polygon pieces, for example, the skills of looking up for a word in the dictionary, observation skills, psychomotor skills (established as they were cutting the angles and line segments) and measurement skills (as they were comparing one angle to another and one line segment to another). The intervention activities students engaged in made them to realise that learning is about active participation. In the process students gained the knowledge of how to use mathematics dictionary and polygon pieces to learn about geometry, which is a component of metacognition. However, students came to realise that properties of triangles are established through hands-on and self-dependent learning mediated by mathematics dictionary and polygon pieces.

A summarised version of students' results per question is presented in **Table 2**.

Table 2 presented shows how each of the students managed to achieve questions at various levels of van Hiele theory of geometric thinking after utilising mathematics dictionary in their learning. The questions were set to test students' geometrical proficiency which includes geometric vocabulary, terminology and conceptual understanding. As shown in **Table 2**, no learner managed to perform at the set level in the diagnostic test; these results are in agreement with those of [13] who found out that the comprehension of mathematical language enhances mathematical proficiency in students. This implies that if a learner's geometrical vocabulary is not clear, he/she cannot be able to perform well in geometry.

To improve students' understanding of geometry, it calls for teachers to integrate mathematics dictionary into teaching and learning. The integration of dictionary into the teaching and learning of geometry can help to deal with the five common problem areas identified by [10] as prevalent cases in deaf students: "words with multiple meanings, technical vocabulary, words with specialized importance in mathematics, varied but related forms; and abbreviations and specialized symbols" (p. 419). Yet, in reality the challenges are also dominant in all other students.

3. Conclusion

This chapter has given an empirical and theoretical account of and the reasons for the need to integrate mathematics dictionary into the teaching and learning of geometry. The study has established that students' independent learning and understanding of geometrical vocabulary and terminology were heavily influenced by the use of mathematics dictionary and polygon pieces mentioned in **Figure 2**. The integration of the two, mathematics dictionary and polygon pieces, into teaching and learning helped students to modify their way of learning geometrical vocabulary and terminology unlike in a traditional classroom where no hands-on learning tasks are executed. However, the availability of the dictionary in the lesson made students aware that once they were stuck with understanding of geometric vocabulary and terminology, mathematics dictionary had the answers. During the lesson students would make use of mathematics dictionary without being told what to do with it.

As highlighted in **Figure 2**, the use of polygon pieces also promoted independent learning in students in the sense that they were engaged in the cutting of line segments and angles of a particular triangle in order to establish its properties. The cutting and measuring of line segments and angles promote independent learning for the reason that no student was told how an isosceles or a scalene triangle looks like. No student was told how to do the cutting of polygon pieces; each one independently devised a way of cutting line segments, so that they were not half-way cut. Half-way cut line segment could not give students opportunity to execute the task of finding properties of triangles in terms of line dimensions. Each and every response was established through practical investigation and solution written down; hence, this promoted independent learning.

How the use of mathematics dictionary and polygon pieces nurtured the students' independent learning is reflected in how most students responded to the post-test. **Figure 2** attests to this. The errors that students committed in the diagnostics test, for example, spellings and failing to name triangles properly, after they were engaged in the use of the mathematics dictionary and polygon pieces were corrected in the post-test (refer to **Table 1**). This chapter contributes additional evidence that suggested how the dictionary and polygon pieces can be integrated into teaching and learning to promote independent learning. However, I highly recommend that mathematics teachers integrate the use of mathematics dictionary and polygon pieces into their lessons.

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Conflict of interest

I declare that no financial or personal relationships have inappropriately influenced me in writing this book chapter.

Disclaimer

This chapter was prepared by Dr. S.M. Chiphambo who has the capacity as a researcher. The views expressed in the submitted chapter are solely the author's findings of the research conducted and do not reflect official views or position of any academic institution or funder.

Appendix 1. Diagnostic and post-test content

Instructions

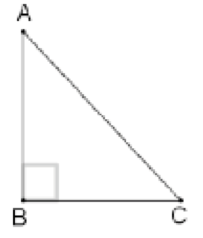
i. Answer all the questions.

ii. Write neatly.

iii. Provide your answers on the spaces provided under each question.

Question 1.
Study the 2D figures below and then answer the questions that.
follow:

1.1

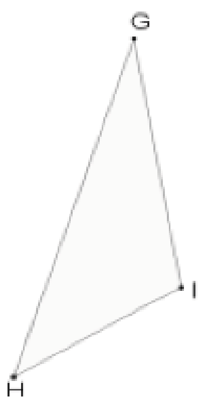


i. What can you deduce about the sizes of $\hat{A}$ and $\hat{C}$?

ii. What are the properties of triangle ABC in terms of $\overline{AB}$, $\overline{AC}$ and $\overline{BC}$?

iii. According to answers in 1.1. (i) and (ii), what specific name is given to a shape with the properties mentioned above?

1.2

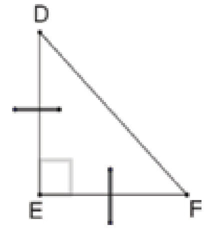


i. What are the properties of the triangle GHI in terms of $\hat{G}$, $\hat{H}$ and $\hat{I}$?

ii. Determine the properties of triangle GHI in terms of $\overline{GH}$, $\overline{HI}$ and$\overline{GI}$.

iii. What name is given to a triangle with such properties?

1.3



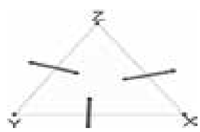
DOI: http://dx.doi.org/10.5772/intechopen.86409

i. Write down the size of each of the following angles $\hat{D}$ and $\hat{F}$.

ii. Determine the length of $\overline{EF}$, $\overline{DE}$ and $\overline{DF}$; use terms like shorter, longer than, equal and the longest of all.

iii. What name is given to triangle DEF?

1.4

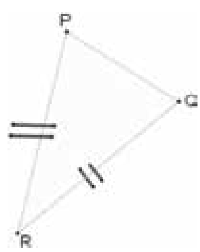


i. What type of a triangle is drawn above?

ii. Determine the size of $\hat{X}$, $\hat{Y}$ and $\hat{Z}$.

iii. Write down the length of $\overline{XY}$, $\overline{YZ}$ and $\overline{XZ}$; use terms like shorter, longer than, equal and the longest of all.

1.5



i. What name is given to triangle PQR?

ii. What is the relationship between $\hat{Q}$ and $\hat{P}$?

iii. What can you conclude about the properties of triangle PQR?

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Chapter 4

Using Problem-Solving as a Method for the Development of Self-Regulation of Learning with Adolescents: An Experience Report

Giovana Chimentão Punhagui

Abstract

The tendency to take risks without measuring consequences properly and the decrease in motivation are features presented at adolescence that may presuppose the need for changes in the traditional way of teaching and learning. This hypothesis leads to the search for educational solutions for a more effective work in the classroom. This study analyzes the methodology applied to adolescents at Sesi School, a basic education school in Southern Brazil, using Robert Sternberg's theory of problem-solving (2010) in cognitive psychology and Barry Zimmerman's concept of self-regulation of learning (1989). The analysis aims to draw relationships between the adolescence phase and the impact of a methodology focused on problem-solving, in order to perceive possible contributions to the development of more autonomy and responsibility for learning. This experience report points out as main contributions: (a) problem-solving can be a promising method for the development of autonomy and responsibility for learning; (b) as adolescents are moved by risks, problems can turn into challenges, motivating students to seek pleasure and reward in the search for the best solution; (c) problem-solving in the adolescents' formal learning environment promotes the development of a repertoire of strategies, which effectively helps with the autonomous and responsible management of learning regulation.

Keywords: adolescence, self-regulation of learning, problem-solving, learning autonomy, responsibility for one's own learning

1. Introduction

School has become responsible for disseminating elaborated culture and encouraging the construction of knowledge, making learning a constant. It is understood that acting in the field of education requires student learning outcomes. However, there is no single, external formula that addresses the problem [1]. What is known is that learning needs to be seen as an activity that students do to themselves proactively, rather than as a reaction to teaching [2].

According to Zimmerman [2], "a major function of education is the development of lifelong learning skills." Therefore, responsibility and autonomy are two essential aspects. It is common to find students who like to be told what to do or do it only if it is essential to a good grade. These attitudes diminish confidence in their own actions and depress the use of strategies to promote learning [3]. Learning needs involve the use of specific strategies to achieve academic goals [4]. And these actions come from research and development of problem-solving, coupled with the motivation to achieve solid results.

Cognitive psychology brings problem-solving as a motivated activity to reach a goal or answer a question [5]. And this will be the work front for the analysis of this study, which has as guiding element the methodology of teaching and applied learning for adolescents in high school at Sesi School network in the State of Paraná. The objective of the study is to relate aspects of Sesi's methodology to the theoretical notes referring to the problem-solving of Sternberg [5] and the self-regulation of learning in the vision of author Barry Zimmerman, both guided by cognitive and socio-cognitive psychology.

2. Facing the challenge: the cycle of problem-solving by adolescent students in a learning workshop

The ability to learn is a result of the need for our genes to make predictions in very unpredictable environments. The brain is built by these genes, with the ability to make decisions to ensure the survival of the individual. Decision-making is provided by strategies for learning and simulation of future events, enabling the execution of action plans [6].

Learning, therefore, is associated with the need for survival of genes and therefore needs a motive and situations that involve the development of this need, considered a "trick" to guarantee the art of living [6]. In the earliest times, this need was focused on acquiring the skills to hunt, procreate, and defend clan members and aspects formed by genes and executed by the brain. The brain is able to evolve over time because of the association of gene propagation with lived experiences, allowing for new connections and the development of subjective awareness, simulation capacity, and the innate movement of learning. Patterns of behavior are also tied to this evolution, spreading species selfishness and altruism to members from the same clan.

School learning, an aspect created from society's need, is, in this sense, a set of strategies to be acquired in order to live and survive in a given time, in accordance with the current standards and rules. If we take into account the current time that we live, autonomy and responsibility continue being essential elements for human survival. According to Zimmerman and Cleary [7], it is necessary to offer (to individuals) sufficient opportunities to develop and exercise their autonomy within the classroom. For this, mechanisms opposed to the traditional form of teaching need to be thought and applied. The development of the individual capable of managing one's own knowledge depends on how he or she faces the acquisition of new information. And today, with the demand for inclusion in an increasingly complex society, changes in the work world are increasing, requiring the formation of people capable of exercising effective strategies in problem-solving.

Sesi School network in Paraná has in its methodology the premise that the only way to do this is to break the paradigm of the traditional school as a response to social demands and to the industry. Its teaching and learning proposal is based on the participative education of the adolescent, and it focuses on developing the learning workshops. One of its main objectives is the education of leaders capable of efficiently using their cognitive and relational capacities for success in the labor market. Learning workshops provide the constant investigation and exploration of challenges related to reality, providing a continuous conflict and the use of a range of strategies to achieve possible responses.

If this is the goal of the methodology, is it possible to work on these aspects in high school, a time when students are in their teens, where the individual undergoes important physiological and psychological changes?

Analyzing the perspective of neuroscience, research reveals that the extensive structural and functional development of the brain continues during adolescence, which means that there is still great flexibility for adjustments in intrinsic motivation and goal priorities, allowing for changes in their social context [8]. It is considered a period of development and consolidation of its social being and its identity and understanding of society and the opinion of others [9]. They also develop the capacity to retain larger multidimensional concepts and, therefore, acquire the ability to reason more strategically [10].

However, because of the hormonal changes, mainly due to puberty, the risk propensity becomes greater, because the individual loses up to 30% of dopaminergic synapses, strictly related to pleasure or reward. It is for this reason that certain situations considered pleasant during childhood are no longer interesting [11]. This lack of interest and the need for more robust rewards are related to changes in the adolescent's own brain that during puberty undergo a process of synaptic reorganization, and as a consequence, the brain becomes more sensitive to new experiences linked to executive functions and social cognition [10]. This means that, because of this reorganization, there is a greater need to search for sensations that bring back the sensation of pleasure and reward, and, therefore, there is vulnerability to risks.

Sternberg [5] points out that, although these manifestations derive from biological aspects, one of the factors that increase the risk activity, especially in negative risks, is the strong influence of the environment in which the adolescent is inserted. For the author, there are few hormonal effects that are not conditioned to the environment and that to contribute to the healthy development of the individual's brain at this stage, efforts to prevent or minimize negative risks should focus on changing the environment, transforming what the adolescents know and the ways they think. They are able to put energy into both analytical and heuristic processes for judgment and decision-making when immersed in contexts that activate their social schemas [12].

Positive influences in helping to develop greater autonomy and responsibility in the environment are therefore possible because the flexibility and the myelin layer formed in the axon of their neurons increase the speed of the electrical transmissions from one neuron to another, contributing to the maturation of the frontal cortex, a fundamental part for problem-solving and decision-making [10, 13].

In this sense, if we assume that the adolescent has a decrease in dopamine—responsible for pleasure and feeling of reward, resulting in a greater propensity for risk—but presents great potential for thinking strategically, making larger and faster neural connections due to the myelin layer, it is possible to consider work with problem-solving as a lever of autonomy and responsibility. Problems can become challenges and can be thought-provoking to the point of becoming a positive risk, motivating the student to seek pleasure and reward in finding the best resolution, resulting in knowledge.

In this context, the conventional teaching methodology worked as current education does, in a way, does not provide for the adolescent's need to cope with changes in his body and mind, and therefore does not fulfill his potential to utilize his neural and motivational capacity for learning. Therefore, the proposal of a new educational formation for the adolescence phase becomes real from the neuroscience explanation, impelling adaptations to the new time, as affirmed by Silva [14]: "Students should be taught to understand and use personal resources that allow them to reflect on their actions, to exercise a greater control over their own learning processes and to strengthen their learning skills; teachers, on the other hand, should be able to stimulate in their students a more competent, efficient and motivated use of the learning processes and the technological and cultural means to which they can have access." It is the conscious, knowledgeable, and controlled possession of these internal and external means that can lead students to play an active role in the construction of their knowledge, in the fulfillment of their aspirations, in the elaboration and direction of their intellectual, affective, social, and professional goals and guarantee them an active and responsible integration in the society.

Academic learning, when based on the understanding of learning itself and on the construction of greater cognitive, metacognitive, and behavioral independence, favors the autonomous development of the individual and assists in the continuity of his/her formation after the school period [15]. It is assumed, therefore, that the role of the school is to provide the students with subsidies that allow them to develop cognitive, metacognitive, and behavioral mechanisms to help them to seek knowledge to improve and face the obstacles encountered in the course of their learning, even when, and especially in the absence of a mentor. "[...] the educational process must be based not so much on the transmission of knowledge and information, but rather on guiding and facilitating the formation of thinking and the action of the citizen" [16].

Dawkins [6] warns to the fact that "[...] it is a fallacy to assume that genetically inherited traits are by definition fixed and unalterable." What makes us autonomous is the ability to stimulate and exercise the brain to learn and contribute to the environment. In addition, the human being is directly influenced by culture and transmission of habits.

The methodology of the learning workshops has as one of its pillars the individual's independence, able to solve conflicts and problems in an intelligent and effective way. Studies show that synaptic reorganization promotes a decrease in synapses to give rise to a specialization of areas and abilities in adolescents [11]. This exercise in the brain is considered fundamental for the refinement of functional networks in the brain tissue, making neural circuits more efficient and prone to strategic work. In addition, this refinement also allows for the perception of the other, a crucial aspect for social communication [10].

In order for the adolescent to be able to put his or her areas and skills into practice, also by exercising this communication, contributing to problem-solving, the classrooms do not include individual desks, but tables with seats for 4–5 students, so that they can work the challenge of the team workshop, promoting discussion, reflection, and decision-making. This proposal is in line with Sternberg's [5] statements, reporting that for cognitive psychology, group work facilitates problem-solving as members can contribute with a greater variety of skills by sharing acquired skills. Moreover, interactions with peers, as well as societal influences, are likely to influence their social behavior, contributing to neural maturation in positive situations and contexts [9].

Solving the challenge proposed in the workshop, students have a period of a 2-month period to complete it, that is, the answer is not tied to the simple memorization of certain content. Problems require time, not opening space for immediate answers, but rather hypotheses [5]. It is expected that the executive function of the adolescent brain develops, providing better selective attention and decision-making [10], and for this reason, work with problems helps in the exercise of this brain function. According to Sartorio [11], "If we confront adolescents with problem situations that require from themselves the execution of moral decisions, of anticipation of damages caused by acts and in the adequate recognition and judgment of the emotions, we will be propitiating maturation of the areas of the brain responsible for these abilities, thus increasing the chances of being cooperative, empathic, and emotionally healthy adults."

Working with problem situations—challenges—is part of a cycle that is composed of well-defined steps and, according to neuroscience, activates the prefrontal lobe each time we come across it [5]. "The brain is not only in charge of the continuous control of the occupations of survival machines but also acquired the ability to see the future and act accordingly," having the power to instantly decide what to do, increasing its efficiency in the various ways of living [6]. The decisions are thought from the strategy of simulation developed by the human brain itself and potentiated by the experiences lived by the individual.

The steps in the cycle to work with problem situations, which help and improve the decision-making performed by the brain, are clear in the Sesi/PR teaching proposal, as shown in **Table 1**.

There is a relationship between the Sternberg cycle [5] and the so-called self-regulatory learning skills, since, according to Zimmerman and Cleary [7], in order for students to solve school problems and meet expectations, they need to have a repertoire of strategies of study and self-regulation that they can access and use. Self-regulation is understood as a complex, multifaceted process that integrates key

Problem-solving cycle [5]	**Sesi/PR School teaching proposal**
1. Problem identification: first and important step to recognize the goal to be reached	The pedagogical team elaborates the projects to be implemented, each one with a challenge to be solved. The students identify what the challenge is and how the goal will be met. Thus, they choose which challenge they feel motivated to solve during the 2-month period
2. Problem definition: define it and represent it to understand how to solve it	By entering the chosen learning workshop, the facilitator teachers help the teams to understand the challenge and represent it
3. Elaborating a strategy for solving the problem: plan ways to solve it	During the workshop period, the student team is motivated to think of strategies to meet the challenge proposed. These strategies come from the experience with teammates, the facilitator teacher, and the resources available for research
4. Organizing information on a problem: to integrate the necessary information for meeting the challenge	Each learning workshop includes a content web related to the theme and the proposed challenge. The contents come from an area/subject proposed in the National Common Basis of contents for the Brazilian High School. History, geography, mathematics, biology, etc. are intertwined by the challenge. The students gather what they learn in the given subjects to achieve the desired goal
5. Resource allocation: the use of time, space, materials, and knowledge	It is necessary to have the time, the mental resources, and the help of the facilitating teacher, of colleagues, and of the didactic material available so that the planning and the applied strategies have effectiveness in solving the problem
6. Monitoring: measuring and evaluating the taken steps during the course	The students take up and evaluate the challenge at all times, being in individual works, being in works with their team. Through this review, it is possible to understand if the path mapped to the challenge solution is being effective
7. Evaluation: evaluate the solution after being concluded	The process of investigation and resolution of the challenge is evaluated by the student himself not only on the day of his presentation but also in his moment of reflection and decision-making: individual and team self-assessment. And through this activity, the student becomes aware of the steps taken and their performance so that the process is completed

Table 1.
Identification of Sternberg [5] problem-solving cycle in the methodology of Sesi/PR School.

motivational variables and self-processes. Self-regulation involves students who direct their behavior or strategies proactively to achieve self-established goals. They also rely on affective, cognitive, motivational, and behavioral feedback to modify or adjust their strategies and behaviors when they are unable, in the beginning, to achieve their goals [7].

According to Albert and Steinberg [12], a self-regulatory competence has high potential for negative risk decline by adolescents. Metacognitive activities are also placed as strong allies for processing and monitoring abilities of adolescent cognitive activities [10]. Unfortunately, students not only have a poor knowledge basis in effective strategies but also do not understand how to select, evaluate, and adjust faulty strategies. For the authors, it is important to create classrooms for problem-solving by incorporating principles of self-regulation of learning in daily activities, optimizing the time factor to promote greater cognitive evolution. According to Dawkins [6], the time factor is an object of strong competition in society because the human brain cannot do more than one or more than a few things at a time. Therefore, working with learning strategies in school becomes essential when it comes to ensuring survival and contribution to society.

Students at Sesi School must constantly exercise self-regulation capacity, controlling the use of personal, behavioral, and environmental strategies [2]. The autonomy and the responsibility for learning are structuring axes of the students' learning [17, 18]. And these axes are strictly linked to problem-solving. That is, in order for the learning workshop's challenge to be unraveled and unveiled, the problem-solving cycle and self-regulation capacity must be well adjusted, which is no easy task.

The first step of the cycle, besides demanding the identification of the problem/challenge, is also affected by the generated motivation [5]. According to the author, our emotions can influence how we solve problems, sometimes harming the course. Extrinsic motivation must be strong to the point where, during the process, it has to be reverted to intrinsic motivation. Bzuneck [19] states that with the help of facilitators, extrinsic motivation can be changed, gradually, to intrinsic motivation. In research investigation of extrinsic motivation by external regulation, Bzuneck and Guimarães [20] affirm that there is a tendency, by students, to avoid the challenges, to lose initiative and to worry more about the completion of a certain task than with their quality, conferring the possibility of a certain type of reward or punishment for their (non) compliance. Adolescents are led to seek more extreme incentives to compensate for the brain's low motivational circuit [10]. Therefore, it is important to instigate the student to build the skills necessary to accomplish positive assignments. Intrinsic motivation facilitates and increases the chances that the problem will be solved.

According to Schneider [21], although children do not effectively monitor the use of strategies, they can be trained to do so by developing mechanisms that are extended to adolescence and adulthood. The adolescent's cognitive capacity for learning self-regulation develops gradually in a linear fashion, responding better to reward than to punitive feedback, helping him to support long-term goals [12]. In the classroom, the teacher has a potential impact to develop monitoring and control processes by students of their own learning [21]. The elaboration of strategies and the organization of information are embedded in the actions implemented by the students in the classrooms of Sesi/PR School. The facilitating teacher, working with one of the contents from the web in the learning workshop, launches a study roadmap for the student and his or her team to conduct research before discussing with the class. In the midst of activities, the use of heuristic calls (mental shortcuts) becomes frequent. According to Sternberg [5], heuristics are implemented due to the limits of our working memory. The solution of problems depends on these mental shortcuts so that a solution can be reached. The student team needs to develop certain shortcuts related to the organization of space and time, action planning, volitional strategies, and even interpersonal relationships so that the team can do the job in the best possible way. Whether they are isomorphic problems, well or poorly defined, the provision of strategies becomes necessary.

The strategies that benefit self-regulation are based on four levels: behavioral, referring to the control of study time, organization of the environment to favor concentration and better use, materials and internal and external resources, seeking help from colleagues, teachers, or parents; metacognitive, involving perception of the role of cognitive strategies in the actions performed, knowledge of when, where, and how to use them, reflection of the objectives of the tasks and the planning to be carried out, monitoring the implementation of the plan, verification of results, and recognition of difficulties and of the strengths for conducting a new plan; motivational, encompassing understanding of what drives them to learning; and, finally, volitional control, referring to the development of strategies that help them with negative failures and feelings, better controlling attention and time, as well as demotivation, and better managing the resources and the assistance received [14].

The use of the strategies promotes greater awareness of the evolution itself so that the students reach the established goals, improving their school performance at all levels of the schooling process. The use of learning strategies, although still in an initial phase, can contribute to reduce problems found in the educational environment [22].

Conflict at Sesi/PR School classroom is natural. Therefore, sometimes the intervention of the facilitating teacher and the pedagogical advisor is fundamental. At meetings to discuss team performance, the coach usually asks members to reflect on how the team's skills are and the pace of response to the challenge. Then, from the answers, he builds, along with the members, strategies favorable to the growth and success of the team in the accomplishment of their tasks. This is necessary since the challenges of learning workshops, according to Sternberg's theory [5], are considered to be poorly structured, that is, there are no clear and readily available pathways to the solution, and, this way, depend on (a) knowledge of the domain, (b) skills, (c) cognitive and emotional factors, and (d) attitudes toward science and the regulation of knowledge. If the team does not elaborate and does not use effective strategies, the process of solving the team's problem and even the workshop challenge falls apart.

Teachers have a determining role for the final quality of the work performed [23]. The figure of the teacher as mediator, at the Sesi/PR proposal, comes precisely to mediate the process between creating their own action mechanisms and responding to the challenge.

3. The team facing the challenge: obstacles and the expert's role at Sesi/PR School's methodology

For Sternberg [5], factors such as mental configuration or entrenchment can hinder the solution of problems. If the work team fixes on a specific strategy and, seeing the failure in the result, does not modify its strategy, the goal cannot be achieved. This is why experience in constantly exercising the brain to solve challenges prevents the individual from allowing functional fixation, which is nothing more than being unable to understand something by having only one way of seeing it to trigger in a certain situation [5].

For Rigon [24], the precursor of the methodology at Sesi/PR School, doing is the basis of the learning workshop, and arguing is one of the most important skills sought for the acquisition of experience in solving challenges. For the educator, formulating hypotheses, testing, analyzing, and formulating the rule are not only actions of mathematics or philosophy. They serve for any science—it is thorough knowledge. Therefore, it can be said that the methodology opposes functional fixation as an obstacle to solving problems, corroborating the efficient work with the challenge presented and, consequently, with the mission used by the school: "Forming leaders with social and environmental responsibility, with high level of negotiation, respectful and committed to cultural diversity and prepared to work in quality teams, leading them to be creative, ethical and innovative professional entrepreneurs and thus, face and win life challenges" [24].

The mission presented is complex, demanding, and instigating. It demands regulatory and self-regulatory efforts committed to learning. According to Rosário [23], self-regulating students of their learning see the events in school as opportunities to expand their experiences, valuing them. This becomes important insofar as these experiences lived and worked through strategies and can support the others that will come after the school period. For the author, "this process assumes 'skill & will,' that is, the application of cognitive and motivational resources to the concrete task of learning. [The strategies] should be trained on distinct types of school tasks to facilitate their transfer to other contexts, since students do not focus learning tasks in a similar way regardless of the contexts and nature of the learning tasks."

In cognitive psychology, Sternberg [5] defines "transfer" as the use of knowledge and/or skills from one situation to another, which can be of two types: the negative and the positive. The positive is the one brought by the author Rosário, which occurs when "[...] the solution of a previous problem makes it easier to solve a new problem, that is, the transference of a mental posture can help in solving problems" [5]. And this is also the one sought in the methodology of Sesi/PR School, when it proposes a learning workshop at each 2-month period. With each new workshop, students have the opportunity to practice the positive transfer in accordance with the experiences lived in the previous workshop.

Sternberg [5] states that an effective strategy to avoid negative transfer is incubation. This action promotes small pauses between the steps from the problem-solving cycle to promote conscious reflection of the problem. For the author, the incubation process allows new stimuli to activate new perspectives, promote the perception of analogy, and aid in mind relaxation to develop assertive attempts.

Another strategy considered effective by Sternberg [5] is the formation of a plan of action to solve the problem, working the prefrontal cortex. Planning also appears as one of the components of Zimmerman's self-regulation cycle [2], the so-called preliminary phase, which consists of analyzing the problem encountered in developing a plan that favors the achievement of the stipulated goal. In the methodology of Sesi/PR School, planning is one of the elements of the challenge resolution (**Figure 1**).

However, the ability to solve problems does not come only from planning or aspects already mentioned in this study. For Sternberg [5], knowledge is also a key factor in the process. For this reason, effective problem-solvers are called experts,

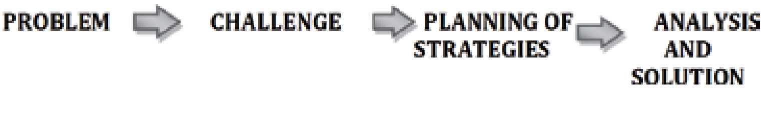

Figure 1.
Elements of resolution of the challenge from the learning workshop [24].

that is, they have "[...] superior skills or achievements that reflect a well-developed and well-organized knowledge basis" [5]. Experts are able to devote more time to planning and organizing the problem and less time in implementing strategies to solve it. They also have "automation" to develop strategic steps transferred from previous experiences, prediction of certain events, and flexibility during the process.

However, to become an expert, one must practice, experiment, and experience. Practice and living should focus on the acquisition of new skills, not repetition without purpose [5]. For Rigon [24], a school must be the place of doing and not the simple "decorating" of disconnected and meaningless content for real life. That is, why the author, referring to the methodology of the learning workshops, affirms that the integration of knowledge is done through transdisciplinarity and that this should be the form of content approach in school, intertwined by the proposed challenge.

Living and non-alienated experience activate the development of creativity, an important complementary aspect to problem-solving [5]. According to the author, creativity is the process by which something original is produced and that is also valid. It is creative who is an expert, who practices self-regulation and exercises the intrinsic motivation to reach his goals. "[...] Take advantage of what they know and diverge from knowledge to create innovative methods and products" [5].

For Rigon [24], education serves to assist in the process of changing a society, to develop potentialities. Therefore, it is not linear. It can be said, therefore, that education, in the methodological vision of Sesi/PR School, also depends on the development of the creative process, which facilitates the use of previous experiences, mobilizes strategic planning, and promotes innovative solutions. Creativity, therefore, is one of the guiding principles of problem-solving. Perhaps, it would be bold to say that it is developed by and moves the cycle proposed by Sternberg [5].

4. Conclusion

Learning arises from the need for our genes to make predictions in unpredictable environments so they can survive in today's society. And that is why learning requires a motive and situations that involve its development. Autonomy and responsibility in learning demand experiment and experience of conflicts, challenges, and goals to be achieved that do not have to wait for the adult stage to be exercised. The more time we spend to develop problem-solving strategies, the more effective experts we will be to exercise the knowledge and skills most effectively acquired.

Problem-solving work in school can potentiate this development, especially in adolescence, as it becomes a challenge that drives the learner's motivational and neural capacity to learn. The phase of adolescence encompasses physiological and psychological changes that are directly influenced by the environment. The need to take greater risks to satiate the search for pleasure and reward can be positively influenced by the practice and experience of metacognitive activities strongly associated with the development of self-regulatory skills, helping in the decline of negative risk and potentiating subsidies for the development of cognitive mechanisms.

Therefore, here are recommendations that can guide research and practice at enhancing adolescents' learning experiences:

1. School's curriculum: for most countries, schools have to follow an established curriculum with compulsory contents and subjects. How to make learning meaningful if the school has to make students study the curriculum in order to

conclude basic education? Organizing it into learning aims and skills students need to achieve by the end of the school year is the first step to create a more meaningful curriculum. Most documents point out only isolated contents which do not explain why it would be useful to learn them. By having learning aims and skills as its main pillars, the pedagogical team can then organize clusters according to areas of interest (environment, citizenship, technology, etc.), and not fragmented subjects. These clusters will be the background for proposing themes that will raise students' interest toward learning.

2. Methodology: the school is an extension of the adolescent's life. Therefore, it should promote different experiences to help them learn how to think of alternatives, solve situations, collaborate, know how to deal with frustration, learn how to search for answers, become proactive, exercise creativity, develop socioemotional skills, and use risk taking to contribute to a more productive environment. A problem-solving methodology is an appropriate approach as it influences students to act in order to learn. It touches their willingness to "survive." For this reason, (a) the curriculum organized by aims and clusters will help teachers to set big questions as challenges. Students will achieve the learning aims by seeking solutions for the challenge. (b) Protagonism: they should be able to choose what challenge to work on. This will give them power to work on what interests them and have more responsibility toward what they choose and what they need to learn is not imposed. (c) Infrastructure: spaces in the school should be tools to influence experiences. Furniture in the classroom should be planned in a way to make students work in teams, collaborate, use materials to help them work on the challenge, debate, search, etc. (d) Regulation of learning: students need to be assessed using the learning aims from the curriculum and in different perspectives. They should also be challenged to self-evaluate themselves in order to perceive progress and gaps they should work on. Technology can be a great ally to teachers in order to personalize what each student needs to focus more on. Simple questions at the end of the lesson, or making the learning aims available at the beginning of the term, or teaching study techniques can help students perceive their own learning and become more effective in focusing on overcoming their difficulties or improving their strengths. More research on possible methods regarding the student-centered field could be run in order to find more alternatives to enhance adolescents' self-regulation skills.

3. Teacher's role: for a student-centered methodology, teachers need to work as facilitators. They need to learn strategies to activate students' willingness to "survive" and, therefore, learn more and better. This will develop their autonomy to seek for answers, to collaborate more and to learn from their mistakes. Teachers are no longer information owners (which can be found anywhere with the spread of the Internet): their job is much more complex than that. Their job is to teach strategies to help students become more self-regulated. Therefore, it is of great importance to work on research that tests different strategies by the teachers in the classroom and identify which ones can be effective for adolescents.

4. School's role: the school's environment is also a focus when self-regulated learning is the goal. It should engage adolescents in activities in which they can either suggest or show contributions of their own. Social work, sports, students' council, students' school band, and book club are some examples of engaging activities that could help students practice their responsibility and

autonomy. Parents' activities, such as parents' school with workshops and lectures on how to potentiate adolescents' protagonism, can also be an important tool to help families work with them outside school.

The present study had the intention to analyze the methodology of Sesi/PR School from the point of view of solving Sternberg's problems [5] in cognitive psychology and learning self-regulation. The brief analysis showed important comparisons and convergences, a relationship between the theory, and an education proposal that shows the concern to develop more autonomous and responsible adolescents through the resolution of problems, promoting greater meaning for effective learning. More deep research on analyzing specific strategies from this article toward enhancing adolescents' independent learning is recommended to be conducted in order to both raise the importance of a self-centered approach in the classroom and guide teacher training with the most effective tools.

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Chapter 5

Drawings as Diagnostic Cues for Metacomprehension Judgment

Keith Thiede, Katherine L. Wright, Sara Hagenah and Julianne Wenner

Abstract

The accuracy of comprehension monitoring affects the effectiveness of rereading, which in turn affects comprehension. Thus, much research has focused on finding ways to improve monitoring accuracy. The cue-utilization framework of metacognitive monitoring provides a framework for understanding how to improve monitoring accuracy. It suggests that accuracy is driven by cues people use to judge comprehension. When people utilize cues that are highly diagnostic of performance on a test of comprehension, accuracy should improve. Many interventions that have been shown to improve monitoring accuracy have attributed the improved accuracy to increased access to highly diagnostic cues, but have failed to identify highly diagnostic cues. In our recent research, we found that instructing students to generate drawings before judging comprehension improved monitoring accuracy. Using graphic analyses protocol, we identified highly diagnostic cues. In this chapter, we will describe the procedure we used to identify these cues contained in drawings.

Keywords: metacomprehension accuracy, drawing, cue diagnosticity, cue utilization

1. Introduction

In their seminal work, Nelson and Narens [1] described the theoretical relation between metacognitive monitoring and regulation of behavior. Building on this work, contemporary models of self-regulated learning describe learning as the interaction between metacognitive monitoring and regulation of study [2–6]. In particular, according to these models, as people study, they monitor their learning and use this information to guide subsequent study. Thus, accurate monitoring is required to effectively and efficiently manage one's study [7, 8]. If people do not accurately differentiate well-learned materials from less-learned materials, they could waste time studying material that is already well learned or worse fail to restudy material that has not yet been adequately learned. Given the important role that monitoring plays in learning, it is important to find ways to improve the accuracy of metacognitive monitoring.

Accurate metacognitive monitoring is especially important in the area of reading [7]. A number of interventions have been developed to improve the accuracy of comprehension monitoring (called metacomprehension accuracy [9]). However, only recently have researchers examined the effect of drawing on metacomprehension accuracy. The primary objective of this chapter is to present data that provide a potential explanation for the beneficial effect of drawing on metacomprehension accuracy.

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To provide context for our study, we will first describe how metacomprehension has been measured. We will then present a theoretical framework that identifies key factors for improving monitoring accuracy and show how this framework can help explain why previous interventions have improved metacomprehension accuracy. Finally, we will present empirical evidence that suggests drawing improves metacomprehension accuracy by providing access to cues that are diagnostic of comprehension and facilitating the utilization of these cues when judging comprehension.

2. Measuring metacomprehension accuracy

Glenberg and Epstein [9] developed the now widely used procedure for studying metacomprehension accuracy. They had participants read a series of short texts, judge their understanding on each text, and then completed a test for each text.

Metacomprehension accuracy describes the relation between a person's judgments of comprehension and actual test performance. Accuracy can be described in two distinct ways. One is the degree to which the magnitude of the judgments is related to the actual magnitude of test performance. This kind of accuracy has been called *absolute accuracy* (also called calibration). Absolute accuracy indicates the degree to which a person is over or under confident about his or her performance. The other measure of accuracy is the degree to which the judgments discriminate between different levels of performance across texts. This kind of accuracy has been called *relative accuracy* (also called resolution), is reported as the intra-individual correlation between predicted and actual performance computed across texts. Relative accuracy indicates the degree to which a person can differentiate better-learned materials from lesser-learned materials.

These measures are theoretically orthogonal [10]. That is, while absolute and relative accuracy could both be high for a person, absolute accuracy could be high while relative accuracy is low or vice versa. Moreover, variables that influence one kind of accuracy may not influence the other. For example, domain knowledge has been shown to influence absolute accuracy, but does not influence relative accuracy [11]. Thus, to avoid confusion, it is important to be clear whether one is examining absolute or relative accuracy. We will focus on relative accuracy for the remainder of this chapter.

3. A framework for improving metacomprehension accuracy

Understanding approaches to improving metacomprehension accuracy requires theories of both metacognitive monitoring and comprehension [12]. Rawson et al. [13] used the cue-utilization framework of metacognitive monitoring [14] and the construction-integration model of comprehension [15] to identify ways to improve metacomprehension accuracy. The cue-utilization framework suggests that people's metacognitive judgments are not based on direct access to memory and comprehension processes; instead, judgments are based on cues people have available about the content of their memory and comprehension processes. The accuracy of metacomprehension judgments is then determined by the degree to which the cues used to judge comprehension are diagnostic (predictive) of performance on a test of comprehension.

Theories of comprehension, like the construction-integration model [15], help identify the cues that should be diagnostic of performance on tests of comprehension. According to this model, readers construct meaning from text at several levels: a lexical or surface level, a textbase level, and a situation model level. The lexical

Standard Procedure	Retrieval-Based Approaches	Encoding-Based Approaches
Read Text 1 Read Text 2 ... Read Text N	Read Text 1 Read Text 2 ... Read Text N	Read Text ***with Encoding*** Task 1 Read Text ***with Encoding*** Task 2 ... Read Text ***with Encoding*** Task N
	Retrieval Task Text 1 ***Retrieval Task*** Text 2 ... ***Retrieval Task*** Text N	
Judge Text 1 Judge Text 2 ... Judge Text N	Judge Text 1 Judge Text 2 ... Judge Text N	Judge Task 1 Judge Task 2 ... Judge Task N
Test Text 1 Test Text 2 ... Test Text N	Test Text 1 Test Text 2 ... Test Text N	Test Task 1 Test Task 2 ... Test Task N

Note. Retrieval tasks include generating summaries or list of keywords, or completing informational diagrams. Encoding tasks include generating concept maps, self-explanation, or drawings.

Figure 1.
Approaches to improving metacomprehension accuracy.

level is constructed as the words and phrases appearing in the text are encoded. The textbase level is constructed as segments of the surface text are parsed into propositions, and as links between text propositions are formed based on argument overlap and other text-explicit factors. Deeper understanding of the text is constructed at the level of the situation model, which involves connecting information from the text with the person's prior knowledge and using it to generate inferences and implications from the text. A person's situation model largely determines performance on tests of comprehension [16]. Thus, getting people to base their metacomprehension judgments on cues related to their situation model rather than their textbase should increase the predictive accuracy of judgments [13, 17].

As noted by Thiede and de Bruin [18], interventions designed to improve metacomprehension accuracy have attempted to focus readers on cues related to the situation model when judging comprehension. Some have sought to increase the salience of diagnostic cues by instructing readers to encode texts in specific ways that facilitate construction of the situation model, while others have sought to increase the salience of diagnostic cues by instructing readers to retrieve information about the texts prior to judging comprehension. The different approaches are to improving metacomprehension accuracy alter the standard experimental procedure developed by Glenberg and Epstein [9], these changes are illustrated in **Figure 1**.

4. Encoding-based approaches to improving metacomprehension

One approach shown to improve metacomprehension accuracy is to provide instructions for reading texts that promote construction of the situation model—connecting ideas in a text to one another and to one's prior knowledge. By promoting construction of the situation model during reading, cues associated with the situation model presumably become more salient at the time of judging comprehension. Given these cues should be predictive of test performance, using these cues for judgments should increase metacomprehension accuracy.

In the metacomprehension literature, two studies have examined how metacomprehension accuracy is affected by promoting construction of the situation model while reading. Specifically, Redford et al. [19] examined the effect of concept mapping on metacomprehension accuracy. A concept map is a graphic representation of the underlying structure of the meaning of a text. Constructing concept maps can be an effective organizational strategy, which helps readers connect ideas in a text [20]. Thus, as concept mapping helps readers construct a situation model for a text, Redford et al. [19] hypothesized that generating concept maps would increase metacomprehension accuracy. In accord with this hypothesis, they showed that metacomprehension accuracy was greater for a group who generated concept maps than for a group presented concept maps during reading and a control group. Concept mapping has also been shown to improve metacomprehension accuracy for at-risk readers [21].

Another technique used to promote construction of the situation model is to have readers self-explain while reading. Chi [22] showed that self-explanation improved reading comprehension by helping them connect ideas into a more coherent representation of a text. Griffin et al. [23] hypothesized that self-explaining would help students connect ideas within a text and would focus students on cues related to the situation model when judging comprehension, thereby improving their metacomprehension accuracy. Consistent with this hypothesis, Griffin and colleagues showed accuracy was greater for a group of college students who self-explained as they read than for a group who did not self-explain while reading.

In sum, interventions that promote construction of a situation model for a text during reading improve metacomprehension accuracy. These interventions appear to focus readers on diagnostic cues for judging comprehension. The literature suggests the effects on metacomprehension are robust; interventions that promote development of a situation model have improved accuracy for typical, at-risk college students, and younger students.

5. Retrieval-based approaches to improving metacomprehension

Another approach to improving metacomprehension accuracy is to incorporate a retrieval attempt prior to judging comprehension into the standard procedure [24]. According to the cue-utilization framework of metacognitive monitoring [14], as the person contemplates how well a text was understood, he or she may rely on a variety of cues to make this judgment. Retrieving information about texts may allow a reader to evaluate the quality of cues used to retrieve information about a text. That is, when judging comprehension, the person may reflect on how successfully he or she had retrieved information. Accordingly, a text may receive a high rating of comprehension if the person had been able to retrieve a great deal of information about the text during the retrieval attempt. By contrast, a text may receive a low rating of comprehension if the person struggled to retrieve information about the text. Assuming availability of information during the retrieval attempt is related to availability of information at the time of the test, then using the retrieval of information as a basis for metacomprehension judgments should improve metacomprehension accuracy because the basis of the judgments should be highly related to test performance.

Accuracy of metacomprehension judgments may be affected by the timing of the retrieval attempt. Activation theories [25] may help explain why. According to these theories, spreading activation occurs during reading and more information is active in working memory shortly after reading than after a delay—when information has decayed from memory. When retrieving information immediately after reading, a person may have access to a highly active mental network. This is, even for less-understood texts, the person may have access to information in short-term memory. Thus, the retrieval attempt for less-understood and more-understood texts may produce a set of homogeneous cues for judging comprehension that may not help discriminate less-understood texts from more-understood texts. By contrast, when the retrieval attempt occurs after a delay, activation of the mental network for a text may have decayed and a person may have access to only that information retrievable from long-term memory. Thus, for a less-understood text, the person may have little to draw on when retrieving information; whereas, for a more-understood text, the person may retrieve much more information. Retrieving information after a delay may produce a set of heterogeneous cues for judging comprehension that may highlight differences between more-understood texts and less-understood texts. Moreover, cues available in long-term memory are likely to be highly indicative of test performance because both cues attempts and tests occur after a delay and are based on retrieval of information from long-term memory. Thus, retrieval after a delay may produce higher levels of metacomprehension accuracy.

Researchers have examined the effect of different retrieval tasks on metacomprehension accuracy. For instance, Thiede and Anderson evaluated the effect of writing summaries on metacomprehension accuracy [26]. They compared metacomprehension accuracy across three groups: a control group, an immediate-summary group, and a delayed-summary group. The control group read a set of texts, judged comprehension of each text, and then completed a test of each text. The immediate-summary group read a text then immediately wrote a summary for the text. After reading and summarizing each text, they made metacomprehension judgments and completed a test for each text. The delay-summary group read all the texts, they then wrote summaries for each text. After reading and summarizing all the texts, they made metacomprehension judgments and completed a test for each text. Consistent with the theory outlined above, metacomprehension accuracy was greater for the delayed-summary group than for the other groups. This effect holds for typical and at-risk college students [27].

Thiede and colleagues evaluated the efficacy of a less time consuming retrieval task on metacomprehension accuracy [28]. They had students generate a list of five keywords that captured the essence of each text. Metacomprehension accuracy was greater for the delayed-keyword group than for the immediate-keyword group or the control group. The delayed-keyword effect has been replicated with college students [29, 30] and younger students [31, 32].

van Loon et al. [33] evaluated the effect of completing an informational diagram of cause-and-effect relations on metacomprehension accuracy. Students read short texts describing cause-and-effect relations. Then they were shown a diagram of the cause-and-effect relation described in a text with key information deleted from the diagram. Participants in diagramming groups were instructed to provide the missing information. Metacomprehension accuracy was greater for the group that completed diagrams after a delay than for the group that completed diagrams immediately after reading or for the group that did not complete diagrams.

In sum, retrieving information about texts prior to judging comprehension improves metacomprehension accuracy; however, only when the retrieval attempt is delayed. A variety of retrieval tasks have been shown to improve metacomprehension accuracy. The literature suggests the effects on metacomprehension are robust; retrieval tasks have improved accuracy for typical and at-risk college students, as well as for younger students.

6. Drawing to improve metacomprehension accuracy

Theoretically, drawing has promise as an intervention to improve metacomprehension because it has been shown to facilitate construction of the situation model. Although the results examining the effect of drawing on learning are mixed, with some studies showing drawing improves learning [34] and others showing no benefit to drawing [35]. The results fairly consistently show that drawing improves conceptual understanding but not factual learning [36]. Put differently, deep comprehension, which requires a complete mental model, benefits from drawing.

The generative theory of drawing construction [36] helps explain the benefit of drawing on conceptual understanding and comprehension. According to this theory, readers construct a verbal representation of written words and a visual representation when drawing. Constructing a mental model of the content involves (a) selecting key elements from the verbal and visual representations, (b) organizing the key elements and connecting them to prior knowledge, and (c) integrating the verbal and visual representations into a coherent mental model. Thus, a drawing generated while reading represents a reader's integrated verbal and visual representations, which may provide a more coherent representation of a phenomenon that a representation based purely on verbal information (e.g., a summary of a text).

A high quality drawing connects key elements and illustrates how the system as a whole functions. If a person can create a high quality drawing, he or she should be able to perform well on a test of deeper comprehension because the drawing and the test both depend on a coherent mental model. If a person cannot generate a high quality drawing, he or she should not be able to perform well on a test of deeper comprehension. Therefore, the quality of a drawing should be predictive of performance on a test of comprehension—and using drawings as a cue for judging comprehension should promote high levels of metacomprehension accuracy. Thus, drawing while reading has potential as an encoding-based approach to improving metacomprehension accuracy.

Drawings have also been shown to provide valuable feedback regarding level of understanding [37]. That is, drawings help students identify gaps in understand. Thus, drawing also has potential as a retrieval-based approach to improving metacomprehension accuracy.

Despite the theoretical appeal of using drawings to improve metacomprehension accuracy, only recently have researchers examined the effect of drawing on accuracy. In particular, drawing has been used as an encoding task [38, 39] and as a retrieval task [40]. The results of these studies are mixed; however, methodological differences make it difficult to compare the results across studies.

Drawing had no effect on metacomprehension accuracy in two studies [38, 40]. In these studies, rather than read a set of different texts and generate a drawing for each, participants read contiguous texts and generate a *single* drawing based on all the texts. Although generating a single drawing might help participants create a model for all the texts, generating a single drawing would not likely provide cues to help participants differentiate more-understood from less-understood texts. Without cues for individual texts to help differentiate texts, it is not surprising that drawing did not improve metacomprehension accuracy.

By contrast, Thiede et al. [39] had fifth grade students generate drawings for different science text while they read. Student then predicted their performance and completed a test for each text. This is the standard experimental procedure with the encoding-based approach to influence metacomprehension, as illustrated in **Figure 1**. A key finding of this study was that drawing dramatically improved metacomprehension accuracy when students received instruction on generating organizational drawing—drawings that connect ideas within a text to one another and to prior knowledge. By contrast, drawings had no effect on metacomprehension accuracy when students were not instructed to create organizational drawing. The current study builds on the study by Thiede et al.

6.1 Overview of study and study design

According to the cue-utilization framework, monitoring accuracy is dependent on cue diagnosticity (how predictive a cue is of test performance) and cue utilization (which cues a person uses for the metacognitive judgment). van Loon et al. [33] developed a procedure to decompose judgment accuracy into these two components. In particular, they examined the diagnosticity of a cue by computing the correlation between the cue and test performance across texts. Similarly, they examined cue utilization by computing the correlation between the cue and the metacomprehension judgment across the texts. As in Thiede et al. [39], we used an experimental design to examine the effect of drawing instruction on cue diagnosticity and cue utilization.

We evaluated the effect of two kinds of drawing instruction on cue diagnosticity and cue utilization. Ninety-two fifth grade students were randomly assigned to two instructional groups. Students in each group read five texts on different science topics and generated drawings as they read. They then predicted their performance, and completed a test for each text. The Organizational-Drawing group (n = 47) received instruction on generating organizational drawing of scientific texts, which emphasized including relational information in their drawing. The Representational-Drawing group (n = 45) received instruction on generating representational drawing, which emphasized including many elements in their drawings. As the organizational instructions were designed to promote connecting ideas in the text to each other and to prior knowledge, we hypothesized that this group would generate more diagnostic cues than would the group receiving representational instructions.

6.2 Potential cues for metacomprehension judgments

As noted above, theories of comprehension, like the construction integration model [15], define deeper comprehension as a representation of a text that includes connections of ideas contained in a text to each other and prior knowledge (the situation model). The metacomprehension literature suggests that metacomprehension accuracy improves when people base their metacomprehension judgments on cues related to their situation model. Moreover, studies of self-reported cue use provide evidence that accuracy is greater for people who report using cues related to the situation model (i.e., their ability to link ideas contained in a text) than for people who reported using other cues [21]. Thus, cues that provide information related to connecting ideas and use of prior knowledge should be highly diagnostic.

To examine cue diagnosticity and cue utilization of drawings, we refined the graphic analysis protocol (GAP), which had been used to score graphics contained in science textbooks [41, 42], to score student drawings of scientific texts. The GAP-drawing provides a more fine-grained measure of drawing quality than the overall measure of quality typically used in drawing literature [43]. The GAP-drawing provides scores on two broad dimensions: drawing content and drawing relations.

Drawing Content describes the composition and substance of drawings. For each text, we created a master list of the actions, elements, and big ideas described in a text. We then scored each drawing for the number of these attributes. We also scored drawings for the number of novel elements related to the topic but not explicitly described in the text and unrelated elements.

Drawing Relations describes the relations among the elements in the drawing. Based on the definition of systematicity for published graphics, the *systematicity* of drawings describes how well the drawing demonstrates that a reader has built a situation model of the system described in a text. *Systematicity* ranges from a score of 1 (low) indicates the drawing illustrated isolated units, not integrated into a larger system, 2 (medium) indicates the drawing has some aspects of the system, and 3 (high) indicates the drawing is a complete model of the system. *Semantic relations* describe how the text and drawing are related. Drawings earn a score of 0 when they are only vaguely related to the text context, 1 (representational) when drawings directly show what was described in the text, 2 (organizational) when drawings add coherence by putting the information within a greater scheme or system, and 3 (interpretational) when drawings that contain both representation and organizational elements, but extend this by showing how the elements are related. *Connections* describe whether drawings represent the information in the text and include information from the reader's background knowledge or prior learning. A drawing scored as 0 does not add information not present in the text; 1 provides additional examples of a topic described in the text; 2 indicates the drawing includes additional examples of a process or phenomena not explicitly described in the text; and 3 appropriately connects the information to a different field of scientific study. Captions and labels can identify the parts of a diagram, the steps in a process or both. We categorized the *captions* and/or labels on a scale of 0–4. A score of 0 indicates a lack of captions, a 1 indicates that captions only identify the target of the graphic, a 2 indicates the captions identify parts, a 3 indicates captions identify the steps in a system, and a 4 indicates that the captions identify both the parts and steps in a system. We hypothesized that drawing relations metrics would be more diagnostic than drawing content because these metrics capture features of a situation model.

For each text, students generated a drawing as they read. Students also made a metacomprehension judgment (i.e., they predicted their performance on a five-item test of comprehension) and completed an inference test of reading comprehension for each text. Drawings were scored using the GAP-drawing. Cue diagnosticity was operationalized as the intra-individual correlation between drawing metrics and test performance. Cue utilization was operationalized as the intra-individual correlation between drawing metrics and metacomprehension judgments. To illustrate these measures and how cue diagnosticity and cue utilization influence metacomprehension accuracy, consider the example shown in **Table 1**.

For the student below, the number of elements was fairly weakly correlated with test performance, which indicates this is not diagnostic of performance on the test of comprehension. The number of big ideas was more strongly correlated with test performance than was the number of elements, but the correlation is only moderate. By contrast, the connections are perfectly correlated with test performance—test performance was higher for texts with higher connections scores and lower for texts with lower connections scores. Connections are a highly diagnostic cue of comprehension. Regarding cue utilization, the number of elements is weakly and negatively correlated with metacomprehension judgments, the number of big ideas was moderately correlated with judgments, and connections was highly correlated with judgments. These correlations suggest that this student used connections as bases of metacomprehension judgments and relied less on the number of big ideas and the number of elements to judged comprehension.

Cue diagnosticity and cue utilization help explain the relative high level of metacomprehension accuracy for this student (metacomprehension accuracy = 0.78).

Text	Judgment	Performance	Number of elements	Number of big ideas	Connections
Text 1	5	4	12	5	3
Text 2	2	3	21	3	2
Text 3	4	3	18	1	1
Text 4	2	1	10	4	1
Text 5	1	0	16	2	0
Metacomprehension accuracy = 0.78					
	Cue diagnosticity		Cue utilization		
Number of elements	0.20		−0.11		
Number of big ideas	0.40		0.33		
Connections	1.00		0.75		

Table 1.
Sample data to illustrate cue diagnosticity and cue utilization.

For this student, connections were a highly diagnostic cue and the students used this cue for judging comprehension accuracy. Had this student relied heavily on the number of elements to judge comprehension, metacomprehension would have been reduced because the number of elements is not predictive of test performance.

6.3 Results of study

This chapter focuses on cue diagnosticity and cue utilization; however, it is important to note that metacomprehension accuracy was significantly greater for the Organizational-Drawing group (mean metacomprehension accuracy = 0.51) than for the Representational-Drawing group (mean metacomprehension accuracy = −0.03). Cue diagnosticity and cue utilization help explain the difference in accuracy across groups.

As shown in **Table 2**, several drawing metrics were predictive of performance on tests of comprehension for the Organizational-Drawing group. In particular, for this group, systematicity, semantic relations, connections and the number of big ideas were are significantly correlated with test performance. By contrast, for the Representational-Drawing group, none of the drawing metrics were predictive of comprehension test performance.

These results suggest that instruction on how to generate drawings significantly affects cue diagnosticity. That is, with instruction on how to generate organizational drawings, drawing metrics related to connecting ideas to one another and to prior knowledge are predictive of performance on a test of comprehension (see the rightmost column of **Table 2**). It is important to note that the cues identified as diagnostic for this group are those hypothesized to be predictive of comprehension by theories of comprehension. Without instruction on generating organizational drawings, drawings do not provide diagnostic cues. Thus, for this group, drawing does little to provide useful cues for judging comprehension.

To better understand how these cues might affect metacomprehension accuracy, we need to examine cue utilization. As shown in **Table 3**, for the Organizational-Drawing group, a variety of drawing metrics were correlated with metacomprehension judgments, which suggests students in this group utilized a number of different drawing metrics in making their judgments. Most importantly, this group utilized four of the cues that were highly diagnostic of performance on comprehension test

Drawing metrics	Representational	Organizational
Drawing content		
Number of actions	−0.15 (0.13)	0.13 (0.11)
Number of related elements	−0.01 (0.11)	0.18 (0.11)
Number of novel elements	−0.12 (0.12)	0.13 (0.13)
Number of unrelated elements	−0.15 (0.14)	−0.01 (0.14)
Number of big ideas	−0.14 (0.18)	0.42 (0.14)*
Drawing relations		
Systematicity	0.22 (0.23)	0.24 (0.11)*
Semantic relations	0.03 (0.15)	0.22 (0.11)*
Connections	−0.09 (0.16)	0.66 (0.18)*
Number of captions	−0.02 (0.13)	0.15 (0.12)

Note: the number in parentheses is the standard error of the mean.
**Indicates a correlation is significantly different than zero ($p < 0.05$).*

Table 2.
Cue diagnosticity for drawing metrics by group.

Drawing metrics	Representational	Organizational
Drawing content		
Number of actions	−0.16 (0.12)	0.24 (0.09)*
Number of related elements	0.14 (0.11)	0.07 (0.11)
Number of novel elements	0.40 (0.09)	0.10 (0.11)
Number of unrelated elements	0.07 (0.10)	−0.11 (0.13)
Number of big ideas	0.10 (0.13)	0.22 (0.10)*
Drawing relations		
Systematicity	0.21 (0.15)	0.27 (0.13)*
Semantic relations	0.16 (0.11)	0.24 (0.12)*
Connections	0.73 (0.17)*	0.60 (0.14)*
Number of captions	−0.02 (0.12)	0.07 (0.10)

Note: the number in parentheses is the standard error of the mean.
**Indicates a correlation is significantly different than zero ($p < 0.05$).*

Table 3.
Cue utilization for drawing metrics by group.

(i.e., systematicity, semantic relations, connections and the number of big ideas). By contrast, for the Representational-Drawing group, only connections were correlated with metacomprehension judgments. However, for this group, connections were not correlated with test performance; therefore, utilizing this cue would not contribute to a high level of judgment accuracy.

These results provide additional empirical evidence that metacomprehension accuracy is influenced by cue diagnosticity and cue utilization. Metacomprehension accuracy was greater for the Organizational-Drawing group than the Representational-Drawing group. Drawings provided diagnostic cues for the Organizational-Drawing group but not for the Representational-Drawing group. Moreover, diagnostic cues were utilized for metacomprehension judgments for the Organizational-Drawing group but not for the Representational-Drawing group.

7. Conclusions

Metacomprehension accuracy is important to reading comprehension because monitoring guides decisions about rereading [31, 44], which improves overall comprehension [32, 45]. Thus, it is important to find ways to improve metacomprehension accuracy.

The cue-utilization framework of metacognitive monitoring [14] suggests improving monitoring accuracy involves identifying cues that are highly diagnostic of test performance and then instructing people to use those cues when making judgments. Thus, as described above, researchers have employed a variety of techniques to help facilitate the construction of a situation model or access the situation model prior to judging comprehension because this arguably provides cues that are highly diagnostic of comprehension tests. Researchers have also employed other techniques to promote use of diagnostic cues when making metacomprehension judgments [18].

Recent research using drawings as an encoding task shows promise in improving metacomprehension accuracy. This research shows that drawings need to emphasize the underlying organization of the phenomenon described in the text to improve metacomprehension accuracy, which is consistent with research showing the effect of graphics on metacomprehension accuracy is determined by the nature of the graphics presented with texts [46–48]. Specifically, organizational graphics improved metacomprehension accuracy and other graphics have little or adverse effects on metacomprehension accuracy [47].

The GAP-drawing provides a scoring system to help identify specific attributes of drawings that could be diagnostic of comprehension and utilized as a basis for metacomprehension judgments. Our findings suggest that with instruction on generating organizational drawings while reading, metrics related to drawing relations are predictive of test performance (diagnostic). Moreover, the instruction promoted utilization of these cues when judging comprehension.

Instructions focused on generating organizational drawings improved metacomprehension accuracy and comprehension. Thus, drawing can influence learning. More research is needed to identify the most effective instruction for drawing. With attention to cue diagnosticity and cue utilization, this research could reshape the field of metacomprehension.

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Section 2

Intrinsic Metacognitive Enablers

Chapter 6

Self-Regulation in Early Years of Learning Mathematics: Grade R Observed Self-Efficacy Skills Shared and Aligned

Nosisi Nellie Feza

Abstract

Numeracy development of young learners has been proven to be innate. Research asserts how 6 months old infants were able to subitise group of quantities. The inner ability integrate itself with their curiosity as they develop further. Kammii also asserts that young children develop autonomy through their observations and curiosity of figuring out events. This indicates that, children have natural independent abilities for learning. However, schooling seems not to be able to maintain this. This chapter demonstrates through clinical interviews how this independent discovery occurs and such observations can be used to observe trends that inform Grade R/reception class numeracy instruction. Intellectual autonomy as presented by Piaget and Kammii is used to analyse students' data to elicit trends and themes that influence instruction to maintain self-regulation in their development. This chapter employs qualitative enquiry in getting insight to student's intuitions and how they contribute to independent learning.

Keywords: independent learning, numeracy, autonomy, self-efficacy, intuitions

1. Introduction

Independent learning is a powerful skill needed by all students across nations to achieve and reach educational levels that will address societal challenges and eradicate poverty. The fourth industrial revolution demands creative thinkers to make connection between technology and soft skills. This cannot be realised if students are highly dependent on educators for their own learning. However, many students do not possess these skills. The sad thing is that these skills are natural skills a child is born with as they try to venture their world. New born babies are explorers of their world in order to navigate it safely, know it and conquer it.

Literature suggests that active participation of children in their mathematics development lead to improved performance especially for children from low socio economic backgrounds [1, 2]. This active participation is promoted through games and resulted in increased number development of young children [1, 3, 4]. This chapter capitalises on these innate abilities and intuitions of children as bases for their independent learning and mathematics development. Young children have natural curiosity and elasticity to learn new ideas and explore new things.

This could be used for their benefit in developing their self-regulated skills towards learning. This chapter teases out these intuitions to inform instruction of young students that nurtures independent learning and self-regulation skills. This chapter aims to explore young children's mathematical intuitions before they enter formal schooling. This is achieved by conducting clinical interviews with 5–6 years old entering reception class for the first time. These intuitions are explored to inform research on possibilities of developing self-regulation of students while they are young and flexible to attain good habits, furthermore natural self-regulation can still be nurtured and sustained during the early years of education. This chapter responds to the following questions: (1) How do young children demonstrate their mathematical intuitions? (2) How are these intuitions aligned with curriculum specifically South African Curriculum for reception class? and (3) How do these intuitions mediate self-regulated learning?

2. Young children's mathematical intuition

Jung [5] and Kammii and DeClark [6] describe young children's mathematical intuitions as internal abilities possessed by young children. In discussing the origins of such abilities [5] employs Piaget's three kinds of knowledge: "physical; logico-mathematical and social" (p. 7) knowledge. The difference amongst these knowledge is derived from their sources and modes of structuring. Physical knowledge is knowledge of "objects in external reality." This knowledge can be observed, touched or felt using senses. This knowledge cannot develop without external influence or experience. On the other hand, logico-mathematical knowledge is formed internally through connections that are mentally made. For example, [5]'s story of a 6-year-old girl trying to understand the concept of Santa Claus. This girl started noticing some patterns about Santa Claus that made her ask some questions such as: "How come Santa Claus uses the same wrapping paper as we do?"; "How come Santa Claus has the same writing as Daddy?" (p. 45). Kammii's story of Santa Claus indicates that a young child believes all what her parents tells her. However, as she develops she begins to make connections in her brain. The girl in Kammii's story believe in Santa Claus/Father Christmas in South African language but one day he made some observations: (1) she observed that Santa Claus's writing on his presents is the same as her father, and (2) the way the presents are wrapped is the same as the way her mother wrap up presents at home. This pushed the girl to make connections that, she has never met Santa but Santa always knows what she wants. She therefore realized that there is no Santa as Santa is her father assisted by her mother in wrapping up the present. This indicates that the external or physical knowledge observed was then internalized by this child and became internal knowledge and connections were made and a logico-mathematical knowledge is formed.

Furthermore, [6–8] affirm that children demonstrate spontaneous quantitative recognition at a young age. This spontaneity is a natural ability that is identified as intuitions by researchers [9]. For example, at 6 months old children are able to discriminate small numbers [6]. Clements [7] suggest that this skill demonstrated by the children at this infant stage is subitizing. Hyde and Spelke [10] extend this discovery by suggesting that babies under 9 months own two systems of nonverbal numerical cognition: one that is retorting to small quantities of individual objects and the other to approximately larger quantities. These systems contribute to the development of counting skills [11]. In addition, [12] brings forth the spatial intuitions of children's crawling which allows them to navigate and understand space. The above literature clearly indicates children's mathematical intuitions that need one to tap on in developing them further and deeper. For this chapter the big question is on how does this intuition assist in developing independent learning of mathematics to young children? Kammii presents Piaget's concept of autonomy as a vehicle to mediate mathematics to young children capturing their intuitions and interests to nurture independent development.

3. Autonomy

The autonomy concept comes from Piaget's theory of construction of knowledge that originates from children's experiences of their world. The intuitions discussed above resonates well with the children's experiences. These experiences happen through senses physically. Kammii and DeClark [5] defines autonomy as being directed by yourself. In other words, being self-driven. In the case of mathematics learning the concept of autonomy will refer self-dependency and independent learning. There are two types of autonomy from the original theory: moral autonomy and intellectual autonomy.

3.1 Moral autonomy

Moral autonomy is an ability to choose between right and wrong without pleasing others taking own responsibility for doing the right thing without expecting any rewards [13]. This ability is one of the important characteristic needed for leadership and citizenry. Kammii and DeClark [5] advocate for nurturing of this ability to children at an early age to develop responsible, accountable, adults with integrity.

3.2 Intellectual autonomy

Intellectual autonomy is important for successful learning because it challenges the mind. Feza [13] describes intellectual autonomy as "the connection made by children within the physical world that leads them to question things they observe that do not connect" (p. 63). The curiosity demonstrated by children in knowing more and relationships made between patterns. For example, a young child when s/he gets a toy plays with it for a moment and start dismantling it until it is broken, once it is in pieces the child will try hard to rebuild the toy. This indicates that when the child was breaking the toy into pieces the purpose was not to destroy it but to figure out something about its composition. Therefore, after seeing all the components of it the child wants to be able to deconstruct it, but unfortunately cannot and they cry with frustration.

Another example of figuring out things come from [14] as a unique difference between animals and humans. A story of a crawling baby and a dog fetching a cloth stuck on the tree explain Vygotsky's meaning of this difference. In this story the baby and the dog are playing with a cloth amongst the two. A strong wind came and snatched the cloth and threw it on the branch of the tree. The dog started barking and jumping in attempt to reach the cloth the baby on the other hand sat and looked up. After sometime the baby crawled towards a stick lying on the ground. The baby took the stick and crawled back to the tree with it he tried to reach the cloth until on the third attempt the stick hooked the cloth and the cloth fell on the ground. This story again supports Kammii's example of Santa Claus. The baby observed the physical space and distance and realised that, nor matter how high the dog jumps, it's strides are small and the distance is longer. Therefore, the baby looked around for something that can cover the observable distance and found a stick.

The stories give account to children's intellectual autonomy that needs to be nurtured by educators as it arises. A number of opportunities come in classrooms but are ignored. This chapter advocates for nurturing of intellectual autonomy that is innate to young children to nurture self-efficacy, and independent learning.

4. Nurturing self-efficacy of young children

Self-efficacy means independence and self-driven individual. Feza [15] synthesized a number of strategies to nurture mathematics stimulation of young children form the literature on early childhood mathematics. These strategies align in allowing children to use their intuitions to guide learning and instruction, hence they nurture self-driven learning. The strategies are as follows:

4.1 Purposeful play for mathematics development

Play on its own draws on young children's interests, curiosity and intuitions leading to full voluntary participation. The power of play resonates with peer interaction, development of vocabulary through interaction, development of social skills through behaviour and development of team work attributes [16, 17]. Hence, in mathematics block building nurtures spatial relationships and problem solving. It is during this play an educator can tap through observation into children's interests with the aim of extending them for further development.

4.2 Scaffolding children's mathematics learning

Scaffolding is a concept that originates from Vygotsky's theory of social construction where scaffolding refers to the extension of the student's level of thinking [14]. Having observed the children playing or doing their own directed task the educator has to first identify the child's level of thinking through observations and engagement. Once the child's level is identified the educator can participate as a peer to assist the development of the next level of thinking. For example, a group of children were playing with pattern blocks sorting them. Their sorting rule was not clear whether it is by shape or colour since the same shapes share the same colour. The educator took a green block and asked the group to tell her where to place it. The group pointed her to the green triangles. That gave a hint to the educator of where the learners were. This also give the educator an opportunity to bring another block of a different colour and ask learners where to place it a colour that does not match others to start an intentional conversation [18].

4.3 Developing mathematics from children's activity

Cognitively guided instruction (CGI) designed by [9, 19, 20] encourage educators to allow students use their intuitive strategies. This approach has proven to have significant gains on young students' mathematics performance. These studies proved that students' intuitions when allowed to be employed in problem solving, self-esteem and mathematics confidence of students increases [9]. This lead to self-regulated behaviour in learning.

4.4 Encourage and provide manipulatives for exploration and inquiry

As indicated by [5] young children make more sense of the physical knowledge and therefore need physical manipulatives, and virtual manipulatives to explore and learn through the exploration. Jung [21] suggest that educators provide a variety of manipulatives and representations to extend and challenge children's thinking. Sigler and Ramani [3] also suggest use of non-examples to develop higher levels of thinking.

5. Research design

This chapter employs qualitative inquiry as it aims to provide insights on young leaners intuitions of mathematics in their free play. In order to achieve this aim interviews together with observations are used as exploring tools that will unravel these intuitions giving insights into learners mathematical thinking that exist before their formal schooling.

5.1 Participants

The chapter reports data from a three-year study that was funded by the National Research Foundation (NRF). The data reported was collected from 67 reception class students in five primary schools in the Eastern Cape. These schools are part of the funded project that provides professional development to educators of the 5–6 years old.

5.2 Ethics approval

Parental consent and learner ascent was negotiated and granted for all learners and educators participating in the project. However, for this study not all learners with consent from parents participated. In each school 15 students were selected across reception classes participating in the study. The selection was conducted by the students' educators prior beginning of the formal instruction in the beginning of the year. This chapter reports only on 67 students' data due to poor recording of the interviews and few learners who lost interest and left during interviews. In addition, an ethics approval for this study was also received from the authors' university. It is important to note that learners' comfort was important during data collection. Learners were allowed to leave the room when they needed to and also when they lose interest they were allowed to take a break and come back if they want to. Only few learners left before completing the interview in general less than 9.

5.3 Instruments

An interview protocol was developed on students' intuitions of mathematics. This protocol was accompanied by manipulatives to be used freely by students. The 20 minutes, interview protocol was piloted to six 5-year-old students in a primary school in Gauteng Province and revised after the analysis of the pilot data. The following **Figure 1** is a picture of manipulatives students were playing with during interviews.

It is important to note that the interview protocol allowed for questions guided by learners' play and activities. Students were left to play with the bottle tops for 3 minutes without interruption, then the interviewer asked to join in the game asking students to show her the correct way of playing. While playing, the interviewer probed about the interest of the student on the activity and if s/he will be willing to share it with others. After a while the interviewer does the pattern on **Figure 2** below and asks the student to play with her following her rules.

The interviewer gives the student a chance to develop his/her own pattern if possible. The same procedure continues with the shapes and pattern frames, except that for the shapes in **Figure 3** learners are asked to fill up the pattern frames.

Figure 1.
Counting manipulatives.

Figure 2.
Pattern demonstration.

Figure 3.
Shapes and pattern frames.

5.4 Data collection and analysis

This data was collected towards the end of January; this indicates that these students were not yet involved with their formal schooling some were from pre-schools and some from home, as January is the beginning of a new year in South Africa. Video cameras were used to observe students' actions and field notes were also taken to triangulate the two data sources. The collected data was then captured on an excel spreadsheet following the interview procedure and making notes of all the data captured. The field notes were neatly typed and annotated separately using [22] iterative process. The codes that came from the field notes and the spreadsheet were then triangulated. In engaging with these codes analytical memos were written. The analytical memos together with the codes were triangulated and revisited using raw data as evidence and themes started emerging. The biographic data was analysed using frequencies. A thematic report is used to present the findings.

6. Results

Some background data indicate that only 11 out of the 67 students reported that they did not attend pre-school or day-care before reception class. All these students come from the low socio economic background attending no fee schools.

The thematic report responds to the following questions of the study: (1) How do young children demonstrate their mathematical intuitions? (2) How are these intuitions aligned with curriculum specifically South African Curriculum for reception class? (3) How do these intuitions mediate self-regulated learning?

The two themes that emerged from the analysis give integrative response to the three questions of this chapter.

6.1 Free play stimulating mathematical concepts

6.1.1 Counting

Most students first reaction on manipulatives was to count them, whether they know how to count or not. All 67 learners were able to do **rote counting sequentially** to 50. This is observed as they count sometimes re-counting bottle tops they were able to proceed to 50 without accurately counting the objects. About 42 out of 67 were able **to count objects** accurately until 27. However, some of them could not respond to "how many" about 23 of the 42 learners, instead they used their fingers that became their immediate tools to respond to the question of "how many" when asked by the researcher, each finger representing a bottle top. Only 19 of these learners were able to respond to the **"how many"** question. An interesting observation from the group that could respond to "how many" is that their bottle tops are organised in **a particular structure** which makes it easy for them to do object counting and keeping track of their counting as shown in **Figure 4**.

On the other hand, those who only do object counting lack the structure although they are able to count the objects accurately in **Figure 5**.

Meaning their **eye co-ordination** is good and assists them in keeping track of the counted and uncounted bottle tops. All this counting **is learner directed** except the "how many" question that comes from the researcher. When the researcher demonstrated the pattern to the learners, learners could not follow. They all struggled and moved on with their own activities after trying.

Figure 4.
Students structured counting strategies.

Figure 5.
Students unstructured counting strategies.

6.2 Three dimensional emerging spatial intuitions

6.2.1 Building of shapes

Those who did not start by counting they made **geometrical structures** some of which were rectangular houses, yards in square shape and sleeping beds also in rectangle shapes. Most of their structures represented items at home or their homes and were more skewed toward three dimensional reasoning.

6.2.2 Sorting

Bringing similar colours together by grouping them happened naturally from these students. Even when students encountered shapes, their first reaction was **to sort** them **into colours** before any other activity they wish to do. With shapes the sorting was including similar shapes together in the sorting.

6.2.3 Tessellation

Tessellation of shapes became some of the students' activity and the amount of time spend on it was greater than other activities. This tessellation was **side by side** tessellation as shown in **Figure 6**.

The tessellation of shapes that emerged from learners created an assumption that they will be enjoy and be able to complete the frames using the shapes they were playing with.

6.2.4 Piling

When learners are given these pattern frames to play with below are their strategies. Some learners tried to fill up as shown in **Figure 7** but were challenged by the angles. Some learners piled up the shapes instead of filling up the frames.

Figure 6.
Students' tessellation structures.

Figure 7.
Students' piling of shapes.

7. Discussion

Generally, the findings show the importance of free play in providing educators an opportunity to get access to students' intuitions and interests. Secondly, it is important to observe children without interfering and be patient in order to gain entree to their way of thinking. For example, when the researcher observed that students were tessellating shapes, she made an assumption that they will enjoy filling the pattern frames, instead students piled the pattern blocks to indicate how the perceive space. This could allow the educator to understand that the two dimensional space is not the first practical encounter for young students. Building structures might have become natural for these students. This also challenges the curriculum that always introduces the two dimensional space to students first versus connecting with their experience of the three dimensional space.

Aligning students' intuitive activities with the curriculum guide educators in understanding that counting and its concepts are innate abilities that need to be nurtured from the student's point of view. The findings of this study highlight the counting concepts such as rote counting, object counting, cardinality as concepts that are already there and need nurturing with stimulating interesting activities and games. The only difference is the level of some learners versus curriculum expectations that are lower. DBE [23] in the curriculum assessment policy statement requires reception class learners to count from 1 to 10 meaningfully. On the other hand, the majority of these learners exceed 20 in counting objects. The question is, what does it mean to these learners when the teacher has to teach them to count from 1 to 10 the whole year while they came to this grade counting more than 20? How do these learners conceptualise the role of school? These findings speak to the research in early childhood mathematics stimulation. According to [3] the majority of these learners are on the progression level of one to one correspondence. Some about 20 are beyond this level at the cardinality level and counting on level. The role of the educator here is to extend these learners' developmental levels to ordering of numbers, composing and decomposing numbers, and the emphasis of the value of the number using objects and number line. However, the curriculum does not indicate so. Is South African mathematics curriculum of the reception class aimed at the level it is supposed to? Literature has indicated that educators who do not have high realistic expectations to their learners impede successful learning [24]. These findings challenge the role of curriculum itself in developing learning at this level.

These findings support the literature on young children's intuitions and intellectual autonomy. Students in this study are interested in counting and have abilities that can be advanced through scaffolding and teacher directed activities at some point mathematising their activities as literature indicates [3, 14]. Already, these students are self-driven their free play shows how they want to try new ideas and learn. In the shape activities it is clear that their experiences are limited, this points to the educator's role in exposing them to puzzles and more activities of similar nature. This chapter argues for nurturing of students' intuitions extending them into formal mathematics without discouraging student's curiosity and interests. In a nut shell this chapter calls for educators to allow student to reach "self-realisation" in their learning through the student's interests.

8. Conclusions

The findings of this chapter reveal that young students have mathematical intuitions regardless of their socio-economic status. These intuitions form a rich foundation for nurturing independent learning. Students also indicate interests in exploring geometrical ideas like building structures. In this study curriculum for these students is aimed at a lower level. This has influence on how students can lose interest in their learning as it undermines their abilities. This loss of interest is the main variable that takes away curiosity and eagerness to figure out new things and new experiences. The role of schooling becomes a disabling one than a developmental. Therefore, this chapter recommends curriculum that sets high expectations and teachers who respect and embrace students' interests for their development.

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Conflict of interest

The author declares no conflict of interest.

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Chapter 7

Generating Internal Motivation through Mobile Application Technology

K. Thomas Baby

Abstract

This paper is a practical account of the author's experimental analysis of using mobile application technology in the undergraduate ELT classes of Dhofar University, Salalah, Oman. In today's world, technology plays an indispensable role in human life. Integrating latest technological applications in the classrooms can be a challenging task for many teachers, but it is undoubtedly a powerful tool for enhancing the quality of education. This paper outlines how to generate internal motivation and enhance the cognitive skills of students through the innovative use of mobile/smart phones in the classroom. Nowadays, innovative use of mobile applications in the classroom is advocated by numerous educational experts. This shift in perspective is necessitated by the large-scale digitalization of education and educational resources. Consequently, this study explores how mobile devices can be used effectively for enhancing involvement and motivation of students in various learning activities to promote learner autonomy and peer learning opportunities within the classroom. This experiment eventually resulted in a visible rise in the motivational graph of the whole class as testified by students' performance in their tests. Finally, this paper also outlines how mobile learning can be integrated into a conventional university curriculum.

Keywords: ELT classrooms, motivation, teachers, learners, mobile applications

1. Introduction

Motivation is generally considered to be the primary moving force behind the success of any learning activity. It drives the learner to focus on his intended goal with single-minded devotion to achieve success in all his endeavors. Therefore, generating internal motivation in a learner is the primary task of a good teacher. Integrating mobile applications in the classrooms can enhance the motivation level of students because mobile devices have become an essential part of their everyday life. Consequently, an innovative teacher should think of integrating mobile applications in his curriculum resulting from a critical evaluation of his own current teaching practice. According to Ciampa [1], it is very important to understand critically the scope of technology-supported learning activities on aspects of motivation before implementing any learning programs.

The digitalization of education and educational resources is a direct outcome of the rapid technological development of our times. Therefore, mobile devices can be used effectively in the classroom not only to promote electronic skills but also to improve engagement and motivation in their learning activities. The choice of mobile/smart phones for enhancing the learning outcome in the classroom resulted from a subjective personal experience of this author. The subjective experience was from an undergraduate ELT class at Dhofar University in Oman. In grammar classes, this author's usual practice was to explain the rules of a given concept followed by the distribution of worksheets to test students' understanding of specific grammatical concepts. The explanation of concepts lasting up to a maximum of 15 min is usually done at the beginning of the class. During this time, it was noticed that many students were secretly engaged with their mobile phones under the pretext of listening to the teacher.

The above-mentioned episode of student's excessive involvement with their mobile devices is a clear instance of the lack of motivation for traditional learning activities on the part of the students. On deep reflection, the author realized that it was the mobile phone and its different applications that attracted and engaged students more than the verbal explanations from the teacher. Therefore, it was decided that the initial part of learning the grammatical concept will be done independently by the students through their mobile phones. The teacher would only be a facilitator in this task by moving around the groups to make sure that students are using their mobiles phones only for the task of learning the concept. If they fail to find out all aspects of the concept, it would be supplemented by the teacher during the last 5 min of the session. This strategy proved to be very successful as claimed by West [2]. He contended that student engagement and mastery of important concepts can be easily achieved if learning with mobile devices is carefully designed to create more collaborative and participatory learning experiences.

This innovative experiment was implemented in three different undergraduate classes simultaneously as it did not affect the traditional teaching and assessment system of the university. Eventually, it resulted in a visible rise in the motivational graph of the whole class as testified by students' performance in the subsequent grammar tests. The positive outcome of this experiment is corroborated by various studies on employing mobile phones as an effective tool for education. According to Looi et al. [3], the highly personalized nature of mobile phone provides an excellent platform for promoting learner autonomy and peer learning opportunities marked by flexibility, collaboration and active participation. This initial experiment in the class resulted in an increased student involvement in the learning process leading to better interaction between individual students. This paper is also a practical account of how mobile applications can be integrated into classroom teaching without affecting the traditional syllabus and schedule of a conventional university curriculum. More specifically, it is an account of how the innovative use of mobile application technology in the regulated environment of a traditional ELT classroom can generate internal motivation in students.

2. Literature review

Numerous studies have been conducted on the effectiveness of mobile learning. Evidence on academic achievement is provided by researches from different parts of the world showing the effectiveness of mobile/smart phones as an educational tool. For example, some researchers like [4–7] focused their attention on the improvement in learning outcome. On the other hand, many others such as [5, 8–11] provided differing information on the impact of mobile learning and its role in enhancing the motivation of students in their learning activities. However, many teachers and students agree that mobile devices can be considered to be a motivating factor for teaching and learning.

A number of case studies have been conducted in the area of mobile learning and motivation by different researchers. The findings of a case study by Ciampa [1] based on Malone and Lepper's taxonomy of intrinsic motivation have proved that learner motivation can be enhanced considerably through the application of mobile learning technology in classrooms. Ciampa [1] has undertaken this case study of sixth grade students who employed only digital devices for all their learning activities in the class to decipher the variation of motivation level and learning outcome achieved in mobile learning. In addition to its theoretical foundations, the study also explored the important practical aspects of motivation in technology-supported learning environments. Another study by Miller and Cuevas [12] also claims that the use of mobile devices is more effective than using paper-based approach in classroom learning and academic motivation. Their findings encourage the use of mobile devices due to their effect on motivation, which may offer an interactive classroom environment where students feel enthusiastic and eager to learn.

Many researchers have shown that teachers perceive enhanced motivation level in students when mobile learning technology is incorporated into their instructional strategies. For example, Navaridas et al. [11] recommended application of mobile learning activity in classrooms to enhance student motivation and achievement. Similarly Sung and Mayer [13] found that participants using mobile devices were more satisfied by their learning activities. Their enhanced performance indicators and motivational factors were also taken into account for recommending mobile application technology in classrooms.

2.1 Research methodology

Partial mobile learning was implemented in two undergraduate classes consisting of 29 and 32 students each. In the grammar classes, the usual practice was to explain initially the rules of the grammatical concept which would be followed by the supply of worksheets to test the students' understanding of the concept. The explanation of concepts lasting up to a maximum of 15 minutes is usually done at the beginning of the class. During this time, it was noticed that many students in Class A (29 students) were secretly engaged with their mobile phones under the pretext of listening to the teacher. More than 75% of them are boys in this class. In Class B (32 students), boys were only around 20%. In this female-dominated class, students were more motivated to learn as evident from the scores they achieved in the previous test before switching over to partial mobile learning. In both classes 15 minutes of initial explanation was shifted to mobile mode of learning. The students were allowed 10 minutes to learn the grammar topic independently through the free use of their mobile phones. The teacher would act only as a facilitator in this task by moving around the groups to make sure that students are using their mobiles phones only for the task of learning the concept. If they fail to find out all aspects of the concept, it would be supplemented by the teacher during the last 5 min of the session for the whole class after eliciting answers from the students. The socio-economic and cultural aspects of the learners are not taken into consideration in this study.

2.1.1 Results and discussion

In this mode of mobile learning around 15 min, it was noticed that student engagement and participation in the group activities were at a higher level leading to improved motivation especially in the male-dominated class as reflected in their higher test scores. Furthermore, in this class there was a considerable difference between tests 1 and 2. This result revealed that mobile learning technology is effective in enhancing the motivation level of low achievers. In class 2 where female students constituted around 80%, the difference between tests 1 and 2 was negligible. This result shows that if motivation level is high among students, the mobile learning application is not of much consequence. However, mobile learning application is very effective among low achievers for enhancing internal motivation as it promotes learner autonomy through peer learning opportunities.

This simple observational experiment is highly useful for a class of low achievers with poor motivational level. Since this study doesn't use any scientific parameters to measure the motivation level of students, it is only an experimental or observational analysis based on the personal experience of the author vindicated by test scores achieved by the students. To verify the result of this finding, a more scientific approach to the study is necessary. However, a number of studies in mobile learning application support the findings of this study. Since the focus of this study is on generating internal motivation, this paper dwells at length on the importance of motivation and its different aspects.

2.2 Generating internal motivation

Motivation is an indispensable part of any learning activity. It has an important role in modifying the behavior patterns of the learner, and it is the key to achieving success in second language acquisition. Generating internal motivation in the learner can be accomplished through different strategies supported by innovative educational technology. A mobile device has an ingenious technology that can perform multiple functions essential for our everyday life. Therefore, nowadays, innovative use of mobile applications in the classroom is gaining popularity as advocated by numerous educational experts. For example, Shuler [14] claims that cognitive process involved in mobile learning has witnessed unprecedented growth over the past decade. The universal availability of mobile phones and their easy adaptability for educational purposes have brought in revolutionary changes in the education sector. Presently, mobile learning technology has been employed effectively for generating internal motivation to achieve success in life.

According to Vanpatten and Benati [15], motivation may vary based on individual differences; however, the effect of motivation can be measured by the degree of 'wanting to learn' and consequently, the degree of the 'realization of that desire'. Motivation is basically an inner urge caused by certain external conditions or specific events happening in one's own life or the world around. Primarily, it is an innate desire to achieve certain specific goals through one's own effort. However, when there is motivation, the process or the effort expended for achieving the goal becomes in itself an object of happiness and satisfaction. Therefore, motivation has been regarded as an important element that brings success in a person's life. It is instrumental in providing a person with unfailing energy to move forward to achieve his/her goals. Therefore, generating internal motivation in learners can be considered to be the most important function of a teacher.

2.2.1 Different types of motivation

Motivation can be defined as internal and external factors that stimulate desire and energy in people to be continually interested and committed to a job, role or subject or to make an effort to attain a goal (businessdictionary.com). In other words, motivation results from the intensity of desire, the value of the reward and the expectations of happiness that the individual can get ultimately on achieving his goal. It is an internal state or condition that activates the mind in a specific direction. In other words, it is an ardent desire that energizes and directs goal-oriented behavior. Furthermore, the persistence of behavior is an essential component in achieving the desired goal. According to Huitt [16], motivation is involved in the performance of all learned behavior, and a learned behavior will not occur unless it is energized. Moreover, he believes that there are primary and secondary motivations based on individual differences influenced by perception, memory, cognitive development, emotion and personality.

Ellis [17] described two main types of motivation as internal and external motivation. According to him people are motivated by both external factors such as rewards, grades or the opinions of others and by internal ones such as personal interests, curiosity or experiencing an activity as personally satisfying or rewarding. When motivation is caused by internal factors, it is called intrinsic motivation. It is the type of motivation which appears from the inside of the individual because it is naturally satisfied with what one is doing. On the other hand, extrinsic motivation drives someone to an external reward such as money or grades. Extrinsic motivation appears from the outside, whereas intrinsic motivation arises from the inside of a person. Some classifications further talk about instrumental and integrative motivation. For example, students with instrumental motivation will study a subject for practical reasons, but students with integrative motivation will study a subject only to understand and know more about it in order to expand the horizons of their knowledge.

2.2.2 Intrinsic and extrinsic motivation

Intrinsic motivation for learning is generated mainly by three factors called the triple 'C' known as challenge, curiosity and control. When the learning process is neither too easy nor too difficult, it can offer challenge for the learner. The immediate feedback in mobile learning applications satisfies the challenge instantly leading to enhanced motivation of learners. This can result in seeking further challenges to prove their skill or ability with renewed vigor. Curiosity is the most direct intrinsic motivation for learning. It can be categorized into sensory curiosity and cognitive curiosity. According to Liu et al. [18], the interactive multimedia capabilities of mobile devices can easily stimulate an individual's sensory and cognitive curiosity. Finally, the freedom of choice over one's learning can offer an illusion of control. According to Malone and Lepper [19], it can significantly improve motivation level and academic performance by providing a sense of personal control over meaningful outcomes.

Extrinsic motivation for learning constituted of cooperation, competition and recognition. Cooperation can be defined as a group of individuals working together to attain a common goal. According to Johnson and Johnson [20], cooperation promotes effort exerted for the achievement of a common goal resulting in greater productivity. It will enhance motivation leading to higher quality of relationships among participants. Competition can enhance motivation because it involves competition against a standard of excellence and not in terms of two or more people working against each other with differing or opposing goals. Recognition means learners want their accomplishments being recognized and appreciated by others. The motivation level of learners will be enhanced when their achievements become visible to other people.

2.2.3 Mobile application technology and motivation

The idea of establishing digital classrooms was originally intended to promote and develop the electronic skills of the students and to prepare them for the practical world outside school. However, it served the higher purpose of generating motivation in new-generation learners because of their attraction to digital devices. According to Ferguson [21], digital devices are instrumental in improving students' engagement and motivation in their learning activities. Watfa and Audi [22] believe that digital devices will be an added impetus for active participation from all students during class hours. Consequently, it will maximize the learning outcome by the immediate real-time feedback offered for improving the performance of students.

Digital classrooms are essentially learner-centered because peer intervention is a salient feature of this learning activity. In addition to this, digital classrooms provide learners with various methods of accessing and structuring their knowledge through active interaction with other learners. Hence Grigoryan and Babayan [23] opined in a digital classroom the teacher is empowered and conditioned by the learners to enhance his competence to provide appropriate technological instruction to the students. As a result, mobile application technology in classroom offers a new paradigm of learning and not just a new tool or a method of teaching and learning [24]. An observational analysis of students' behavior patterns revealed that many undergraduate students enjoy using their smart phones most of the time. They are seen engaged with these devices secretly even during the lecture time.

2.3 An innovative experiment

The partial use of mobile application technology in the ELT classroom of Dhofar University was necessitated by the lack of student motivation noticed in an undergraduate class. The choice of mobile/smart phones for enhancing motivation in the ELT undergraduate class is based on a very personal experience of this author. In the grammar classes, the usual practice was to explain initially the rules of the grammatical concept. Consequently, it would be followed by supplying of worksheets to test the students' understanding of the concept. The explanation of concepts lasting up to a maximum of 15 min is usually done at the beginning of the class. During this time, it was noticed that many students were secretly engaged with their mobile phones under the pretext of listening to the teacher.

The above-mentioned episode is a clear instance of lack of motivation on the part of the students. On deep reflection, the author realized that it was the mobile phone and its different applications that attracted and engaged students more than the verbal explanations from the teacher. Therefore, it was decided that the initial part of teaching the grammatical concept would be substituted with learner autonomy. The students were allowed 10 min to learn the grammar topic independently through the free use of their mobile phones. The teacher would act only as a facilitator in this task by moving around the groups to make sure that students are using their mobiles phones only for the task of learning the concept. If they fail to find out all aspects of the concept, it would be supplemented by the teacher during the last 5 minutes of the session.

This experiment proved to be very effective in an undergraduate class consisting of 29 students. The specific task given in the class was about present perfect tense. Fifteen minutes each from two sessions were utilized for this experiment. Instead of explanations from the teacher, the rules of constructing present perfect sentences were elicited from the students who utilized their mobile phones for this learning activity. This simple but innovative learning activity supported by technology enhanced the motivation level of the students as reflected in their score of the subsequent grammar test. During this independent learning session, the engagement and participation of the students also testified their enhanced motivation. In terms of learning outcome, this experiment can be recommended because students scored higher mark in this test than their previous test taught in the traditional method.

The above episode is mentioned elaborately to vindicate that mobile application technology can enhance student motivation as new generation learners are naturally inclined toward the idea of using mobile/smart phone whenever possible. The higher score obtained in a rather difficult topic (present perfect tense) learned through the digital mode is a further indication that learners prefer mobile application technology rather than traditional mode of classroom lectures. Although many learners are ignorant of the theoretical implications of digital classrooms, most of them endorse the innovative use of the digital devices in classrooms. In short, the use of mobile devices in teaching learning activity will enhance the motivational level of students as shown in this experimental research.

2.3.1 Analysis of internal motivation

Most of the studies testify that mobile learning has a positive impact on their motivation. Many researchers find potential correlation between mobile devices and student motivation. The traditional mode of textbook learning is widely substituted by mobile learning nowadays because of its role in generating motivation in students. In a significant comparative study on the effect of mobile learning and textbook learning, researchers observed higher engagement, enthusiasm and motivation among mobile users than students who depended on textbook learning [5]. In addition, electronic learning with competitive elements led to an increase of motivation to outperform peers. According to Worm and Buch [25], competition incorporated into mobile learning may further increase motivation and engagement. Other research examined mobile learning's effects on intrinsic motivation. For example, [1] found that students achieve higher score when mobile learning application is incorporated into teaching learning activity.

3. Conclusion

In short, this simple observational study shows that mobile learning application technology can transform low achievers by enhancing their internal motivation. Since this study does not employ any scientific parameters to measure the motivation level of students, it is only an experimental or observational analysis based on the personal experience of the author vindicated by test scores achieved by the students. To verify the result of this finding, a more scientific approach to the study is necessary. However, a number of studies in mobile learning application support the findings of this study. Since the focus of this study is on generating internal motivation, this paper dwells at length on the importance of motivation and its different aspects.

The technological development of today brought about the widespread use of digital devices in classrooms. Moreover, the new-generation learners enjoy exploring various applications of technology not only in their day-to-day activities of life but also employing technology for their educational advancement. Doherty [26] shows the relevance and practical implications of digital classroom in contemporary life by declaring that digital classroom is a place where twenty-first century technology tools enhance communication and enable students to stay organized in their learning activities through collaborative and creative classroom experiences. He considers the classroom to be a training ground for the effective use of technology that will prepare them for twenty-first century life. In the words of Ferguson [21], digital classrooms coupled with the innovative use of technology will enhance the engagement and motivation of students in their learning activities.

Although a number of studies have found that no significant improvement in academic grades among students who employed mobile phones for their learning activities, almost all the studies have recommended the use of mobile devices in the classroom for the purpose of enhancing the motivation and engagement of students in their learning activities. Therefore, innovative use of mobile devices should be encouraged in the classroom for empowering students through regulated task-based instruction for optimum output. The application of mobile phone for learning activities in the class is significant in many ways because it is an effective method for motivating even disinterested students in their class. In short, controlled and regulated intervention of mobile devices for learning activities in the classroom can empower students and promote learner autonomy through such interactive and participatory learning experience.

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Chapter 8

Multilateral Relationship between Information Literacy, Self-Concept and Metacognitive Ability

Oluwole O. Durodolu and Joseph M. Ngoaketsi

Abstract

This study examined information literacy, metacognitive abilities and self-concept capabilities. The evaluation of this research indicated that self-concept is the totality of psychological, emotional, psychosomatic and mental development that provide confidence to individual in the ability to search, use, appraise and assess information resources, which are critical qualities needed to enable information literacy; an individual needs to be conscious and develop aptitude to identify useful information. Metacognitive ability is important because of the age of information overload which an individual is overwhelmed with which signified that information available is exceeding processing capacity of an average individual. Accordingly, once information overload ensues, it is possible that a decrease or decline in quality of decision-making will happen. In view of this, metacognitive ability becomes necessary in order to equip people with the critical ability to contemplate rigorously before action is taken. The objective of this research is to embark on content analysis of the subject matter of information literacy, metacognitive abilities and self-concept in which existing research was thoroughly evaluated in order to identify gap in research and bring out new knowledge. This research uses qualitative content analysis as a method of data collection in which existing journals and other information resources were evaluated. Research has been silenced on the triangular relationship of metacognitive ability, self-concept and information literacy, that is, the gap this research attempt to bridge.

Keywords: information literacy, self-concept, metacognitive ability, information overload, information access

1. Introduction and background to the study

The history of mankind access to information has never been easier than it is in this contemporary world, but easy access to information does not necessarily guarantee access to quality, genuine, reliable and truthful information. The Internet is an open platform where many people can ventilate and publicize their opinion, idea, impression and views, without necessarily going through peer review mechanism by expert in different fields of knowledge or the opinion be subjected to rational scrutiny, before accepting it ex cathedra. Regrettably, the inability to separate fake, counterfeit and forged information can be a major source of embarrassment. Wrong sources of information can lead to erroneous and costly decision to organizations and professional body. Therefore, to reduce and limit this predicament, it becomes imperative to acquire skill that will empower individual on how to identify trustworthy sources of information on the Internet especially by teachers whose roles and responsibility is to expand the frontiers of knowledge. In view of this, many scholars are of the opinion that metacognitive dexterity equips people with high level of thinking capable of boosting higher-order thinking [1]. In order not to fall into the error of using unreliable sources of information, it is worthwhile to source for information from accredited academic databases that has been endorsed and certified collectively by professional body; this ensures to establish quality control particularly within the academic community.

Metacognitive skill is the knowledgeable ability that empowers information seekers to pursue their information need with critical mind, evaluate information resources meticulously, make inferences and deduce evidence in the perspective of one's own information needs and, finally, make evaluative judgment about sourced information. A characteristic of this set of thinking is the awareness that information seekers have of their own thinking procedure, which is referred to as metacognitive knowledge, which is a vital piece of ability to resolve information literacy puzzle [1–3].

2. Objective

This article embarks on content and in-depth analysis of the subject matter of information literacy, metacognitive abilities and self-concept.

3. Purpose of the study

The purpose of this study is to evaluate the characteristic necessary to overcome the challenges of the contemporary period associated with information overload. Information literacy is a twenty-first tool to help in managing and circumnavigating the ocean of information. It can also be compared to an instrument or compass to help navigate the world of abundant information resources. The challenges of information overload are acknowledged as a source of anxiety for today's information seekers as they are frequently being overwhelmed by information from countless sources. Without the knowledge of metacognitive ability which is an aptitude to strengthen the ability to ratiocinate and make a reliable choice based on valued judgment anchored on the process of logical reasoning, metacognitive strategies are centred on organization, monitoring and appraisal which are qualities that can be applied in seeking, utilizing and communicating information. Information age requires self-confident and self-regulating learners fortified with lifelong learning skills. Independent learning ability and information literacy are fundamental expertise necessary not only for lifelong learning but also for attainment in the information-centred societies.

This chapter addresses scholars' views from different backgrounds on their perspectives on the information literacy skills and special abilities like self-concept and metacognitive ability. The chapter therefore reviews literature in the subject area of the evolution of information literacy, perceptions of information literacy and information search strategy; the chapter also identifies a significant correlation linking of self-concept and information literacy skills, investigates the level of self-concept and personal abilities and identifies a significant correlation between this abilities and information literacy skill acquisition for teaching purposes.

4. Methodology

This research is guided by interpretive research paradigm in which concepts are discussed to bring in-depth understanding. This research uses qualitative content analysis as a method of data collection in which previous recorded document were studied systematically; journal, conference papers, reliable online resources and policy document were carefully evaluated in relation to the subject matters of information literacy, self-concept and metacognitive abilities that were reviewed. This is done in order to identify gap in research and bring out new knowledge. The identified keyword above was used in search of information resources from manly web of science and EBSCOhost. The researcher left out other databases for this research because of easy accessibility to the selected database, namely, web of science and EBSCOhost, which the researcher has access to in the place of work. The synthesis in the review of literature was achieved by combining important keyword that forms the bedrock of this research, that is, metacognitive ability, self-concept and information literacy; these keywords were evaluated to bridge the knowledge gap and established a new knowledge.

There is paucity of research contribution in the area of metacognitive learning; therefore, it poses a great deal of challenge in getting sufficient research material to embarking on this research in relation to information literacy and self-concept. The purpose of this research is to also close the research gap, for instance, embarking on informetric evaluation of the available information resources using web of science

Timeline of publication used		**%**
Years	**Number**	
1979	1	1.82
1995	1	1.82
1998	2	3.63
2002	1	1.82
2003	2	3.63
2004	2	3.63
2005	3	5.45
2006	4	7.27
2007	2	3.63
2008	1	1.82
2009	6	10.91
2010	5	9.09
2011	5	9.09
2012	5	9.09
2013	8	14.55
2014	4	7.27
2015	2	3.63
2018	1	1.82

Table 1.
Timeline of publications.

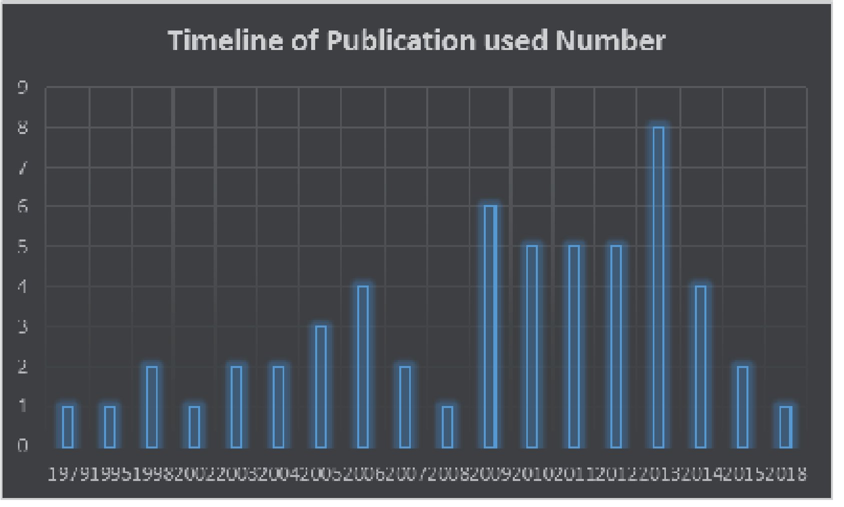

Figure 1.
Graphic representation of timeline of publication.

which is a database that has up-to-date and retrospective coverage from 1900 to the present, which includes 34,200 journals along with numerous books, proceedings, patents and data sets. The informetric result generated shows that within the span of 27 years (1992–2019), research output in metacognitive leaning is 395 (see **Table 1**) out of which research articles are 263 followed by conference proceeding with 138. Countries leading in these research areas are the United States (57), People's Republic of China (46) and England (24). Therefore, for the sake of this study, 55 research articles were selected starting from 1979 to 2018, and most of the selected articles were relatively recent (see the timeline in **Table 1** and **Figure 1**).

5. Perception of the need for information literacy skills

Technology, especially the Internet, has amplified the quantity of information accessible, but this also comes with challenges associated with seeking and using information resources [4, 5]. The author observed controversies among librarians and information professionals in some countries yearning for new literacy to enable access and use of information resources in many formats from an increasing information environment [5]. Access to overwhelming information resources has undermined the need for libraries across the globe to serve as gatekeepers between those who seek for information and information resources. This new revolution in information atmosphere and the skills that promote independent information seeking have stimulated the academic debate on teaching and learning information literacy [6]. It was affirmed that information seekers are dazed by the enormousness of information available to them from different sources. Taking decisive action to know when information accessible is adequate is a foremost reason for apprehension and doubt often experienced by information seekers [5].

Information can be seen as that which reduces doubt, uncertainty and ambiguity in decision-making [7]. The quality of information is critical for efficient operation and decision-making and important to modern society in carrying out daily productive activities. Thus, information need is described as a personal or collective aspiration to find and acquire information to fulfill a conscious or unconscious need. Information need occurs when an individual is faced with a dilemma in which knowledge acquired over a period of time is not adequate to help his/her objective. As a result, the need for information will trigger the curiosity to seek for it and thus satisfy the need [8].

Various other studies have discussed information need, for example [9–11]. In the opinion of the researcher, information needs or question formations can be viewed from four basic progressions, namely, visceral need (need as dictated by intuition or instinct), conscious need (the result of deliberate effort), formalized need (the product of human invention) and compromised need (need as expressed verbally) [9]. Various researches have also been carried out on the need for information, for instance, to embark on an evaluation of the changing need for information among professionals [12]. The study suggested that there is a need for curricular change in coping with current information need. A study analyses the information needs and pattern of information-seeking behaviour of professionals and observe that information is needed in order to obtain more knowledge. The authors also observe that professionals need to be familiar with and improve the availability of and accessibility to the Internet in the workplace for better job performance, supporting innovation and sustaining economic development [10]. There are stable and unstable information needs to explain the perpetual change in needs over a period of time and differentiate between a changing world, types of information need and interpretation of data [11].

An information literate person is proficient in determining the nature and scope of information needed to meet personal and professional requirements [13]. The present information background is rich and categorized by an abundance of information sources and providers, a multiplicity of methods for accessing information and a redundancy of content from numerous sources [14]. In this information-saturated environment, many information users tend to experience a sense of inadequacy and anxiety [15]. The prevailing difficulty is how to navigate this intricate landscape of information to enable satisfaction of information need.

The awareness of information overload symptoms and causes would help scholars in meeting and satisfying information needs, as the flood of potentially relevant information has become pervasive [16]. In an attempt to meet daily information needs, individuals are compelled to consider more information and opportunities than they can effectively process. This information overload is made worse by "data smog", which is a concept describing the proliferation of low-value information, which can also lead to anxiety, stress, alienation and potentially dangerous errors of judgment, which can adversely affect productivity [17].

One of the major consequences of meeting information need has been the exponential growth of the Internet and information and communication technologies, which is the prime reason for information overload, and the speed and complexity of developments in society. A study contends that people find it more complicated to handle the amount of new information they receive, regular changes in the organizations and technologies they use and the increasingly complex and unpredictable side effects of their actions [18].

The need for information is as important as blood in the human system, because without information, transformation will not be possible. Information is essential in all human endeavors for problem-solving. Information need triggers information search, the practice by which a person seeks knowledge about a difficult circumstance constituting a major impediment, which leads to seeking for information on the Internet by millions of users [19]. The web is now a primary source of information for many people, motivating a critical need to understand how users search or employ search engines [20]. Information need and information seeking are different but related concepts because both of them are components of information behaviour [21]. The adventure to seek for information begins with the need for information, and to meet that need, an individual must be aware of the various information sources available.

A body committed to promotion of educational development worldwide has also been keenly upholding the perception of knowledge societies in which information literacy plays a prime role in structuring comprehensive, pluralistic, just and participatory societies by enabling people to understand and make valued judgments as active users of information and become producers and distributors of information and knowledge in their own right [22]. It was also affirmed that information literacy enables citizens to make informed choices to meet the information needs which will help them achieve their full potential and it enables them to maintain their political, economic and social development [23].

There is a dire need for information literacy training of teachers; researchers [24, 25] affirmed that the need is particularly required in rural areas for students in training and working adults and could be addressed by considering the approach of ICT for development and the need for international standards and curricula for information literacy. This approach should be followed by action based on the prevailing circumstances of teachers, a wide and systematic review of supporting literature and encouraging critical inquiry.

It is evident from studies conducted by many researchers that there are teachers who have the right view of online education as they are aware of its usefulness to the education system. Although personal issues like time constraints, perceived usefulness, perceived ease of use and low enthusiasm are a relatively common phenomenon, awareness, capacity building and enabling environments should be provided to encourage the use of online information resources among teachers [26].

Examinations of teachers' competence in developing countries have revealed that they gain information literacy knowledge and ICT skills through personal efforts aided by families or friends to gain training outside the schools. The implication of this, in the view of scholars, is that much of the training provided by the schools for student teachers does not meet the need for them to integrate information literacy skills into their teaching. This underscores the need for more emphasis to be placed on exposing student teachers to advanced courses in information literacy skill and ICT knowledge [27]. Schools and indeed universities in the developing nations must improve on their information literacy skills and ICT technique in line with the UNESCO recommendation. Therefore, metacognitive ability and strategies can lead to positive information research experiences and, consequently, should be imparted during library instruction and orientation programme, to trigger metacognitive strategies [22].

6. Effects of metacognitive ability on information literacy

Metacognition can be defined as the ability to think about one's thinking process, which combines two components of knowledge and regulation about oneself in relation to factors that might affect performance, strategic knowledge and knowledge to be applied based on present challenges [28]. Metacognitive ability has been seen as having knowledge, understanding and control over mental activities and appropriate use of the acquired knowledge [29]. Metacognitive regulation is the monitoring of one's cognition and includes planning activities, awareness of comprehension and task performance and evaluation of the efficacy of monitoring processes and strategies [28]. Metacognition refers to sophisticated thinking which comes with dynamic mechanism over the intellectual methods engaged in learning.

According to a researcher, information literacy is a foremost metacognitive skill; i.e. information literacy skills are exactly the expertise people require to be able to take control of their own thinking and learning in order to find the best information for their needs. To be information literate demands self-awareness. This refers to an attentiveness towards and understanding of learning processes [30]. Learners who possess highly developed metacognitive skills are more likely to acquire information literacy skills as a precondition for modern learning [31]. It was also explained that metacognitive ability reinforces information literacy as a reiterative, holistic process where individuals continually assess their own ability to increase their information literacy [32].

John H. Flavell, the progenitor of metacognition, describes it as purposeful, planful, deliberate, goal-directed, future-oriented intellectual behaviour that can be directed at achieving cognitive tasks [33]. Metacognitive ability also refers to knowledge concerning cognitive ability and affective states and control over knowledge in order to achieve a specific goal. Such knowledge can be classified into declarative, procedural and conditional knowledge which are the overall qualities expected to advance knowledge acquisition [34]. Metacognitive experiences involve awareness of one's own cognitive ability and affective processes. These experiences are retrieved by actively monitoring one's own mental processes [34]. A metacognitive ability integrates, among other things, ability in time management, limits information searching to the most pertinent rather than the most available and considers conflicting viewpoints and emotional intelligence, which means that learning can involve complex moods of uncertainty, frustration and doubt [35].

Metacognitive strategies include a variety of simple processes such as underlining, outlining, notetaking, summarizing, self-questioning and more complicated methods such as hierarchical summaries, conceptual maps, thematic organizers and metaphorical thinking [36]. In investigating how to efficiently teach information literacy and reliability assessment skills in the use of online information atmosphere, in the context of students' dependence on the use of Internet resources. The lack of information in literacy skills can limit critical appraisal. It was therefore suggested that innovative instructive techniques are necessary for effective online information literacy skill and to integrate scaffolding and metacognitive support [37].

Metamemory refers to the ability of people to demonstrate the capacity to search the content of memories, either prospectively or retrospectively, out of which judgements or clarification are drawn. Metamemory is not memory per se, but depends on it [38]. Understanding memory reveals that memory can fall short of the expected need in two diverse ways: the first involves forgetting or being incapable of retaining information despite one's best efforts. The other involves "misremembering" or remembering something incorrectly [39].

According to a research, metacomprehension means the capability to examine the degree to which one understands information being communicated, to recognize the reason for failure to comprehend and to employ repair strategies when failures are identified [40]. It was observed that metacomprehension derives from two keywords: meta and comprehension. For example, metadata would mean that data is being analyzed about data. Comprehension means an ability to understand or show lack of understanding. Metacomprehension thus means an ability to be aware of or understand one's understands of a topic [41].

Self-regulation, colloquially known as willpower, refers to self-directed competence for altering behaviour. It helps to increase the flexibility and adaptability of human behaviour, helping people to adjust their actions to a remarkably broad range of social and situational demands [42]. Thinking about the importance of self-regulation can help individuals to become objective and to understand in responding to behaviour.

Understanding the impact of temperament and considering goodness of fit can assist teachers in selecting strategies that support the development of self-regulation [43].

6.1 Personal knowledge

Personal knowledge refers to knowledge applied in the profession which has been accumulated and proved over time to possess permanent value, worldwide application and universal truth. It is acquired mainly through formal and informal training [44]. The process of gaining knowledge is a method essential to survival which begins early and continues all through life. Metacognitive knowledge involves consciousness and manifestation of the content of an individual's thought, ranging from simple awareness of the content of one's immediate and prior thought [45].

The importance of knowledge cannot be over-emphasized in any profession, especially in the area of classroom management techniques. Knowledge is a set of skills and information obtained through experience and/or education, giving someone the ability to perform well in a specific field or ability [46]. Personal knowledge can be translated into a progressive classroom environment capable of boosting the intellectual ability of students and fostering intelligent behaviour for problem-solving purposes, decision-making and creative thinking. Figuratively, the intelligence friendly classroom serves as a caring companion and mindful guide to the intellect of each and every learner in it [47].

6.2 Task and procedural knowledge

In the opinion of researchers, people constantly become skilled because of the knowledge acquired from years of experience, but since personal experience is always insufficient, people tap from the experiences of relatives, friends and colleagues in an attempt to enlarge their knowledge or solve problems [48].

Procedural knowledge is the knowledge that is demonstrated through the procedure of doing it. It shows how people understand things and how the mind works to gain, recall and use the knowledge. This is often unconscious knowledge: though someone may demonstrate it, it can be something otherwise not considered by the person. For example, a teacher may know when to apply a particular technique in the classroom but may not be able to precisely explain this to his colleagues. In other words, it can be considered a trade secret that makes one individual distinct from others [49].

6.3 Strategic and declarative knowledge

Declarative knowledge is known as the ability to recall stored or acquired information. This procedure entails three stages of learning declarative knowledge: first, establishing a link between new information and an existing body of knowledge, which means learning how to remember new information; second, categorizing information by putting new information into groups, placing it into different parts of the memory; and third, elaborating information by making connections among the information being received as well as connecting new information to existing knowledge [50].

Learning strategies are devices used by learners to aid acquisition of knowledge and skills. Instruction should guide the learner in the choice of appropriate learning strategies for particular learning tasks. Facilitating the learning of declarative knowledge, concepts, procedures, principles, problem-solving, cognitive attitudes and psychomotor skills begins with decisions on what content should be presented, how it should be presented and in what sequence the instruction should follow [51].

6.4 Conditional knowledge

It has been claimed that the ability to decide when and why a particular approach is necessary for the purpose of problem-solving is conditional knowledge. A teacher can do a wonderful job in passing knowledge across to students but may find it difficult to teach them how to weigh up options available to them and make informed decisions about when to employ this skill [51].

7. Effects of self-concept in information literacy skills

Many researchers have pointed to the fact that personal abilities can no longer be overlooked when investigating information literacy skill. For instance [52–54], postulate that personal abilities are vital in scrutinizing the connection between information literacy and the self-concept which is the bedrock of personal ability and academic attainment. Such scrutiny is necessary in order to salvage those who may be victims of self-destructive beliefs which may also be damaging to students [55].

The most important attribute of modern societies is that everything is in a perpetual state of flux. At the same time, the quantity of information is now overwhelming, and technology has become relevant to every aspect of human life. There is hardly any professional calling today which has not felt the positive influence of this change. It is therefore almost mandatory for all who wish to be relevant in any career to embrace this new technique. Societies of the information age must be confident in the application of modern technology to be able to access information to foster independent, self-regulated learners equipped for lifelong learning. The manpower needed by today's societies can be described as effective consumers of information who can find, evaluate, use, produce and share information and make use of technology in all these activities [56].

Satisfactory self-perception of scholarly capability is fundamental for the recognition of intellectual ability, thereby promoting learning of complex skills like information-seeking skills. It was also suggested that academic self-concept should moderate the connection between intelligence and information literacy: a constructive relationship between intelligence and information literacy is expected for an academic self-concept. Thus, it is accepted that this moderator effect is mediated by personal effort. Whenever people are able to distinguish between personal deficits or strengths, they will come to understand how to develop the level of confidence they aspire to have [57].

Self-concept is characterized as the sum total of a person's mental and physical features and evaluation of self. As such it has three aspects: the cognitive (thinking), affective (feeling) and the psychomotor (action). It is important to consider the self-concept as developing in these three areas. It can also be seen as individual awareness of self and awareness of identity [58]. It was also noted that it has become an acceptable fact that one's self-concept is a way in which one sees oneself. This is not restricted to physical appearance, which is reflected in one's academic, professional and social existence, but includes private and personal awareness [59].

Personal confidence in the use of modern technology is important for effective use of expertise. Scholars affirm that skill acquisition is insufficient unless individuals develop self-confidence in the application of what is learnt. In other words, success based on the possession of required skills for performance also requires the confidence to use these skills effectively [60]. Therefore, apart from possessing information literacy skills, individuals in modern society must also be convinced about their proficiency in the use of these skills. Information literacy self-efficacy is capable of motivating academic performance; information literacy can help in predicting academic achievement, while self-concept is considered a major factor in developing information literacy [61].

Psychological factors affect human ability to learn new skills. Therefore, in addition to attaining information literacy skills, it is also important to develop perceived self-efficacy concerning these skills [56]. This will help in better appreciation of self-efficacy as a way to boost problem-solving capacity as a needed feature for lifelong learning. Self-concept is a vital component of teaching, not just to help with academic performance; it supports social skills and makes it easier for teachers to influence positive behaviour. Students are also better equipped to cope with mistakes, disappointment and failure if the mental attitude of teachers is positive; they are more likely to stick with challenging tasks and complete learning activities [61].

The self-concept of teachers has lifelong impact in the overall performance of learners, because it has positive effects on their self-esteem. This is because reinforcing the self-esteem of students is a direct consequence of increased motivation and learning. Teachers' positive attitudes can create a satisfying teaching environment and help to give students the impression that they belong and are welcome in the school setting. Teachers with positive mental attitudes must constantly communicate to students that mistakes are part of the learning process and that no student should ever feel embarrassed to ask questions if he or she does not understand something [62].

Self-concept comprises an individual's perception, emotion and attitude towards him or herself and is usually shaped in the course of familiarity with and understanding of one's environment. It was affirmed that self-concept is a combination of environmental and psychological conditions [63]. These two factors can affect human behaviour, as people become vulnerable to social factors in their search for independence [60]. Self-concept is a multidimensional entity which consists of very different cognitive and affective components [64, 65].

Perception of self can be a consequence of cumulative effects during biological, social and psychosocial transitions. Constructive transitions result in healthy self-concept developments, which make possible the achievement of many advantageous outcomes. Positive educational environments, family, school and community youth groups can shape personal qualities, which support cognitive, psychological, psychosocial and socio-emotional achievement. Positive outcomes will motivate the desire to attain high educational goals that are integral in self-concept formation [66].

Eight elements form the foundation of a person's self-concept; they are morality and ethics, personal and physical attributes, family, identity, social satisfaction and behaviour [67]. Self-concept also refers to an act of self-evaluation or self-perception, and it signifies the total sum of a person's belief about his or her own qualities. Self-concept reflects how people evaluate themselves in domains in which they consider success important [68].

8. Conclusion

The thematic analysis of this qualitative research emphasizes the importance and complimentary relationship between the selected variables for this research. For instance, metacognition is inherently part of ability needed to be mindful in planning, regulating and evaluating of one's intellectual processes such as the one needed in navigating the overabundance of information resources available from different sources; the study emphasizes the role of personal knowledge, task and procedural knowledge, strategic and declarative knowledge and, finally, conditional knowledge and the role they play in helping to shape activities channel towards information acquisition. Metacognitive control supports the ability to help in managing learning and fostering problem-solving skills.

At the heart of modern problem is information overload; therefore, it is imperative to acquire the skill that will lessen the burden of having access to genuine sources of information and be able to separate chaff from wheat in the world of information; otherwise, complex decision-making process influenced will be negatively affected. Incorrect, erroneous or misinformation, particularly on social media which are deliberately spread with intension to deceive, can be costly and lead to consequences that may be difficult to reverse; therefore, it should be a modern requirement for the knowledge of information literacy to be acquired. Since most of the modern information resource is driven by technology, it is important for any establishment to be restructured to accommodate these changes, which is often replaced with newer model, and consequently it is vital for the information literacy to become a lifelong skill. Doing this also requires self-concept which is the ability to demonstrate confidence and self-assurance in the handling of this modern tools and techniques, which comes with persistence and irrepressibility in the face of daunting and overwhelming challenge. Metacognitive skill is the ability to ponder seriously on any line of action before ultimately reaching decision; in view of the abundance of inaccurate information abundantly available, this quality becomes a sine qua non for survival in the information age and empowers individual to effectively search and navigate the world of information.

Conflict of interest

The authors declare no conflict of interest.

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Chapter 9

Redcay's STEM-oscope Model: Connecting STEM Education, Social Robots, and Metacognition

Jessica D. Redcay

Abstract

A qualitative analysis of second grade students' responses to Science, Technology, Engineering, and Mathematics (STEM) Challenge demonstrated that young learners use metacognitive skills throughout challenges (beginning, middle, and end). Students work through Engineer by Design (EbD) loop: (1) define and research a problem (2) brainstorm and explore possible solutions (3) develop a prototype (4) test (5) reflect (6) redesign (7) re-test. Social robots can be used throughout STEM challenges to model think alouds. Educators prepare the environment for young learners. Specially, educators find meaningful ways for students to connect concrete and abstract ideas. Five themes emerged from students' responses to two STEM challenges. The theme with the highest frequency demonstrated that students were making real-world connections. The additional themes included metalinguistic awareness, problem solving strategies, social metacognitive thinking, and concrete to abstract thinking. The five themes were connected to metacognitive thinking, EbD loop, and 6 E's of Science Inquiry. The themes were arranged in a new model called Redcay's STEM-oscope Model used to describe the connection between STEM education, social robots, and metacognition. The research study adds to the existing body of research about STEM education by directly linking metacognitive skills, STEM education, social robots.

Keywords: STEM challenges, metacognition, design loop, engineering by design, qualitative research, problem-based learning, social robots, think alouds, 6 E's of Science Inquiry

1. Introduction

Visualize this…A teacher is co-teaching a group of second grade students with a social robot. The teacher has coded the robot to introduce the Science, Technology, Engineering, and Mathematics (STEM) Challenge to the class. The robot states: "We are going to complete a STEM challenge. Yesterday, we explored different bridges using our Virtual Reality Field Trip. Also, we read April Jones Prince's 'Twenty-One Elephants and Still Standing' about how elephants were used to test durability of the Brooklyn Bridge. Today you are going to start to think about how you will build a bridge that can hold as many plastic elephants (weights) as possible." The teacher shows the student materials that are available to use for the STEM challenge. Further, the teacher tells the students that they need to make sure that they create durable drawbridge that can open and close. The students examine the little baby-pool that was set-up in the classroom to see how the bridge will need to safely connect two different areas. Sophie, a girl in the class, starts to measure the area so she can consider this as he starts to create a plan. Davin, a boy in the class, goes to get his sketchpad so he can start to sketch a possible design. The students start to share ideas with their group members. The students are starting to work through the Engineer by Design (EbD) process.

The previous scenario is similar to what is occurring in a second-grade classroom in Pennsylvania, United States. Dr. Jessica D. Redcay codes Robon, the first female robot, from RoboKind® to co-teach lessons. Previously, teachers have not used robots as teaching assistants in the classroom so a limited amount of research is available. RoboKind® uses the platform of providing Robots4STEM. Therefore, the research study specifically focused-on the connection between using Robon during a STEM challenges with second grade students. Robon is a robot so the teacher can use a loop-code to repeat concepts to students who might benefit from repetition. Science topics include a lot of content-specific terms and concepts. Students can develop strong background knowledge about new content that will be covered throughout the unit. In addition, Robon is coded to model think alouds to students throughout STEM challenges. All of these types of activities should help foster metacognitive thinking. However, since this model for teaching was not previously utilized additional research was need to explore this model.

Science Technology Engineering Math (STEM) Challenges involve students using problem-based learning (PBL) [1]. Engineers are problem solvers who design or improve the design of different things in the world [2]. Designing is a process not a product so the word is used a verb not a noun [2]. Engineers use Engineer by Design (EbD) loop that include: (1) define and research a problem (2) brainstorm and explore possible solutions (3) develop a prototype (4) test (5) reflect (6) redesign (7) test [3]. The steps are centered around three main stages of the loop: beginning, middle, and end. The three main stages are connected to define, design, and optimize [4]. The beginning stage involves engineers defining the problem. This stage occurs during step one of the design loop. The middle stage involves designing. Steps two through four are included in the middle stage. The end stage involves optimizing or changing the new idea to address a problem. Steps five through seven occur during the end stage [4].

2. Literature review

STEM challenges are used in the classroom with students to help students have a chance to learn more about real-world problems [3]. A STEM challenge involves the teacher providing a real-world problem, and the teacher provides a question for the students to try to solve. The students work with a team, within specified parameters, to try to develop and test possible solutions [5]. A STEM challenge has theoretical underpinnings within a constructivist or inquiry approach [6]. Further STEM challenges utilize Bybee's 6 E's Instructional Model. The 6 E's include engage, explore, explain, elaborate, evaluate, and engineer [6]. Research studies have supported the use of STEM challenges with young children [5]. Prior to the current research study, social robots were not used in conjunction with STEM challenges.

2.1 Metacognition and STEM education and social robots

2.1.1 Metacognition and STEM challenges

Previous research studies have not directly linked STEM education and metacognition. However, STEM challenges have skills that have been linked to metacognition, Metacognitive thinking starts to occurs when a child is between the ages of 5 and 6 [7]. At this stage students start to think about their own process of thinking [7]. The research study involved students who are 7 and 8 years old. Students in second grade have only had a year or two to start developing metacognitive skills. Young children are naturally curious. As students work through a STEM challenges, children are using the inquiry model. Previous research studies have demonstrated that students show higher levels of metacognitive thinking when they become curious about task because students become more interested in activity seeking information to explain the unknown [8]. Additional research studies have demonstrated that students learn social metacognitive skills when working with groups [9].

2.1.2 Metacognition and social robots

Students demonstrate higher levels of metacognitive thinking when think-alouds are used by social robots [10]. Students need to be provided with guidance to encourage introspection. Vygotsky believed that students need to be provided with scaffolds or supports to help students understand that they can construct their own knowledge [7]. Additionally, students develop metalinguistic awareness when they are provided with models and time to reflect on experiences [7].

RoboKind® is a company that created a social, codable robot. The robot named Milo from RoboKind® has various facial expressions to encourage emotional awareness. Milo has a visual communicator on his chest. The pictures help make learning easier for students. Further, the robot can speak in different languages [11]. Originally, the robots were used to help children with Autism. Various teachers who have used Robots4Autism explained that social robots helped increase the engagement level of the students. Further, students develop better communication skills [12]. Social scripts are used with Milo to help increase students' ability to converse [13].

RoboKind® expanded Robots4Autism to Robots4STEM with Jett. Students learn visual programming as they work through different modules focused-on different key coding concepts. Students are able to code a personalized avatar, and students can sync the code with a robot [14]. Students are able to see concrete results of what they are coding. Jett has a sister robot who was released in 2019. Her name is Robon [14]. Robon, the first female Robots4STEM robot, was used as a part of this research study. The robot which was a part of the research study is used by a Girls Who Code Robots Club. In addition to the coding club, Robon is coded to act as a teaching assistant in the classroom. Robon was used in the research study to provide students with an introduction to different STEM topics. Since the idea of using social robots as a teacher assistant in the classroom is a new concept, research does not exist yet. Specially, previous research did not explore parallels between the use of STEM challenges and social robots to metacognitive skill development.

2.2 STEM education at an elementary level

2.2.1 Various STEM education formats

Some elementary schools have STEM specialists, and some elementary school teachers are responsible for teaching STEM lessons. Further, some schools have adopted STEM programs, and sometimes teachers are designing their own STEM lessons. STEM education at an elementary level can occur within a teacher's existing classroom or some schools have a STEM lab. The current research study involved a school that did not have a separate STEM lab area. Also, the school did not have a

STEM specialist. At the school of research study, classroom teachers were responsible for the STEM education of the students. The integration of STEM education at an elementary is rather natural because students are with the same teacher for most of the day [15].

2.2.2 Various materials

Teachers often find it challenging to obtain materials to use during a STEM challenge [16]. Recycled or free materials are a great option for STEM challenges. For example, teachers can use things like paper towel rolls, newspapers, cardboard boxes, and egg cartons. Additionally, teachers can purchase items that are versatile, and teachers can provide students with building materials that can be used in combination with other materials. Two examples of versatile materials include Creation Crate® TechCard® and SAM Labs®. The research study involved the use of recycled materials and versatile building materials.

Creation Crate® TechCard® are building materials designed for schools. The company provides kits that teachers can use with students to demonstrate different science concepts. Additionally, teachers can provide the students with materials to use to build freely. The materials are easy for students to use because the card contains punched holes that fit dowel rods. Further, the card sets are scored so students can fold it easily. The card kits are made from 100% recycled materials as well [17]. Young children benefit from using hands-on materials to understand abstract concepts [7]. The crane and drawbridge kits were used during the current research study. The students were encouraged expand or extend the original kit design.

SAM Labs® are wireless Bluetooth blocks that move, light-up, and make noises. The blocks pair with the coding app called SAM Blockly®. Students learn to code. The company provides lesson plans that teachers can use with students to teach coding skills [18]. Young learners need opportunities to see connections between concrete and abstract ideas [7]. Further, teachers can use the materials in other ways too. For example, during the current research study the SAM Labs® blocks were used in combination with the Creation Crate® TechCard® crane kit so the crane would move, light-up, and make a noise.

2.3 Time for reflections

2.3.1 Thinking time in the classroom

The most successful innovators find a balance between things they are doing with time to think and reflect [19]. In an era filled with technology and distractions, students are provided with a limited amount of time to stop, think, and reflect. Brain research has consistently demonstrated that students need enriched opportunities with time to reflect to help increase synaptic connections [7]. Neuroplasticity is the idea that the brain can improve for the better or for the worse. When students are overloaded with information without time to reflect then students are not able to find patterns within their own thinking [7]. Young students are processing a lot of information. The process of assimilating and accommodating information requires time for students to think [7]. The need for think time seems intuitive because every living being requires time. For example, if a Jade Plant is transplanted then it needs several weeks before it can be watered. The Jade Plant needed time to adjust to a new situation. In the classroom students are the same as Jade Plants and other living beings, they need time to reflect to foster metacognitive thinking skills.

2.3.2 The power of student voice

FlipGrid® is an online video discussion. A grid is a class or group of students. The teacher posts topics for the students to respond to with a video response. The students are able to view and respond to the video posts of their peers [20]. Students benefit from going into a privacy pod to think and record individual reflections. The research study involved the use of FlipGrid®. Students shared their reflections in privacy pods. The video responses were transcribed in FlipGrid®, and the transcriptions were exported.

Students need opportunities to hear their voice and the voices of their classmates. Learning occurs when students have the opportunities to express their ideas and opinions [21]. When students have opportunities to be heard in the classroom then students benefit from trying-out new thoughts and ideas [22]. Students develop metalinguistic awareness, or a better understanding of how they develop new words, when they have the chance to practice and try out new words [7].

3. Research question

A qualitative, explanatory research study was used to explore one central research question. Research question 1: What, if any, themes will emerge when exploring the responses of second grade students after complete two STEM challenges?

4. Research design

A second-grade class of 25 students completed two different STEM challenges that involved the use of a social robot. At the conclusion of the challenge the students reflected upon their experiences using FlipGrid®—a video discussion platform. The students were able to hold their physical projects that they constructed as they recorded their reflections. The responses of the students were transcribed, coded, and categorized to explore possible themes to describe students" thinking throughout STEM challenges.

The students were provided with a STEM challenge to create a drawbridge that would be strong enough to hold at least 21 plastic elephants. At the beginning of the challenge, the students were introduced to the vocabulary using Virtual Reality (VR) exploration of different real-world bridges. As the students progressed through Nearpod® VR the teacher and social robot, Robon from RoboKind®, provided a guided a think aloud and helped develop content-specific vocabulary. The students used Creation Crate® TechCard® Bridge Kits. Creation Crate® TechCard® are recycled materials that used by young students to create and design different things. Further, the teacher read aloud *Twenty-One Elephants and Still Standing* by April Jones Prince. The students were able to spend up to 5 minutes reflecting using a video recording.

Another STEM challenge involved building a working crane. The students were able to learn about cranes by exploring VR on Nearpod®. Robon from RoboKind®, was coded and used throughout the challenge to provide a think aloud to support the challenge. The students were provided with Creation Crate® TechCard® Crane Kit. The kit involves the use of air pistons to move the crane. The students added the Crane to SAM Labs® Kit. SAM Labs® include wireless Bluetooth blocks that connect to the app. The students were able to use the blocks to add lights, movement, and sound to the crane.

4.1 Research procedure

Fifty video responses recorded in FlipGrid® were transcribed to explore students experiences when completing two different STEM challenges. The transcriptions included 20 minutes of responses. Only two segments of data were removed the study because the student was unaware that they were continuing to record, and the recording did not connect to the topic.

5. Data analysis

Seventy-seven segments of data were coded. Five themes emerged. The following themes emerged: (1) metalinguistic awareness (2) curiosity and real-world connections (3) problem solving strategies (4) social metacognition strategies (5) concrete to abstract thinking. The themes and frequency are listed in **Table 1**.

Theme	Frequency of response
Metalinguistic	12 (16%)
Curiosity and real-world connections	26 (34%)
Problem solving	20 (26%)
Social metacognition	11 (14%)
Concrete to abstract thinking	8 (10%)

Table 1.
Themes and frequency.

6. Data results

6.1 Curiosity and real-world connections

The theme with the highest frequency of response was curiosity and real-world connections with 26 segments of data (34%). Responses were coded as curiosity and real-world connection when the response connected to real-world examples or the STEM challenge. Additionally, responses that demonstrated an interest in topic of the STEM challenge were coded within this category as well. An example of a response within this category included one student who stated: "Real cranes use lights and sounds when moving." Another example of a response in this category included: "The Brooklyn Bridge took 14 years to build, and 21 elephants walked across it to see if was sturdy." Some students identified the Golden Gate Bridge or other types of actual bridges that were observed during the Virtual Reality Tour.

6.2 Problem solving

The theme with the second highest frequency of response was problem solving with 20 segments of data (26%). Responses were included within this theme when students described how they worked through the problem or challenge. Further, the students described how they figured things out throughout the STEM challenge process. One example of a response that was included in this theme included a student who stated: "The air in the piston makes the crane move." Another student explained: "We used the blue-tooth blocks that were connected to the iPad to make our crane move, light-up, and it made sound." Other examples involved explaining how the drawstring bridge was created so it would be sturdy enough to hold a lot of plastic elephants but it still had the ability to move up and down.

6.3 Metalinguistic

The theme with the third highest frequency of response was metalinguistic with 12 responses (16%). Responses were included within this theme if the students responded focusing on the language. Sometimes students would describe new words, but the students could not remember the name of the word. For example, on student stated: "There was one thing under the toy crane. I forget what it was called, but it was the thing that we used with the iPad to control it." Another student stated: "We used a syringe as an air piston." The students were becoming aware of new words, and the students were learning how to apply the words to describe what they did.

6.4 Social metacognition

The theme with the second least amount of frequency of response was social metacognition with 11 responses (14%). Responses were included within this theme if the students reflected on the process involved with working and communicating with others. For example, one student stated: "We worked together as a team. I saw that people in my group were all doing a good job." Another student stated: "As a group we made a crane. We all had different things to do. I had was able to put the glue dots on the TechCard." Responses that involved group work and collaboration were coded in the Social Metacognition category.

6.5 Concrete to abstract thinking

The theme with the least amount of frequency of response involved concrete to abstract thinking with eight responses (10%). Responses within this category involved students using the concrete prototype to describe abstract concepts. When the students were reflecting on the experience then the student had the chance to hold the concrete object to help with the explanation. One student stated: "Let me show you how this works." Another student said, "Watch this!" Whenever a student referenced the concrete object when explaining abstract ideas then the response was categorized as concrete to abstract thinking.

7. Discussion

The research study results added to the existing body of knowledge in the area of STEM education. Previous research studies did not make a direct connection between STEM education, social robots, and metacognition. Different connections between STEM related skills were linked to metacognitive thinking, but it was not directly linked in a research study. FlipGrid® videos provide researchers an opportunity to explore students reflecting-upon their experiences.

Metacognitive thinking allows learners to transfer and adapt to different situations because learners have a strong understanding of their own knowledge [23]. Metacognition is similar to one looking into a toy kaleidoscope. As one turns or looks into the mirrors and reflections then the perspective changes. The word kaleidoscope is Greek, and the word means "beautiful form to see [24]." When a person is able to self-reflect then the thinking of the person transforms into a beautiful new understanding. The research study involved exploring the responses of students when using STEM challenges and social robots. The themes that emerged were connected the EbD loop and metacognition. When everything comes together then it can be explained by a new model called Redcay's STEM-oscope Model (RSM).

A triangle is located inside of a kaleidoscope. Therefore, RSM has a triangle with the three sides labeled to correspond with the three stages of a STEM challenge: (1) beginning-define, (2) middle-design, (3) end-optimize. The five themes that emerged from the research study fit within the three stages of STEM education. The curiosity and real-world connection theme is connected to the beginning-define stage. The social metacognition and concrete to abstract themes are connected to the middle-design stage. The problem-solving theme is connected to the end-optimize stage (see **Figure 1**).

7.1 Beginning-define stage

Two themes that emerged fall within the beginning-define stage of the EbD loop: (1) curiosity and real-world connections and (2) metalinguistic awareness. Within the beginning stage students are identifying the problem. Further, the engage phase of 6 E's of Science Inquiry is connected to the beginning stage as well [6]. The engage phase involves making connections between old and new knowledge. The two STEM challenges included in the research study included Virtual Reality Tour with Nearpod®, an introduction from Robon from RoboKind®, and read aloud. The purpose of the activities that occur during the beginning-define stage involve developing vocabulary and providing an authentic, real-word connection to the challenge.

7.1.1 Curiosity and real-world connections

Curiosity and real-world connections theme had the highest frequency of response. The engage stage of the 6 E's instructional method occurs at the beginning of a STEM challenge [6]. In the STEM challenge, Virtual Reality with Nearpod®

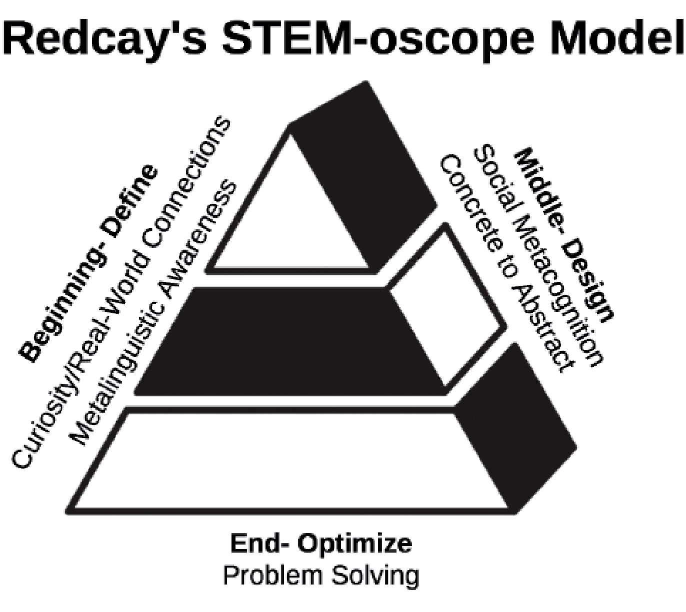

Figure 1.
A picture depicting Redcay's STEM-oscope Model that combines STEM education, social robots, and metacognition.

were used to help students see real-world examples. Further, students were provided with read alouds about the topic. Robon from RoboKind® was coded to give an introduction, and provide the students with background knowledge. Previous research studies have demonstrated that students learn the most when they are curious about the content area of focus [8]. When students are curious then they are able to learn more about something news. Further, when students show neuroplasticity-ability to make synaptic connections in the brain due to an enhanced learning opportunity—then students' ability to learn increases [8]. Students learn best when concepts are linked to real-world examples [11].

7.1.2 Metalinguistic

Metalinguistic was the theme with the third highest frequency. Students were able to use and apply new terms through the design process. Previous research studies have demonstrated that students' metalinguistic skills increased after students had an opportunity to observe and try-out new words within a group [7]. Robon from RoboKind® was coded to provide students with think alouds through the STEM challenges. Previous research studies have demonstrated that students benefited from think alouds provided by social robots [10]. Further, students had the opportunity to try out the new words using FlipGrid®. Students could listen to their own reflections, and the students could listen to the reflections of their peers. These different opportunities helped the students further develop their own knowledge about how they are using and applying new words.

7.2 Middle-design

Two themes were connected to the middle-design phase of the EbD loop: (1) problem solving and (2) concrete to abstract. During the design phase students brainstorm ideas, create a prototype, and test the prototype. The purpose of this phase is to try-out different hands-on activities. Students are working through the explore, explain, and engineer phases of 6 E's of Science Inquiry [6]. As students manipulate concrete objects then it helps students understand and explain abstract concepts. Further, students are working-on learning how to explain and properly communicate their ideas to others. Students need opportunities to collaborate and socialize.

7.2.1 Social metacognition

Social metacognition had the second to least frequency of response. Students were reflecting upon how they worked together in teams. Previous research studies have demonstrated that students benefit from working collaboratively, and this helps develop social metacognitive thinking [9]. Students reflected upon the negative and positive aspects of working within a group. Students were able to organize their thinking into patterns then the patterns or ideas can be applied or used in the future [25].

7.2.2 Concrete to abstract thinking

The category with the least amount of frequency was concrete to abstract thinking. Materials like Creation Crate® TechCard® allow students to construct, build, and re-build an unlimited number of proto-types that can help students better understand the connection between the concrete object and the abstract idea. Further, another versatile material is SAM Labs® students are able to connect different circuits in the app, but the abstract concept is applied to motion in an actual concrete object. Young students learn best when concrete objects are linked to abstract concepts [7]. Some students might have already internalized abstract ideas so they did not need to rely on concrete objects.

7.3 End-redesign

One theme connected to the end-redesign phase: problem solving. During the end-redesign phase the students are re-designing and re-testing. The redefine phase align with the elaborate and evaluate phase of the 6 E's of Science Inquiry [6]. Students are able to expand with new experiences to discover more about the topic. Students self-evaluate and reflect on the STEM challenge to make decisions about how to improve and change their initial ideas.

7.3.1 Problem solving

Problem solving was the theme with the second highest frequency. STEM challenges start with real-world problems [3]. Further, throughout the STEM challenge, students solve problems and students demonstrate flexible and creative thinking. Previous research has demonstrated that students benefit when they think through problems [3]. Students are able to reflect upon the process, and students can organize their thinking around patterns that can be used in future situations [11].

8. Future research

The research study was limited because it only included one group of students in one grade level. Additional research is needed to examine and explore the effectiveness of using social robots as teacher assistants when completing STEM challenges in the classroom. Further, additional research is needed to test the new STEM-oscope Model with students in differing grades and places. The current research had students reflect on the STEM challenges at the end. Future researchers might consider having students share reflections after the individual EbD loop phases. After exploring additional data per phase then possible subthemes might emerge. Quantitative research is needed to further explore the effectiveness of new educational models and methods.

9. Conclusion

The research study added to existing body of STEM Education Research because it connected STEM education, social robots, and metacognitive thinking in a new model called Redcay's STEM-oscope Model. The qualitative, explanatory research study involved the exploration of 100 student responses after completing two STEM challenges. The students responded to the STEM challenges using FlipGrid®. The data were transcribed, coded, and analyzed to answer the research question: What, if any, themes will emerge when exploring the responses of second grade students after complete two STEM challenges?

Five themes emerged: (1) metalinguistic awareness (2) curiosity and real-world connections (3) problem solving strategies (4) social metacognition strategies (5) concrete to abstract thinking. The five themes connected to the three main stages of the EbD loop: (1) Beginning-Define (2) Middle-Design (3) End-Optimize. Further, the 6 E's of Science Inquiry were embedded and connected to the themes as well. The model is arranged in the shape of triangle because kaleidoscopes use a triangle shape with mirrors. When STEM education is connected to metacognition then an experience similar to looking through a kaleidoscope occurs. As one turns and reflects then perspectives and understandings increase. STEM-oscope Model involves students self-reflecting throughout the STEM process to gain better self-awareness.

Metalinguistic awareness was promoted as a social robot, Robon from RoboKind® provided Think Alouds. Students were able to listen to their own recording, and students were able to listen to the recording of their peers. Students benefited from using versatile materials like Creation Crate® TechCard® and SAM Labs® that further allowed students to make connections between concrete objects and abstract ideas. Additionally, students benefited from having the opportunity to make real-world connections using Virtual Reality from Nearpod®. Students benefited from interacting within groups, and students learned more as they solved problems. These themes were previously recognized separately as benefiting students to think metacognitively. However, a STEM challenge allows the students to have an enhanced experience because it fosters metacognition by developing various skillsets.

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Chapter 10

Understanding in Action: An Analysis of Its Levels and Qualities

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Abstract

The present chapter analyzes the features of the understanding of learning in action. Understanding is defined as the ability to think and act with flexibility using what one knows, implies being able to take knowledge and use it in different ways, constitutes a final cognitive process, producing a generative knowledge. Understanding involves an active knowledge, that is, being able to be used in different situations, it is transferable, it consolidates a vertebrate pedagogical model around thinking, allowing students to actively use learning. This paper analyzes the multidimensional role of understanding, describing it in cognitive terms, qualitatively describes its performance. It ends by offering a detailed analytical-methodological description of the levels and qualities of understanding. Finally, it contributes to knowledge by providing clues and solutions for the design of the school curriculum, teaching and evaluation through the principles of understanding.

Keywords: comprehension, comprehension performance, flexible use of thought, levels and culiadades

1. Introduction

Understanding has multiple strata. Its complexity demands attention to the multidimensional nature of each of its pieces in the didactic context in which it takes place. Conceive the whole through the metaphor of the mosaic-universe. In this work, the qualities and levels of comprehension are analyzed, and the comprehension of the conditions for the production of comprehension based on the main tensions derived from schooling. According to Stone Wiske [1], to sharpen understanding, we need to teach novel things and things that oppose school grammar legitimized within the framework of neoliberal policies on educational quality. It also analyzes the concept of key flexible performance in framing systems of comprehension activities, that is, thought-stimulation strategies. In this regard, Perkins [2] argues that it is necessary to foster learning climates that promote the ability to do a variety of things with thought, in front of that, the question arises: what things are useful to forge the memory? Preliminarily, as an answer it indicates the ability to *"look for patterns in ideas, find own examples and relate new concepts to previous knowledge, for example, they serve both to understand and to store information in memory"* ([2], p. 81).

How to know if a student has reached a valuable level of understanding? Undoubtedly, it is one of the main objects of analysis of this work. Understanding goes beyond the possession of a unique style of knowledge, expressed through the ability to go beyond what has been learned, that is, to be able to think flexibly, to apply that information to an infinity of contexts and areas of performance. Understanding is synonymous with acting flexibly, manipulating information, that is, doing things with it. Understanding is going beyond the possession.

Understanding is always a state of autonomy. Understanding in action refers to comprehension activities. As such, it designates a flexible cognitive activity, creative, in turn, is typical of crystallizing environments [3], in them, the student has the ability to do things with thought; it goes beyond its limits. Understanding is always action, movement and permanent challenge. It is synonymous with deep learning [4]. Comprehension activities demand different types of thinking. Understanding is open and gradual, it means mastering the unknown. With regard to mental images, it should be noted that they are one of the most powerful resources of the mind. They help explain comprehension processes and the consolidation of cognitive processes throughout life.

Mental images are the result of the quality and condition of three-dimensionality; this is what allows things to relate to each other. The morphology of comprehension is structured on the basis of mental images, which are closely linked to the devices through which the understanding in act emerges and consolidates. Each dimension and level of understanding reveals a complex mental singularity. It is through mental images that we can perform refined and finished comprehension processes.

The comprehension activities take on a visible character and are what people do when they understand something. A mental image is a holistic and coherent form of knowledge; it helps us to reason when performing a certain operation. Mental images install mental designs, which house ways of doing things, establish systems of reasoning to perform certain comprehension activities. The quality of mental images depends on the quality of comprehension performance; a good mental image fosters comprehension performance. The relationship between mental images and comprehension activities takes on a bilateral character [2].

Why do we need a pedagogy of understanding? For Perrone [5], understanding aims to train critical thinkers, capable of acting in complex environments, is interested in strengthening a deeper understanding of what is taught in schools. It proposes the challenge of establishing new connections based on what has been learned, urges students to build connections that go beyond their traditional ways of conceiving them. Understanding, as we will argue in later pages, establishes a close relationship with learning the meaning of something, doing things with thought, going beyond what has been learned. Understanding is a deep commitment of the intellectual. Epistemologically, it is based on the idea of active, constructive and transformative learning. It explains a powerful educational proposal that is flexible and suitable for all students, conceived as a multiplicity of differences. It fosters a key cognitive evidence about the learning of its students, it incorporates a representational vision of the comprehension and the learning in act, key in the construction of evaluation systems of the learning. The teaching of comprehension poses challenges to the forms of education offered in school, in this conception, the perspective of performance is key, favors the articulation of a *"full range of intellectual possibilities so that students can apply all their talents in the school work"* ([5], p. 65). Teaching for understanding becomes a device of justice and cognitive equity, operationalizing conditions that affect curricular design, the crystallization of educational practice and the reconfiguration of the evaluative system, focusing on the perspective of performance. Indeed, the "performance" perspective says that understanding is the ability to do a variety of things that stimulate thinking with a theme ([1], p. 103). In short, *"understanding is to be able to carry out a diversity of actions or" performances "that demonstrate that one understands the subject and at the same time broadens it, and be able to assimilate knowledge and use it in an innovative way"* ([1], p. 105).

Teaching Comprehension (EpC) assumes the challenge of

> *[...] provide all students with comparable high-quality educational opportunities, while responding to local priorities and individual needs. The curriculum should engage students in a work that is generally considered important and an intellectual challenge that promotes the fundamental values of a democracy and that allows students to move freely between different schools without facing intellectual expectations. totally distant ([5] p. 65).*

In tune with Perrone [5], Perkins [6] in "The full learning. Principles of education to transform education," argues that one of the central objectives of education is *"to help us learn what we do not naturally acquire during our daily lives. Education must always ask itself what can be done to make knowledge and stimulating practices accessible"* (p. 24). The perspective of the performance promotes a situated understanding about how certain knowledge will be used in their daily life, emphasizes the ability to do things with what they have learned. Traditional school grammar-even in higher education-legitimizes curricular construction and teaching practices centered on what Perkins [6] calls 'elementitis,' that is, acquiring various bodies of information without knowing what to do with them, beyond what is commonly required. Elementitis is synonymous with strategic and superficial learning. Bain [4] explains that the first learning style is carried out with a competitive desire, that is, it demonstrates a behavior based on use, on being better, on obtaining the best grades. While, the second, unveils an operation primarily aimed at avoiding problems and school failure. The behavior of the student values the qualifications that can be obtained as compensation system and reward of their own social worth [7] before their peers and relatives. Surface learning makes explicit a nature centered on evasion and lack of motivation. By constituting the elementitis a curricular and teaching praxis of reductionist, simplifying and mutilating character of the cognitive experience of the student body, it gives way to the syndromes of fragile and poor thinking [2], both of which explain the significant deficiencies that education faces transversal in almost the entire world.

The fragile thinking syndrome, according to Perkins [2] is characterized by the inability of students and didactic mediations to actively use what they have learned. The 'fragile' section designates weaknesses of knowledge in various aspects, expressed through a type of knowledge: (a) forgotten, characterized as a portion of knowledge that has been studied, but has been forgotten, or easily disappears. This type of knowledge denotes the absence of an active functioning linked to the thought process. (b) Inert, conceived as a knowledge that is remembered or not, in specific situations. The situation that best exemplifies them is the preparation of exams to pass the subjects, without necessarily pursuing a value of change from learning. It is intimately linked to strategic and superficial learning.[1] (c) Naive, typology of cognitive risk characterized by the mixture and hybridization of stereotyped theories or misconceptions about a particular topic of study. At this level students are able to understand the conceptual component, their difficulties are presented when explaining or interpreting something, erroneous conceptions are almost intact. This knowledge demonstrates a poor level of understanding [2]. (d) Ritual, dimension of learning that expresses a superficial and scarcely authentic understanding. Perkins [2] calls it 'ritual,' since students learn the necessary

[1] The student emphasizes the intention to meet the requirements of the task. Memorize the necessary information for tests, exams or controls (procedural and cumulative). Approach based on loose elements, unconnected and without integration.

procedures to solve certain problems. This knowledge demonstrates a poor level of understanding. For its part, the poor thinking syndrome, Perkins [2] is based on the premise that students are unable to use what they have learned in different situations and contexts, or to think through what they know. Students affected by poor thinking [2], resort to repetition to retain knowledge, instead of using more elaborate techniques that stimulate their higher levels of thinking. Faced with tensions, it is suggested that the mediation of teaching and evaluation consider the following dimensions: (a) clarify, supposed to determine what type of questions allow to better understand some points, strengths or weaknesses expressed in students' work. (b) Value, implies paying attention to the work that students are developing—emphasizing the dimensions of the representational vision of learning. (c) Express concerns, correspond to the set of elements that call the attention to the teacher once he monitors or monitors the work of the students. They are also often referred to as critical points of teaching and mediation. From the perspective of Feuerstein [8], it serves the set of deficit cognitive functions. (d) Make suggestions, a dimension that includes the need to publicly explain the concerns and interests of the teacher regarding the learning of their students.

Understanding [1, 2, 5, 6, 9] and deep learning [4] are intimately related. They coincide in the company destined to dominate the unknown, strengthen the structuring forces of learning, such as imagination, fantasy, play, creativity, play, etc. Strengthens a corpus of capacity that allows us to master the unknown, establish associations of diverse nature and scope, giving the student the ability to do various things with thought. Deep learning is synonymous with cognitive challenge and education with awareness. So, what do we mean by cognitive challenge? As a category of analysis, it designates a multiplicity of positions and meanings, many of them adopting a heterodox status, by becoming strategies of opposition and breaking to the historically legitimated conceptions of how we better learn human beings at school stage. A cognitive challenge is, in turn, an invitation to go beyond what has been learned, requires leaving the space of cognitive and emotional comfort, implies a creative attitude, open to the unknown, implies acting flexibly from what each person knows, looking for hidden possibilities in diverse contexts, fields and situations. A cognitive challenge is first and foremost a psychobiological process, strengthens neuronal connections, if after 48 hours does not re-exist challenging and enhancing cognitive activity, then the set of strengthened neuronal networks tend to disappear. For the assurance of a good learning climate, which in terms of Feuerstein [8] corresponds to an active-modifying climate, demands the need to keep energy high in the student body, keeping the emotional networks calm. A solid cognitive challenge consists of increasing the levels of curiosity and above all, 'novelty' brought by the neurotransmitter of noradrenaline. Its materialization is carried out through a repetitive teaching practice, that is, capable of giving the student the ability to constantly apply what they have learned, connecting it with their daily life. Through a practice of learning based fundamentally on the application and refinement of what has been learned, it strengthens working memory, that is, it invites teachers to design learning experiences articulated fundamentally in the manipulation of what has been learned, which is what Stone Wiske [1], Blythe [9] and Perkins [10] call 'acting flexibly'—henceforth a performance perspective.

The most relevant and recent research on human cognition reveals the great obstacle that these approaches face, with respect to the neoliberal engineering that supports the approaches on the quality of education. In fact, the 'neuro' revolution has shown the need to educate in function of the structuring principles of human nature constitutive of the human being, showing that the regulative notions and the signifiers associated with quality in education, express antagonisms every time more marked. A teaching practice focused on understanding [1, 2, 5, 6, 9] invites teachers to think about teaching through questions such as: Why am I teaching this?, how will I decide which are the most important things my students have to learn?, what activities are I really reaching my students?, how can I plan the practice so that everyone can master it?, how will I find out what they have really learned? Teaching for comprehension proposes that educators avoid *"falling into blind and limited thinking and behavior patterns, making mistakes in situations where they could proceed with greater awareness"* ([6], p. 26). Teaching for comprehension prevents the knowledge and school skills legitimized by their respective curricular frameworks from becoming atomized and become instrumental. Both forms of learning production what Gardner [3] and Perkins [2] call the 'triviality' of teaching, characterized by the accumulation of facts without direct connection with everyday life and the set of cultural relations in which the student.

2. On the concept of understanding: concept and characteristics

The goal of education is to help us consciously do what we do not learn naturally during our daily life [1]. For this reason, education must always ask itself: what can it do to generate spaces accessible to knowledge through stimulating practices? [6]. Teaching for Comprehension (EpC) fosters a global vision of cognition, allowing educators to give a deeper and more complex meaning to the challenges presented to them by their students. It invites them to transform and develop the implicit unconscious knowledge into explicit conscious knowledge, through an active participation that guarantees the strengthening of a generative knowledge through the retention, understanding and active use of knowledge [2].

For Perkins [2] the Teaching for Understanding (EpC), reaffirms the conception that people construct their own meanings from learning experiences to which they are confronted. The multidimensional nature of understanding demands the strengthening of enriching generative connections. A study content acquires generative status when it occupies a 'central' place within the subject or disciplinary field under study, it is 'accessible' as long as it articulates activities of challenging and generative understandings between teachers and students. Finally, it is 'rich' when establishing connections between different subjects and subjects. The relational power is key in the construction of the curriculum and the forms of mediation of teaching. A pedagogy focused on understanding is conceived as a critical commentary and a performative invitation to observe, analyze and reorganize the curriculum around generating themes that give origin and support to various comprehension activities, offering students greater opportunities from which to build, learn and go beyond their possibilities and what is commonly required by schooling.

How to understand the complex and multidimensional act of understanding? The 'understanding' according to Perkins ([2], p. 78) is expressed when a person is able to think and act with flexibility using what one knows. It is being able to take knowledge and use it in different ways. "Understanding" according to Blythe [9]? is achieved when *"the student develops the ability to do with a theme or content a variety of things that stimulate thinking"* (p. 39), whose purpose is to apply it in divergent ways and each more elaborated, with the purpose of going beyond knowledge and repetition, that is, instrumentalization and atomization practices.

3. The multidimensional nature of understanding and levels of metacognition

Metacognition has traditionally been understood as the reflection on one's knowledge, or failing that, the conscious recognition of the learning achieved by each person. However, the usefulness of the concept refers to the possibility of operating mentally in several interconnected tracks or levels in a continuous and permanent manner. The number of clues or metacognitive levels is directly related to the intellectual capacity and mental agility linked to the flexible performance of each student. It considers the subordination and over-ordering of each cognitive process in play, that is, the reference and coordination of some of its cognitive levels. Perkins et al. [11], identify four levels of metacognition, among which stand out: (a) level 1. Tacit: the student does not achieve awareness of their metacognitive knowledge, (b) level 2. Conscious: the student handles some categories of thought that he uses to generate ideas, find evidence but does not use his knowledge strategically, (c) level 3. Strategic: these students can organize their thinking to solve problems, make decisions, etc. and (d) level 4. Reflective: they are able to strategically use their knowledge and review their thinking through the identification of their learning strategies.

4. Learn what is worthwhile: the generator knowledge

The fundamental purpose pursued by the Teaching for Understanding (EpC), is the development of a vertebrate pedagogical model around thinking, where students learn to reflect on what they learn and understand. It requires them to go beyond their abilities and what they have learned. Permanently, challenges educators to transform their praxis with focus on the compensation of educational and cognitive inequalities. It is essential that teachers confront their students to learning experiences that allow them to 'retain,' 'understand' and 'actively use knowledge,' through situations in which students reflect on what they are learning, how they are learning and what they are learning with what they are learning. It is a knowledge based on a style of teaching centered on topics rich in possibilities and connections. This is knowledge that does not accumulate but acts. It helps students to understand the world and to develop in it.

Generative knowledge should be understood as a broad understanding [2]. Students learn to understand, through the development of actions, strategies and learning experiences, fundamentally active, flexible and reflective, that is, paying attention to the processes involved in the construction of knowledge-perspective of performance-. Learning strategies that wish to increase student understanding should devote more of their time to activities that demand intellectually stimulating tasks, such as explaining, generalizing, and ultimately applying that understanding to themselves. It must be done through a feedback (academic monitoring of students, fundamentally, structured to monitor their difficulties and strengths) constant throughout the learning process, in order to put in the foreground the reflective commitment with the performances of understanding. The demonstration of what has been learned plays a crucial role in this type of didactic and curricular mediation, henceforth representational vision.

Students learn more and better, when they are able to *"organize events, relate them to previous knowledge, use visual associations, examine themselves and elaborate and extrapolate what they are reading or listening to"* ([6], p. 40). The ability to learn to understand is strengthened through strategies that help them process the way in a more refined way, giving priority to reflective and flexible performance in complex tasks that admit more than one response. Good learning is the result of a reflective commitment of the student to the content of the teaching. Why do you take advantage of students' expectations? The Teaching for Understanding (EpC), by promoting the development of generative connections in teaching issues, takes as a frame of reference the intellectual passions of teachers and students. These are also conceived as the students' expectations and relate to their motivations and interests. The motivations and expectations of the students are the result of a cognitive predisposition of content achievements and other dimensions of growth, which will project great expectations and forge the trust and commitment of the students with their training process.

Teach to transfer? According to the approaches of cognitive science, the transfer is defined as the ability to learn something in a given situation and then apply it to a very different one, exploring their points of encounter and multiple forms of application and relationship. Perkins [6] identifies three types of transference: (a) distant transfer: it appears when the application of learned knowledge moves to unpublished or completely different situations, provoking a cognitive challenge of great significance for each cognitive structure, (b) close transfer: involves making connections with situations very similar to the original learning and (c) negative transfer: occurs when something that a subject has learned in a particular context inhibits performance or learning in another. It is the most common of the three.

The importance of teaching transfer from the tensions of schooling is closely linked to the concept of full development learning by Perkins [6], which should promote rich and extensible didactic repertoires in diverse fields and contexts of learning that allows them to go beyond their abilities and cognitive potential. Talanquer [12] states that, the didactic development in teaching for understanding emphasizes on the need to reflect on those procedural aspects that contribute to move from a cognitive tendency centered on the intuitive vision of learning, for a constructive tendency that is the type of representation about the learning necessary to successfully face the demands of schooling, promoting a deep understanding of what is learned.

5. Levels and qualities of understanding

The levels of understanding identified by Stone Wiske [1] in: "Teaching for understanding. Link between research and practice," are: (a) content, (b) problem solving, (c) epistemic level and (d) research. Each of these levels is intimately articulated with the multidimensional qualities of understanding. The content dimension according to Perkins [2], refers to data and information of an instrumental nature, reaffirms the nature of transmission of information. The dimension referred to problem solving highlights the direct resolution of common problems of each subject. The epistemic, on the other hand, assumes understanding as the articulation of generalizations and explanations about what students do. Finally, at the level of research, students have strengthened their learning, possess the ability to build new knowledge. According to the tensions of schooling, it is necessary to strengthen the level of content in educational practices, in order to promote mental images. It faces the challenge of strengthening the higher levels of understanding in each section of the school curriculum and of its forms of didactic and evaluative mediation.[2]

Teaching for comprehension (EpC) faces the challenge of configuring powerful representations, what things cultivate comprehension in the school space? In what way do the disciplines support this process? What activities encourage the construction of powerful mental images?, through the disciplines and their multidimensional and multi-structural nature? The mental representations

[2] Los niveles de la comprensión corresponden a una de las dimensiones más significativas de un meta-curriculum.

expresses relation with the creation of mental images, determine the application of singular conceptual models, according to the specificity of the cognitive structure of each learner. How do our students build their mental models? Perkins and Unger [13], affirm that powerful representations effectively articulate the understanding of learning through models such as: (a) analogical models-established analogies with the empirical phenomena that they deal with through teaching. Avoid based on ordinary models because they lead to errors-, (b) concrete models-present in a concrete way the phenomenon in question, mental images, comprehension activities, etc. (c) debugged models-reveal the strange elements that affect to the construction of knowledge- and (d) built models-linked to the construction of diagrams, direct reference to everyday experience. Comprehension activities build mental models. The development of mental models through curricular activities requires the incorporation of criteria such as (a) breadth, (b) coherence, (c) creativity, (d) accessibility, etc. Each of these dimensions encourages the development of a superior understanding. In this regard, Perkins [2] adds that, *"what we commonly understand by the content of a subject does not include higher order knowledge"* (p. 103). How to structure a learning experience that focuses on higher order knowledge? A possible answer suggests the configuration of a curriculum that helps us think correctly. It is a knowledge closely linked to the subjects.

Elements of a curriculum centered on the stimulation of a higher order that is nothing more than knowledge about the functioning of meta-cognition, integrates the questions about what and how-its functionality-, guides its activity to retention, to the comprehension-the conceptual organization of thought and of the disciplines of study that make up the curriculum plan—and the "active use of knowledge"—transfer of learning. A higher order curriculum or a meta-curriculum according to Perkins [2], provides tools to rethink the content of teaching, not only attends to the conventional aspects of the selected study content, but rather, to the meta-scientific aspects, linguistic, philosophical, artistic, etc.—of it. The nature of a meta-curriculum from the perspective of Perkins [2], aims to expand and enrich teaching conditions. A meta-curriculum is configured through dimensions such as: (a) levels of understanding, (b) languages of thought, (c) intellectual passions, (d) interrogative mental images and (e) learning to learn and (f) teaching how to transfer. A meta-curriculum is characterized by the holistic integration of each of the aforementioned elements, its integration allows us to understand the multidimensional nature of the understanding and language of human cognition. Each of its dimensions is transversal to each cycle and educational section. Introduces tools to understand the complexity of cognition, incorporates specific skills for its approach from the specificity of each discipline.

Table 1 presented summarizes the main characteristics of each of the dimensions mentioned above and involved in the configuration of a meta-curriculum according to Perkins [2].

The language of thought strategies is nothing other than the manipulation of various concepts and strategies that allow students to put into action various kinds of thinking to address certain cognitive challenges. The language of thought[3] and strategies of thought expresses a multidimensional nature, articulates a repertoire composed of specific classes of thought strategies. Its focus points to the application of different uses. The nature of understanding and the language of thought operate through the metaphor of the connection grid, following the logic of the foucaultian device, configured by the confluence of heterogeneous elements, forming a representational figure about what is learned. The metaphor of the network suggests a

[3] It refers to symbols of different nature.

Fundamental components of the meta-curriculum	Description
Levels of understanding	They correspond to the classes and dimensions of cooking that progressively goes through the student body with respect to a certain content of stud.
Thought languages	Consist of specific ways of manipulating what has been learned, according to specific kinds of thinking
Intellectual passions	Understands learning as a passion, as an affection, etc. Suggests conditions to captivate the learner A quality thought is highly strong and passionate A thought-centered teaching works in favor of the openness of the mind Strengthens a permanent commitment to thinking, fostering the culture of thinking in the classroom. Encourages and emphasizes the disposition for thought, transcends the idea of skill-how to do it-, emphasizes the inclination towards something (Ennis) Among the characteristics of a 'good thinker' Perkins [2] identifies that: (a) broad, diverse and risky intellectual capacity, (b) permanent curiosity, (c) search for unknown ideas, etc.
Interviewing mental images	It arises from the premise that understanding goes beyond learning the content Focuses its activity on the strengthening of powerful mental images that allow students to clarify what they learn in a timely manner, or they find it difficult Categories play a crucial role in the development of powerful mental images
Learn to learn	Corresponds to the ability to create tools that support learning. It consolidates a mental representation about what is good learning and the set of resources to achieve it
Teach to transfer	Transfer teaching emphasizes the strengthening of actions outside of school and between subjects. Trasferir is synonymous with applying what has been learned in a variety of domains

Table 1.
Main characteristics in the configuration of a meta-curriculum.

multilinear and fractal thought, articulated, fundamentally, in the operations of relational power, that is, to investigate and establish its multiple forms of application and relationship, etc. The teaching assumes the challenge of strengthening the link of students with education, due to the mistakes made continuously in Latin America in terms of public policies, is subject to breakages, assuming a naturalization status, which little or nothing, is discussed in the main political agendas. The forms of education installed contribute to undermine the students with their training process, contributing to practices of simplification and academic banalization. The omission of the educational subject continues being, among others, one of the irresolute tensions of greater pre-eminence. Coinciding with Paul [14], these tensions lead to weak critical thinking. Indeed,

> *[...] Weak critical thinking is the art of reasoning-of formulating valid reasons, of combining them into well-structured arguments, of refuting counterarguments, and so on. Paul states that one can become an expert in this practice without implying a true commitment to equity, or a genuine openness to the views that oppose the one that supports. This commitment implies the will and passion to keep the mind open to all perspectives, however different they may be from one's own. And this has nothing to do with the vacuous, kind tolerance of anything goes, but with a*

meticulous reflection. According to Paul, strong critical thinking is what teachers need to give form and encouragement to their classes, if they want students to overcome their prejudices or other equally harmful manifestations of intellectual narrowness ([2], p. 118).

Stone Wiske [1], unlike Perkins [2], identifies four prototypical levels of comprehension, among which are: (a) naive understanding-acuptation of information directly in the world, there is no awareness of the links that exist between activity and its application in our life-, (b) comprehension of newbies-mechanisms and rituals-, (c) apprentice comprehension-obey disciplinary modes of thinking- and (d) understanding of mastery-critical, holistic, creative and flexible-. Each of these dimensions describe the multidimensional nature of understanding. However, *"deep understanding involves the ability to use knowledge in all dimensions"* ([1], p. 239). Its dimensions vary according to the specificity and interiority of each of its dimensions. To understand in depth the meaning and meaning of levels of understanding, it is necessary to refer to comprehension performances, that is, various ways in which subjects demonstrate what they have learned. **Table 2** presented below summarizes the main characteristics described by Stone Wiske [1].

Returning to the contributions of Stone Wiske [1], in relation to the four dimensions of understanding, identifies unlike Perkins [2]: (a) content, (b) methods, (c) summary of the dimension of purposes and d) forms of communication of what was learned. It also adds criteria associated with each of the dimensions indicated above (**Table 3**).

Dimension of understanding according to Stone Wiske [1]	Main manifestations
Naive understanding	• Characterized by a disconnection from real life • Lack of reflective ways about which knowledge is expressed
Understanding of newbies	• Describe the purposes of the nature of knowledge • They are linked to mediation systems of tests and schooling systems • Comprehension performance is based on an application mechanism, contemplating the development of a set of steps to achieve something
Apprentice comprehension	• Reproduce disciplinary ways of thinking • Flexible use of these ideas within a specific discipline. According to Stone Wiske [1] "the construction of knowledge is seen as a complex task, which follows procedures and criteria that are prototypically used by experts in the domain" (p. 240)
Master's comprehension	• Operate through integration: flexible, holistic • The student moves with flexibility between each of the understandings indicated above • Complex knowledge construction, resulting from complex interactions, confrontations • They use knowledge to act in reality, to intervene in it and transform it • Foster a disciplinary (meta-disciplinary) understanding, the subject of learning combines several disciplines to solve a particular problem

Source: Stone Wiske [1].

Table 2.
Understanding styles.

Dimension of understanding	Central idea	Criteria associated with this dimension
(a) Content	It corresponds to the first level of understanding, it refers punctually to the data, procedures and routine information. In this stage, the fundamental is given by the mechanization and reproduction of knowledge, and not by the active use of it. Level referred to the delivery of large corpus of information	• Transformed intuitive beliefs • Consistent and rich conceptual networks
(b) Methods	It corresponds to the second level of understanding. At this level, knowledge and practice are integrated to solve typical problems of a subject or a field of professional action. Through this level, the student becomes aware of the strategies and processes developed or developed to solve the problem or activity	• Healthy skepticism • Knowledge construction from the interior of the domain • Validate knowledge in the domain
(c) Summary of the purpose dimension	At this level the student must have already acquired and internalized the most relevant theoretical information, having identified the mental processes or cognitive strategies that will allow him to apply this knowledge. The task of understanding is now to generate explanations, justifications on the subject under study	• Consciousness of the purposes of knowledge • Multiple uses of knowledge
d) Ways of communicating what has been learned	Knowledge and practice concerning the way in which the results are discussed and new knowledge in the subject or subject is constructed. Strategies at this level are aimed at raising hypotheses, questioning information, etc.	• Mastery of the genres of realization • Effective use of symbol systems • Consideration of the audience and context

Table 3.
Dimensions of understanding.

6. Conclusions

6.1 The evaluation: demonstrate what has been learned, emphasize the perspective of performance

Orchestrating an evaluative system focused on understanding, that is, on the perspective of performance, suggests consolidating an interpretative path on the representational vision of learning and its functional architecture. It consolidates an evaluative perspective focused on performance, that is, on the demonstration of what has been learned-flexible action-, correspond to activities that demand putting their understanding at stake. It is an evaluation system characterized by strengthening comprehension performance, conceived as a flexible performance criterion [10]. The vision of understanding linked to performance is what allows us to recognize the multidimensional manifestations of nature and understanding. Evaluating comprehension implies attending to the flexibility of the different ways of demonstrating what has been learned-delements-. According to this, understand.

> *[...] means nothing less than being able to perform flexibly in relation to the [content] topic: explain, justify, extrapolate, link and apply in ways that go beyond knowledge and routine skill. Understanding is a matter of being able to think and act with flexibility based on what one knows. The capacity for flexible performance is understanding ([10], p.73).*

In this conception, comprehension performances are evaluated, that is, activities that go beyond information, memorization and typical routinization strategies that mutilate intelligence. Crystallizes a direct evaluation of the student's performance, that is, *"understanding-as-vision requires reaching a mental representation that captures what is to be understood"* ([10], p. 75). Performance is evaluated—demonstration of what has been learned—and the mental representation that each student produces, in order to determine qualitatively, their levels of understanding reached. He is interested in unveiling the action plans articulated by each learner. This evaluative perspective aims to strengthen teaching processes and deficits linked to understanding.

This conception of evaluation centralizes its activity in the multidimensional process of comprehension, allows the teacher to know what has been understood and, from there, trace the possible routes for the enhancement of learning. Among its most relevant purposes are: (a) diagnose, it allows to know what are the ideas of the students, the errors in which they stumble, the main difficulties with which they are, the most important achievements they have achieved. (b) Dialogue: the evaluation should be a conversation instance about learning and discussion about teaching, but this dialogue must be guaranteed by mutual respect and trust. (c) Understand: evaluation is a phenomenon that facilitates the understanding of what happens in the teaching and learning process. (d) Feedback: the evaluation must facilitate the reorientation of the teaching and learning process. Not only in what refers to the work of the students but to the planning of the teaching and (d) to learn: the evaluation allows the teacher to know if the methodology is adequate, if the contents, if the contents are relevant, if the learning that is has produced is meaningful and relevant to students.

The ideas described below acquire a transverse nature, since they are applicable to both formal and alternative procedures in the evaluation. It is necessary that teachers constantly take these ideas into account as it will allow them to identify the critical points that are affecting their learning-teaching process. Among the main aspects to assess comprehension, the following stand out: (a) the procedures used to evaluate must consider all aspects of the knowledge and abilities that are intended to be developed, by confronting constants of cognitive challenges aimed at increasing the reflective commitment of each students, about what they learn. (b) The evaluation must be developed through authentic learning evidences, clearly explaining the typology, characteristics and nature of the learning to be achieved. (c) The evaluation criteria must be known, shared and comprehensible by the students, so that they are aware of what is evaluated, how they are evaluated and for what they are evaluated. It is recommended that they be built jointly between the teacher and the student body, in order to strengthen the culture of thought and intellectual passions in the classroom. (d) Evaluative procedures should be designed in consideration of the levels and features of understanding, taking as a frame of reference the nature of the knowledge at stake, its forms of application for everyday life, multiple forms of connection with other knowledge, etc. First of all, they will promote spaces for permanent demonstration of what has been learned. The evaluation in the Teaching for Understanding assumes the challenge of designing spaces, strategies and evidence of learning in which students can demonstrate the degree to which they have acquired the defined abilities for each subject and disciplinary field.

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Metacognition skills have been proven to have a positive relationship with learning. The strength of metacognition relies heavily on self-efficacy where a student understands his/her learning style, and the ability to use information gathered and align it with his/her learning style. In addition, knowing what you know and how you know it as a student plays a huge role in knowing what you do not know and linking it with what is close or relevant to it, that you know. It is about having skills and knowledge that empowers you to be an independent learner. Literature on classroom practices show a number of short-comings in diverse areas such as poor teacher knowledge, overcrowded classrooms, and lack of resources for learning. An independent student will strive under such an environment by studying independently, searching for resources, and finding multimodal ways of learning. It is also important to note that naturally, human beings are curious and want to learn in order to conquer their world. Hence, Piaget's work of intellectual autonomy cannot be ignored when exploring metacognition. If learning experiences were ideal and developmental, they would be no need to nurture metacognition. Unfortunately, the education systems remove students' curiosity by bringing fake environments into learning that impede creation and imagination. This book emphasises the power of metacognition at different levels of learning. It can be seen as a parallel intervention approach, with expanded knowledge on how to extend existing skills for young children, which is a pre-intervention. Authors in this book bring diverse viewpoints from diverse fields on how to nurture metacognition, thus giving the reader an opportunity to borrow strategies from other fields. This contribution is a mixture of empirical contributions and opinion pieces informed by review of literature.

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