ILLUMINATING MENTAL REPRESENTATIONS-USE OF GESTURES IN TEACHING AND ASSESSING UNDERSTANDING OF COLLEGE BIOLOGY

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Abstract

Does nonverbal cues increase the propensity of teachers' instructive discourse and at the same time assesses students' cognitive construction of knowledge? The researches that attest to the effectiveness of gestures are by far those conducted on younger children. Few of such research have been done on college students and in Science subjects. As such a randomized pretest-posttest control group quasi-experimental design of 14 matched pairs were tasked to watch one of the two videotaped lessons on a topic in Biology. In the video-cum-slides-plus-gesture lesson, the teacher produced gestures to illustrate concepts while in the video-cum-slides-only lesson the teacher did not produce any gestures. In a post-test of 10 Multiple-Choice-Questions attempted by these 28 students, students who watched video-cum-slides-only lesson scored a mean of 7.6 while students who watched video-cum-slides-plus-gesture lesson scored a mean of 6.2. 7 of these matched pairs further underwent a feedback session with the teacher while the other 7 did not. A follow up test showed that students who had feedback given scored higher and progressed from a discordant stage of gesture-speech mismatch to the concordant stage of gesture-speech match of a right concept while those without feedback regressed.

Chapter 1: Introduction to the Problem & Literature Review

Vygotsky in his works on 'Thoughts and Language' espoused the existence of consciousness intertwined with inner and external speech. He elaborated that external speech is not simply the manifestation of the inner speech rather it is an outcome of only a specific dimension of inner speech. Inner speech has its own semantics, structure and encompasses beyond the motor skill of speaking; it covers the impalpable, non-sensory and non-motor speech aspect of cognition (Vygotsky, 1934).

This area of inner speech has been almost inaccessible to experiment until Jean Piaget discovered the existence of cognitive egocentricism and the manifestation of egocentric language in young children (Piaget, 1953, 1959) which in turn led to countless research to unravel the nature of inner speech. Such investigations threw light to the paramount role gestures play in consciousness, (Hopkin, 2007) communication, (Goldin-Meadow et al, 1994, Goldin-Meadow, 2000, Alibali & Heath, 2001 and Tomasello, Carpenter & Liszhowski 2007) cognition (Alibali et al, 1999, Goldin-Meadow, 1999 and Gershoff-Stowe & Goldin-Meadow, 2002) and in the evaluation of learning (Church & Goldin-Meadow 1986 and Alibali & Goldin-Meadow 1993).

Therefore, this attest to the propensity gestures exhibit in contributing to the instructive discourse of abstract concepts in Science teaching and learning (Crowder, 1996) especially in a large class size of 250 students where inquiry-based and problem-based pedagogies are limited (Brew, 2003).

Consisting of three parts, this paper (1) explores the challenges Pre-University educators faced in this revised JC curriculum and proposes a new model termed Science Speech (an extension of Crowder's Science Talk model, 1996 with the inclusion of recent developments on the role of gestures in learning) to assess student's learning (2) investigates the use of gesture in Science teaching in a mid range college in Singapore, and (3) analyzes the use of gesticulated feedback to assess students' learning of Biology via gesture-and-speech matches in Science Speech model.

Singapore's Pre-University Education and its Challenges

Since her independence, Singapore has been transformed from an equatorial 'fishing village' into one of the world's most competitive economy. This is very much due to the imperative focus Singapore has on the development of human resources which has led to her ability to stay abreast with the ever changing economy. These include the use of the education system as an instrument for nation building and an upgrade of the workforce's technical knowledge. Consequently, there is a doubling in the percentage of 'A' level students enrolled into the universities.

However, this shift from an industrial to a knowledge-driven economy has also brought forth new challenges, the education system that have served us well for the last three decades has become inadequate in meeting the demands of the 21st century. The education system of the 20th century has shaped a workforce that is good in following instructions and managed decisions based on a set of rules and regulations which is contrary to the workforce requisite for the knowledge-driven economy of the 21st century. The latter requires a workforce that is creative, proactive, and enterprising; equipped with good problem solving skills, (Brown & Lauder, 2001).

As such a Junior College and Upper Secondary Education Review committee, chaired by then the Minister for Education and Second Minister for Finance Tharman Shanmugaratnam, was conceived in April 2002 to develop a revised JC curriculum framework to better equip our students for this ever-changing world and to keep Singapore viable in this knowledge-driven economy. This committee which consisted of high level stakeholders from the Politics, Education, Private and Public Sector held 22 public consultation and dialogue sessions with professionals, employers, academic, parents, teachers, undergraduates, JC and secondary school students and drew insights from visits and study of school systems in United Kingdom, United States, Hong Kong and China recommended two main thrust of change, (Report of the Junior College/Upper Secondary Education Review Committee, 2002).

They are the introduction of a broader and more flexible JC curriculum that better developed students' thinking skills to engage them in greater breadth of learning; and the creation of a more diverse JC and Upper Secondary education landscape. For the purpose of this paper and the relevance of this topic, I will only discuss the reality in the classroom that I have observed during the course of the introduction of the revised JC curriculum and the challenges that pre-University educators faced amidst this change.

Firstly is the greater focus on skills, much more than content, where teachers are tasked to develop conceptual thinking, data response and communication skills in the students with a greater emphasis on independent learning and creative exploration. Such endeavours require both skilful expertise of teachers (Adey, 2006) and time for students' exploration (Falk, 2005). This is because the development of students' thinking requires pedagogical skills which are different from those of normal, good quality teaching for conceptual development. It requires the active engagement of students in cognitive conflict, social construction and metacognition. Such a change in teaching practice as suggested by (Adey, 2006) takes a long time, requires effort to affect a paradigm shift among the teachers and necessitates assistance for teachers in their own classroom. Here teachers not just have to understand how creative problem solving works, they have to sharpen their problem finding skills, develop a good blend of creative styles, be passionate in teaching their subject area and learn to take calculated risks, (Ng, 2004 & 2007). Such transformation in teaching pedagogies brings about cognitive dissonance which results in resistance among teachers to such change.

In addition, cultivating mental habits of creativity necessitated by the Education Review requires curiosity, resilience; experimentation, attentiveness and thoughtfulness as proposed by Claxton et. al (2006) and cultivating such dispositions need time to engage the students in active questioning. However with the reduction in curriculum time from a 7hr/week of a Science Subject Lesson to a 6hr/week, teachers find it a challenge to engage students in active questioning and to nurture their inquisitive minds to foster creativity in them.

Secondly is the allowance of more flexible options where subjects are redesigned to give the students flexibility to decide on the scope and depth of content they would want to take. Here content-based subject can be offered at Higher 1 (H1) or Higher 2 (H2) levels, where the H2 is equivalent in rigor to the previous 'A' level while the H1 is equivalent to half the content of H2. The purpose of such flexibility is to allow students to take a broad spectrum of subjects so as to develop them holistically. As such each student is required to take at least 3 H2 and 1 H1 content-based subjects where one of them must be a contrasting subject. This is over and above Project Work, Mother Tongue and General Paper which inevitably increases the students' workload as the previous 'A' level syllabus only requires them to only take 3 subjects at 'A' Level, Project Work, Mother Tongue and General Paper. Furthermore, a board base education also entails students reading subjects at the Pre-University Level which usually are not of their strength. This certainly adds on to the level of stress of these young adolescent as taking on an extra subject which is not their forte would mean expending more time trying to comprehend this subject and at the same time coping with the rigor of the revised curriculum.

Thirdly is alignment of teaching and assessment methods with the objectives of the revised JC curriculum where more emphasis is placed on assessing critical and creative skills within the traditional mode of pen and paper. Such a change in assessment method is important if we are to move away from rote learning and content mastery of the students. This is because teachers are bounded by their need to stratify their students and hence they are inevitably locked into particular types of assessment due to examinations requirements and university guidelines. Therefore, in light of such change, teaching strategies should take the form of inquiry-based learning where students construct new knowledge based on existing ones, formulate questions and procedures to test questions and problems; or problem-based learning where students identify important information, generate ideas about what is happening, attempt to answer the problem with what is already known, decide what is not known, study and return with new knowledge for discussion (Savin-Baden, 2004).

Though such changes in teaching strategies are essential to imbue in the students skills to think critically and creatively, there exists a fundamental problem of having <u>large class sizes of 250 to 700</u> in a lecture theatre where inquiry based and problem based learning proved futile in bringing about such change (Falk, 2005).

Thus in view of these constraints, the use gestures can be an avenue to scaffold and assess students' learning of abstract concepts in the topic of Organisation and Control of Eukaryotic Genome in Biology among adolescents in a mid range Junior College of Singapore to determine its effectiveness in Sense-Making Science Speech.

This is because gesticulation accompaniment in teaching does not necessitate teacher learning new pedagogies, requires little or no extra curriculum time in implementing, result in no elevated stress among students and circumvent the standing problem of having large lecture sizes of 200 students in a lecture theatre.

Furthermore, gestures may illuminate students' mental representation and assist teachers' arrest student's alternative conceptions and determine students' readiness to learn new concepts.

Gestures Defined

Gestures come into existence with consciousness as first proposed by Thao, Herman & Armstrong (1986) which is later proven by Hopkin, (2007) whose research into the central thalamus of the brain revealed starling discovery that this area is involved in motor control, formation of gestures and in relaying signals to the cerebral cortex of the brain where consciousness originates. However, this medical breakthrough is of no surprise to many, as linguists, anthropologists, psychologists (Tomasello, Carpenter & Liszhowski 2007) and educators have long advocated the paramount role gestures play in the construction of language (Kendon, 1997), cross cultural communication (Kendon, 1997), and in recent years in the field of teaching and learning (Goldin-Meadow et al, 1994, Goldin-Meadow, 2000, Alibali et al, 1999, Alibali et al., 2001, Gershoff-Stowe & Goldin-Meadow, 2002, Roth, 2001).

In fact, Carpenter, Nagell, Tomasello, Butterworth and Moore (1998) and Tomasello et, al (2007) revealed in their monographs for Research in Child Development, that infant gestures began at around one year of age, even before language emerges and that this is a uniquely human form of communication that rests on a very ‘complex social-cognitive and social-motivational infrastructure of shared intentionality’.

However, gestures do not just occur among infant. It is seen as frequently in the young as in the old. Gesture and speech are often regarded as two aspects of a single process (Kendon, 1997 and McNeil, 1992) where gesture is usually perceived to be the visible act of a dialogue with both the visible (gesture) and the audible acts (speech) being completely interwoven together (Bavelas and Chovil, 2000).

Even with such amalgamation, Kendon (1996) has defined gesture technically to be one that is symmetrical and has a clear beginning and end, with a peak structure or ‘stroke’ to denote the meaning of the movement. He explained that gesture usually begins from a position of rest, move away from the body and return back to the position of rest. McNeil (1992) has successfully categorized gestures into a continuum and superimposition of beat, deictic, iconic and metaphoric.

Beat gesture is distinct from the rest of the gestures in that it is a non pictorial gesture that simply could be the tapping motions or up and down flick of the hand to emphasize certain utterances. It is usually process oriented (Crowder, 1996) and plays minimal role in the instructive discourse of information as illustrated by Alibali and Heath (2001) where it was noted that the frequency of beat gestures remain unchanged regardless of the visibility of the speaker to the listener.

Deictic gesture refers to concrete pointing that represent concrete attributes or relationships between characters and is usually context dependent and content oriented (Crowder, 1996). Deictic gestures can be sub-typed into spatial deictics where gestures are used to convey direction of movement or literal deictics where gestures are used to indicate concrete objects or similar ones (Alibali et al., 2001).

Next, iconic gesture which is also known as representational gesture or lexical gestures, (Roth, 2001) is one whose movements bear a direct relationship with concrete events or entities in a narrative structure e.g. drawing an aptitude to signify action potential in Biology. This gesture is usually content-oriented as findings reported that this gesture frequency increases when speakers could see their listeners and lower when speakers could not see their listeners (Alibali and Heath, 2001).

Lastly, metaphoric gesture is a three dimensional, content-oriented gesture (Crowder, 1996) that is used to shape an idea; and whilst it is similar to iconic, its abstract content is usually referred to metaphorically and could be in the form of an imagery of objects, space and movement (Roth, 2001).

Analogous to languages, gestures has its own nouns and verbs, as Goldin-Meadow, Butcher, Mylander and Dodge (1994) illustrated in their case study on a hearing impaired boy born of hearing parents who displayed a set of gestures as verbs and another set as nouns to illustrate the difference between them. These gestures are significantly different from those of his hearing parents and unlike any of those in the American Sign Language. Hence, gestures, akin to any universal language have its own structure and function that is able to communicate information to untrained listeners.

Role of Gesture in Teaching and Learning

Beyond its role as a language in communication, gesture is instructive to learning by revealing knowledge not expressed in speech as shown by Alibali et al (1999) where speech and gestures provide a more complete representation of solution strategies in solving Mathematical problems than via speech alone. This is seen when 20 undergraduate students were asked to solve a set of 6 structurally analogous word problems that involved constant change. In instances where gestures reinforced speech; participants were very likely to use solution compatible with the verbal representation. However, when gesture was neutral with respect to speech, participants used the strategy compatible with the verbal representation less often and when gesture conflicted with speech, participants used the problem solving strategy expressed in gesture more than the strategy expressed in speech. This is indicative that gestures are produced from the deep recesses of the brain which is heavily involved with knowledge construction that necessitates cognitive development.

Besides, gesture-speech relationship is also used as an indicator of what learners already know and their readiness to learn. Church & Goldin-Meadow (1986) revealed that when children have a mismatch in gesture and speech, the child actually has 2 distinct ideas- one in speech and the other in gesture, which in turn will cause them to activate both ideas when solving problems. This is a stage of cognitive discordance which increases the child receptivity to instruction and learning. Consequently if this mismatch is not rectified, regression of receptivity to instruction and learning also occurs.

Alibali & Goldin-Meadow (1993) extended the earlier findings and threw light on cognitive transition in children. They reported that changes in gesture-speech relationship reflect knowledge change where each child transits from a stable cognitive concordant state in which the child produced gesture-speech matches conveying incorrect procedures to an unstable cognitive discordant state in which gesture-speech mismatches occur and finally to a stable cognitive concordant stage in which the child produced gesture-speech matches conveying correct procedures. Such findings are especially useful in arresting learners' discordant stage and in ascertaining that students shift from gesture-speech matches that convey incorrect procedures to gesture-speech matches that convey correct procedures.

Gestures also play a quintessential role in teaching where gestures though non-deliberate contribute to both the thinking and instructive process. This is seen when the frequency of beat gestures remain the same regardless of the visibility of the speakers to the listeners (Alibali and Heath, 2001) which validates Baveles and Chovil (2000) findings that gestures are non-deliberate and are produced as means of drawing out ideas, not simply just as a form of communication.

Moreover, research by Goldin-Meadow, S., Kim, S. & Singer, M. (1999) revealed that gesturing in Mathematic instructions aid in the instructive process of teaching Mathematics where children are more likely to reiterate the teacher's speech if it was accompanied by gesture than having no gesture at all. Consequently, these young children are even less likely to reiterate speech if the speech was accompanied by mismatching gesture than no gesture at all. These findings suggest that gestures are pivotal in the instruction and comprehension of abstract concepts.

However, despite the numerous extensive researches on the origin of gestures that revealed the propensity gestures have in illuminating mental representations of human cognition and the revelation of the inner speech of human consciousness, (shown in Table 1) not much research has been conducted in the field of Science were abstract concepts are rampant, e.g. solubility product and mole concepts in Chemistry, forces and electricity in Physics; signal transduction and control of eukaryotic genome in Biology.

This could be because Science Educators are bombarded with incessant approaches in Science Teaching such as the use of Information and Communication Technologies, Problem-Based and Inquiry-Based Learning Strategies with the newly expanded 7E approaches namely, elicit, engage, explore, explain, elaborate, evaluate and extend (Eisenkraft, 2003), Collaboration and Cooperative Learning strategies such as Think-Pair Share, Three-Step Interview, Round Table, Jigsaw and Rally Robin, that an investigation in the use of gestures in Science Teaching may prove futile.

Nonetheless, these teaching pedagogies are either limited in a large class size or require extensive planning that an educator simply do not engage in due to constraints in curriculum time and the need to prepare students for high stakes examinations.

Thus it is in response to these reasons and the challenges educators faced in the revised JC curriculum framework, this study was conceived to propose a new model, termed Science Speech to investigate the use of gesticulation accompaniment in scaffolding and assessing students' understanding by providing the grounding necessary in the instruction discourse on the topic of Organisation and Control of Eukaryotic Genome in Biology.

Authors	Sample	Research Design And Instrumentation		Results
Church and Goldin-Meadow (1986)	28 students ages 5-8	Investigate the implications of frequent mismatch between gesture and speech in child's explanation of concept. Videotaped the testing task of these students on 3 quantity concepts • 2 liquid quantity task • 2 length task • 2 number task Each task consist 3 phrases 1. Initial equality 2. Transformation 3. Final equality	Separate coding of gestural and verbal explanations. Coding of verbal explanations into (1) Equivalence explanations (2) Nonequivalence explanations (3) Non-comparative explanations Coding of iconic gestures into: (1) Action gestures that portray motion used to transform task. (2) Attribute gestures that portray characteristics of task objects Coding relationship of speech & gestures (1) Concordant explanations (2) Discordant explanations	Children are likely to produce gestural explanations along with their speech when asked to give explanations. The concordance and discordance between gesture and speech can be used as an • Index of what the child knows • Index of how consistently the child knows • Index of translational knowledge and readiness to instruction. Discordant children were more likely to acquire new equivalence explanations after training.
Alibali and Goldin-Meadow (1993)	90 4th grade students obtained from classes of 6 schools and divided into 3 groups.	Investigate gesture-speech mismatch and the mechanisms of learning in young children. Selection based on pre-test Divided into 3 groups to solve and explain a series of 12 addition problems and receive different kinds of training experience: 1. No instruction No feedback 2. Addition With feedback given after every problem. 3. Addition+Multiplication To generalize their knowledge in new operation of 6 multiplication questions. Administer Post test. Administer Follow-Up test	Separate coding of gestural and verbal explanations. Coding of solutions: Solutions of the Maths problems were coded within ±2 of the answer. Coding of Explanations: Categorized into a set of 6 qns/child namely pre-test, 1st training, 2nd training and multiplication. • Types of explanation in speech alone in 6 basic steps of spoken explanations e.g. Grouping, Add-Subtract, Equalizer, Add All, Add to Equal and Carry Types of explanation in gesture using lexicon gestures (Perry et al 1988) • Relationship between gesture and speech where if gesture and speech do not match, they are considered as mismatch and if they do, they are coded as gesture-speech match.	Learning transits between these 3 stages: • A stable state in which the child produced gesture-speech matches (accessible by both gesture and speech modes) conveying incorrect procedures • An unstable state in which the child produced gesture-speech mismatches where the child is in discordant stage and is most accessible to instruction and at risk to regression if mismatch is not rectified (accessible only by gesture mode) • A stable state in which the child produced gesture-speech matches conveying correct procedures. (accessible by both gesture and speech modes) Students who skipped the mismatch and go directly from incorrect to correct concept do reliably less well.
Crowder, (1996)	Observation on two 6th grade white, middle class classrooms, two 6th grade ethnically mixed classrooms and two 6th grade African American inner city classrooms	Investigate which type of gestures distinguish 'describing a model' or 'running a model' of language activity. Videotaped focal lessons on students' explanation on shadows and seasonal change using models, props or enactment on the changing earth-sun relation as shadows change length or as seasons progress from winter to spring, summer and fall	Analyse the performances of students that has been previously coded as describing a model or running a model Describer of a model • Is teacherly • Demonstrates an understanding • Can perform one's understanding • Communicates that one already understands • Gestures more for the audience Runner of a model • Is figuring things out • Publicly constructs understanding • Revises and repairs understanding • Communicates while in the process of understanding • Gestures more privately	Describing a model language: 1. Gestures such as pause-filling beats 2. Eye gaze towards audience 3. Gestures less frequently 4. Gestures are with or follow speech 5. Gesturer remained outside the gesture space 6. Communicate fluently with less midphrase hesitations Running a model language activity: 1. Deictic and beat like gestures 2. Eye gaze directed at gestures 3. Gestural foreshadowing 4. Gestures are with or follow speech 5. Gestures are used to adjust components in an overt model 6. Communicate with numerous verbal and gestural hesitations.

Authors	Sample	Research Design And Instrumentation		Results
Goldin-Meadow, Kim and Singer (1999)	8 teachers (6 females and 2 males) who had formerly or is currently teaching Maths. Each has 9.6 years of teaching experience	Investigate the contribution of nonverbal behavior to cognitive and affective components of teaching Videotaped each teacher who will individually instruct 5-7 children within a 20min/session in the child's school using the pre-test addend questions as a guide.	Coding of gestures • Correct strategies lead to correct solution if implemented • Building strategies are strategies that are used to break the problem into parts • Incorrect strategies lead to incorrect solution if implemented Coding of types of turns Coding of relation between teacher's strategies and child responses.	Correct strategies display • High speech and gesture match • Low speech & gesture mismatch • Low speech without gesture Incorrect strategies display • Low speech and gesture match • High speech & gesture mismatch Building strategies display • High speech and gesture match
Alibali, Heath and Myers (2001)	16 (8 males & 8 females) undergraduate who are chosen based on a post-experiment questionnaire	Investigate whether speakers use gestures differently when visible/invisible to listeners. Videotaped story narration which involved (a) retelling the cartoon after watching a cartoon (b) listening to another person retell the cartoon.	Classification of gestures: Beat gestures and Metaphoric gestures which include: (1) iconics, (2) metaphorics, (3) spatial deictics (4) literal deictics Uses rate of gestures/100 words as the dependent measure.	Speakers produce comparable beat gestures regardless of their ability to see the listeners. However, speakers produce more iconic/representational gestures when they could see their listeners and lower when they could not. The rates of iconic/ representational gestures remain high even when the speakers could not see their listeners.
Valenzeno, Alibali and Klatzky (2003)	25 children (12 boys & 13 girls) from 2 preschool classes with a mean age of 4 years and 6 months	To investigate whether teacher's gestures influences students' learning. 13 students watched verbal only video lesson 12 students watched verbal+gestures video lesson Post test on judgement and explanation of 6 line drawings of familiar objects. Children's answers were videotaped and transcribed.	Coding was done on children's 1. correct judgement • one point for each correct judgement. 2. Symmetry explanation • Scored between 0-6 based on correct explanation due to (i) Content (a) Sides explanation (b) Mirror explanation (c) Halves explanation (d) Irrelevant (e) Don't know (ii) Correctness (iii) Presence of gesture	Children who saw verbal+gesture videotaped lesson provided a small and non-significant margin of correct judgement on more items than children who saw verbal only videotaped lesson. However these children who saw verbal+gesture videotaped lesson provided more combined judgement and explanations than children who saw verbal only videotaped lesson.
Alibali and Nathan (2004)	6th grade mathematics lesson on algebraic equations in a suburban community, 'middle-school' philosophy	To investigate the use of gestures in instructional communication along with speech to scaffold students' understanding. 14 minutes video excerpt from a 90 minutes class of the entire teacher's discourse, including verbal utterances & arm movement.	Coded as idea units of utterances such as: Speech with pointing Speech with writing Representational gesture Use 3 categories of referents 1. Depictions of a **pan** balance 2. Visible **equation** used to model the pan balance 3. **Conceptual Links** between the pan balance and the equation.	The more abstract the concept, the more gesture is used as a form of grounding in instructional teaching Conceptual Links>>Equation>Pan In Speech with Pointing: Conceptual Links>Pan>Equation In Representational Gesture: Pan>Conceptual Links>Equation In Speech with writing: Conceptual Link>Equation>Pan
Cook and Goldin-Meadow (2006)	49 3rd and 4th grade children were selected based on their unsuccessful pretest results.	To investigate the role of gestures in learning. Each student was given instruction on 6 Math problems with addends and with or without gesture. Videotaped each student explanation of their solutions to the experimenter. Posttest	Speech and gesture coded separately Tabulated the number of times each child produce an equalizer strategy (strategy taught by instructor) in speech or in gesture during the instruction period	Instruction that included a correct problem-solving strategy gestures was significantly more likely to produce that strategy in the children own gesture than children who are not exposed to it during the same period of instruction. These students are hence more likely to retain and generalized the knowledge than those who do not (not quite proven).

Authors	Sample	Research Design And Instrumentation		Results
Kerfelt (2007)	17 preschool teachers from 17 different departments and 34 children.	To investigate how gestures and utterances are used as resources in the interaction between children and teachers Each teacher was to sit with 2 children, one at a time at a computer to create a story. Interaction was observed.	Coding was through the use of (i) Verbal utterances for inter-subjectivity using a 3 stage method: Teacher utterance → Student response → Teacher response (ii) Gestures (iii) Visualisations on computer screen For 2 areas, namely: (1) technical functions, (2) dialogues that involves around the content and structure of the story	Teacher instructions have different structures depending on whether they are directed towards technical functions of the computer, content and structure of the stories or a dialogue. When dealing with technical functions of the computer, verbal utterances and indexical gestures are used, but they do not extend beyond instructions. When dealing with creation of content and structure of a story with visual image and reciprocal dialogues, an adequate amount of verbal language with an adequate gesticulated language is needed for meaningful learning.
Cook, Mitchell and Goldin Meadow (2008)	84 3rd and 4th grade children selected based on failing pretest results.	To investigate whether gestures play a role in children learning a task. Children are randomly assigned to 3 conditions and are asked to mimic the pre-instructions 3x. 1. Speech only condition Pre-instruction given verbally. 2. Gesture only condition Pre-instruction given gesturally. 3. Speech+Gesture condition Pre-instruction given verbally and gestures simultaneously.	Instructor taught equalizer strategy to all the children by solving 6 problems in speech and in gestures. Each time repeating 2x for each problem, altogether Each student to solve one problem, reproducing the pre-instruction behaviour they had mimicked before & after solving the problem. Post test Follow-Up test 4 wks later. Compare the results of post test and follow up test.	All children improved with instruction; hence the pre-instructions behaviour did not affect children's understanding of the experimenter's instruction. Children from Gesture + Speech group and Gesture group retained their knowledge longer than Speech Group as shown in the follow-Up test. This shows that gesturing promote learning in the one month later follow up study and not in the immediate post test.
Ping and Goldin-Meadow (2008)	61 ethnically mixed kindergarten and first-graders (35 5-year-olds, 22 6-year-olds, and 4 7-year-olds) from Chicago public and private schools.	To investigate the possibility that gesture helps children learn even when it is produced "in the air." Students are selected based on their failing Pre Test score and explanation of 8 conservation tasks. Children were randomly assigned to one of the four conditions for instructional delivery: 1. Objects present–gesture plus speech 2. Objects present–speech alone; 3. Objects absent–gesture plus speech; and 4. Objects absent–speech alone. Posttest comparable to the pretest without feedback.	Coding of the equality judgment (same or different) and problem solving explanation that the child gave for each question during the pretest, instruction, and posttest was done • Speech without the gestures • Gesture without the speech children who produce gesture–speech mismatches on conservation task was excluded from the analyses.	Children in all four groups solved approximately the same number of problems correctly on the pretest. There are no significant differences between the gesture-plus-speech and speech-alone groups, and no significant differences between the objects-present and objects-absent groups. Children in all four groups also expressed approximately the same number of correct explanations in speech on the pretest. There are no significant differences between the gesture-plus-speech and speech-alone groups; and no significant differences between the objects-present and objects-absent groups. Hence adding gesture to instruction allowed children to go beyond what they had been taught, helping them develop additional ways to explain why but only when the task objects were absent during instruction.

Table 1: Summary of the major studies about the role of gestures in teaching and learning

Science Speech Model in Singapore's Pre-University Education

Science Talk, first suggested by Crowder (1996) as shown in Figure 1, comprised of Sense Making and Knowledge Transmission where Sense Making is the mediation of collective explorations and experimentations involved in the cognitive construction of mental representations concerned with active discovery while Knowledge Transmission is simply the relaying of ideas and prior discoveries from one person to another with or without having to make sense out of these ideas.

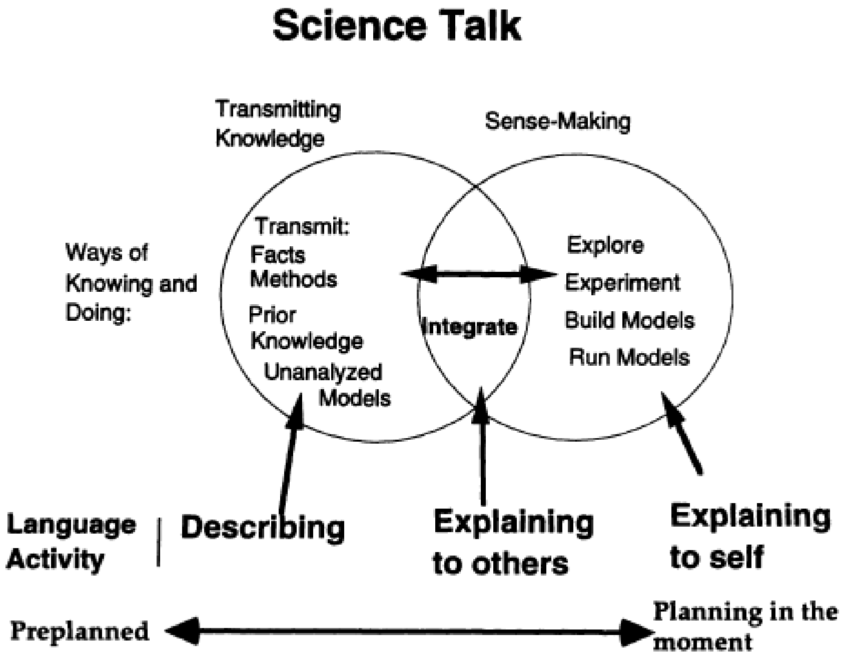


Figure 1: A model of 2 types of Science Talk-sense making and Transmitting Knowledge, Crowder (1996)

The difference between these two languages in Science Talk is the stance each takes to learn Science. Sense making in Science Talk is one who publicly constructs understanding, communicates while in the process of understanding, revises and repairs one's understanding and who gestures privately to help in one's reasoning. This language activity termed as 'Runner of a Model', usually assist one in conceptualising a subject or topic.

On the other hand, Knowledge Transmission in Science Talk is characterized as one who is teacherly, demonstrates an understanding which may or may not be correct, able to perform one's understanding, communicates what one already understands and gestures more for the audience. Termed as 'Describer of Model', this language is usually used when one transmits preplanned knowledge.

Describer of a Model	Runner of a Model
1. Gestures such as pause-filling beats	1. Deictic and beat like gestures
2. Eye gaze towards audience	2. Eye gaze directed at gestures
3. Gestures less frequently	3. Gestural foreshadowing
4. Gestures are with or follow speech	4. Gestures are with or follow speech
5. Gesturer remained outside the gesture space	5. Gestures are used to adjust components in an overt model
6. Communicate fluently with less midphrase hesitations	6. Communicate with numerous verbal and gestural hesitations

Table 2: Gestural characteristics of these two models in Science Talk, Crowder (1996).

The overlapping region between Knowledge Transmission and Sense Making, denoted by '↔' is the area where students and teachers alike enter into a space between planning-in-the-moment to rote transmission of knowledge, where one is 'able to maintain the explained model while retaining the option to revise and integrate newly synthesised knowledge to existing ones'. This is the area where many researches in the last decade has explored and shed much light in.

As such, with reference to the extensive literature reviews in the area of the role of gestures in teaching and learning, I have extended Crowder's Science Talk model to include these recent findings on how gesticulation accompaniment and the use of gesture and speech relationship can scaffold teaching pedagogies and at the same time illuminate the mental representations of students.

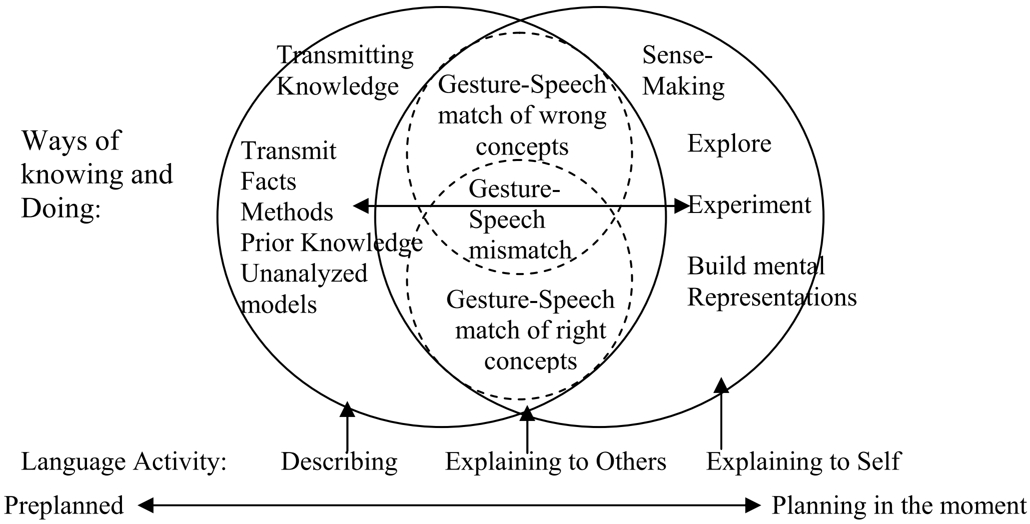


Figure 2: A model of 2 types of Science Speech in Transmitting Knowledge and Sense Making

This extension of Science Talk is re-named as Science Speech (figure 2) because consciousness comes into existence with inner and external speech. The former is illuminated with the use of gesture while the latter is via vocalization (Vygotsky, 1934) and Science Speech is meant to represent mental cognition both in gesture and words.

The inclusion of the gesture-speech relationship in the region of integration of transmitting knowledge and sense-making signifies the cognitive discordance the learner transits between (Alibali et al., 1993), from Gesture-Speech match of wrong concepts to Gesture-Speech match of right concepts. This cognitive dissonance can be elicited as learner attempts to explain his conceptual understanding to others. Here gesture-speech relationship reveals mental representation especially when concepts are abstract and where words fail to sufficiently explain.

Thus Science Speech will be used to assess students' understanding in the abstract concepts of Science especially in the difficult and concept-laden topic of Organisation and Control of Eukaryotic Genome in Molecular Biology, as further illustrated in this paper.

Chapter 2: Methodology

Finally, to address the question on the use of gesture in Science teaching in a mid range college in Singapore, and the analysis of the use of Science Speech model in assessing students' learning of the abstract concepts in the topic of Organisation and Control of Eukaryotic genome among adolescents, a quasi-experimental design, randomized pretest-posttest control group was used.

Here 14 matched pairs (as shown in Annex E) were selected based on their failing Promotional Examination scores on the topic Organisation and Control of Eukaryotic genome, a H2 Biology topic laden with abstract concepts. These students were divided into 2 groups of similar demographics (social economic background and 'O' Level L1R5) to undergo 2 different kinds of instruction. The first group of 14 students attempted a Pre-Test 10 Multiple Choice Questions before they underwent an e-learning instructive discourse on this topic with PowerPoint slides and a talking head. The second group of 14 also attempted a Pre-Test 10 Multiple Choice Questions before they underwent this e-learning instructive discourse on this topic with the same PowerPoint slides and a waist up video recording of the lecturer with the inclusion of gestures.

Beat Gestures

Deictic Gestures

Iconic Gestures

Metaphoric Gestures

also obtained from the students providing the data. This entailed having the participant sign a consent form which detailed the research procedures (as this involves video taping the student interviews) and guaranteeing the protection of the rights of the participants. In addition participants were also informed that they have the rights to withdraw from the study or to request that data collected from them to not be used (Annex C).

The lecturer was selected based both on the level of subject and pedagogy mastery (indicative of having a Degree in the field of Molecular Biology, a major aligned to the topic investigated and had taught for 6 years in a Junior College), quantitative and qualitative evidence of good teaching (proxy using students' test results and anecdotal feedback from students). Since gestures enhanced speech in the teacher's instructive discourse, the latter should translate to better cognitive strategies in the learner's mind hence resulting in better outcomes, indicated by a higher gain score in post test results.

Each group of 14 students were further asked to solve and explain a set of 10 questions that was equivalent to the level of difficulty in the pre-test and a follow-up test 1 week later on another 10 questions of equivalence to assess their retention of knowledge.

These questions were used because they underlined the learning outcomes of H2 Biology and whose content validity and reliability was well established since they were derived from past Cambridge 'A' Level Examinations. Analysis was done on each question to ensure that no questions were repeated and each question tested no more than two concepts. In addition care was taken to ensure that these questions range from simple to more difficult and they were a mixed of 'knowledge with understanding' and 'application questions' so as to provide a range of difficulty.

The Multiple Choice Question framework is presented in the table below.

Questions	Subject Matter Knowledge
10 Questions (Question 1-10)	1. Mutation 2. Steps involved in Gene expression 3. Chromatin modification+ Transcriptional Control 4. Chromatin modification

	5. Transcriptional Control 6. Post Transcriptional Control 7. Post translational Control 8. Protein Synthesis 9. Translational Control 10. Differences between Prokaryotic and Eukaryotic Control

Table 3: Framework of the 'Multiple Choice Questions' on the topic of Organisation and Control of Eukaryotic Genome.

Seven matched pairs (one from each group) were interviewed on their explanation and were given feedback on their explanations of each question while the remaining seven match pair received no feedback. Each explanation and feedback were videotaped and transcribed for their gestural and verbal explanations.

To ensure internal validity, the same interviewer was used throughout the entire interviewing process and in analyzing the data collected. In addition, to address instrument decay, an interview schedule was planned where the interview process was spread out throughout the day to minimize fatigue of the interviewer and that the interview was conducted at the end of the students' lessons so as to ensure that the interview survey was not rushed. A point was of concern was the potential biasness that might arise by the researcher as the data were collected concurrently and especially since it was collected from the same participants and as such, open discussion with the supervisor was necessary to minimize such bias.

The quantitative results obtained from the Post Test were ascertained by calculating the mean test score for the control and experimental groups, followed by the use of Pearson's correlation and Paired sample T-test to determine the relationship between the uses of gestural scaffolding in bringing about conceptual change.

The qualitative data were coded for explanations in speech, in using gestures and in relationship between speech and gestures across four subcategories (Table 3).

Here relationship between speech and gesture could be determined by examining the mental representations presented in speech and in gestures and in comparison of the two mental models. If the mental models converged, this will be termed as Gesture-Speech match and vice versa.

Category 1	Category 2	Category 3	Category 4
7 students who underwent e-learning with PowerPoint Slides and **Talking Head** Solved and explained 10 questions with **no feedback**.	7 students who underwent e-learning with PowerPoint Slides and **Talking Head** Solved and explained 10 questions with **feedback after each explanation.**	7 students who underwent e-learning with PowerPoint Slides and **Video recording of lecturer**. Solved and explained 10 questions with **no feedback**	7 students who underwent e-learning with PowerPoint Slides and **Video recording of lecturer.** Solved and explained 10 questions with **feedback after each explanation.**

Table 4: Four groups of students with four different training experiences

Consequently, if students in category 1 and category 3 **regressed** from a discordant stage of gesture-speech mismatch to the concordant stage of gesture-speech match of a wrong concept while students from category 2 and category 4 **progressed** from a discordant stage of gesture-speech mismatch to the concordant stage of gesture-speech match of a right concept, it will thus support the proposed Science Speech model where the relationship between Speech and Gesture can be used to evaluate students' understanding in Scientific concepts in Science Speech-Sense-Making.

Chapter 3: Findings

Pre-Test Performance

Even though care was taken to ensure that the experimental and control group were of the same demographics and were comparable in calibre, students in the control group generally still scored slightly better in pre-test than those in the experimental group but only by a small non-significant margin. (M=5.8, SE=0.33, vs M=6.2, SE=0.66).

Pre Test Score		Experimental Group	Control Group
N	Valid	14	14
	Missing	0	0
Mean		5.79	6.21
Std. Error of Mean		0.33	0.66
Median		6.00	6.00
Mode		6.00	5.00

Std. Deviation		1.25	2.46
Variance		1.57	6.03
Sum		81.00	87.00
Percentiles	25	4.75	4.75
	50	6.00	6.00
	75	7.00	8.25

Table 5: Pre-Test Score of Experimental and Control Groups

Post-Test Performance

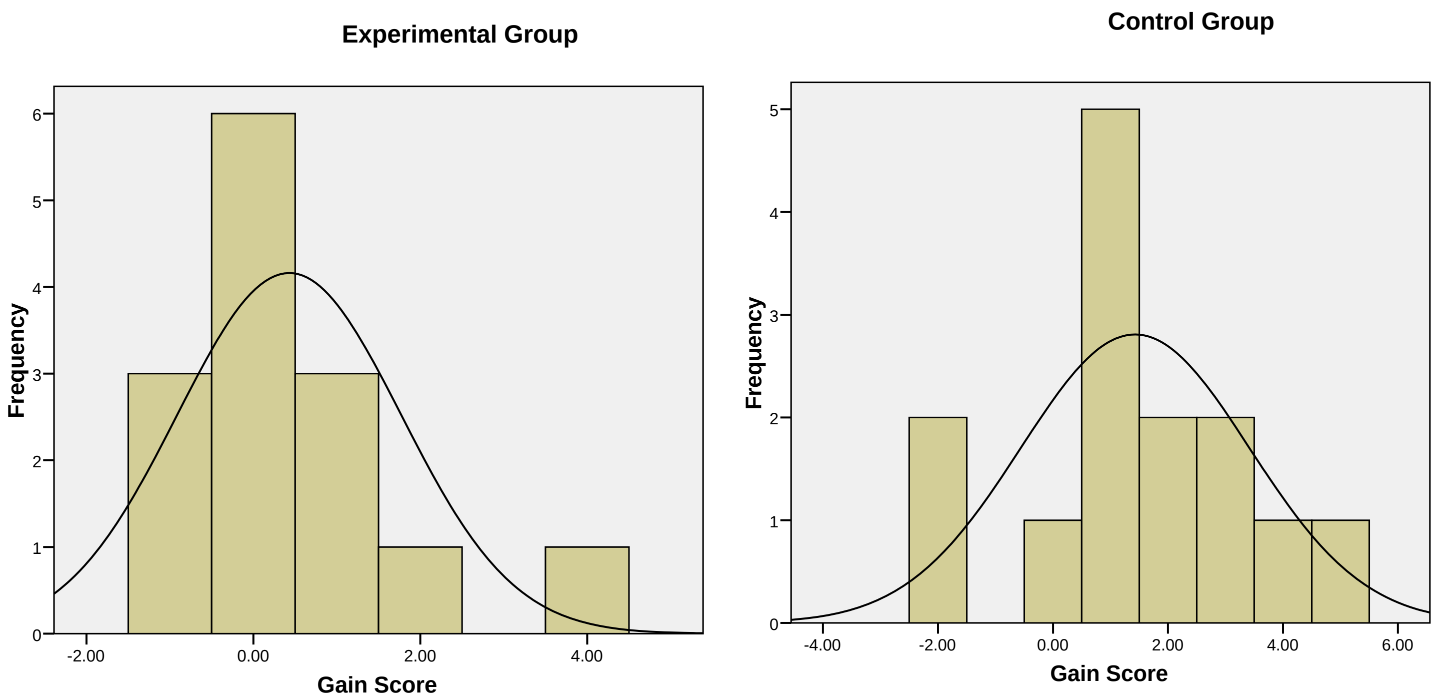
In a post-test of 10 Multiple Choice Questions attempted by these 28 Junior College students, students who watched the video-cum-slides-only lesson obtained a higher score with a mean of 7.6 and a Gain Score of 1.4, SE=0.53 while students who watched the video-cum-slides-plus-gesture lesson scored a mean of 6.2 and a Gain Score of 0.4, SE=0.36 with a Pearson's correlation of 0.15 and a T-test of -2.42.

Post Test Score	*Experimental Group*	*Control Group*
Mean	6.21	7.64
Variance	0.95	4.55
Observations	14	14
Pearson Correlation	0.15	
df	13	
t Stat	-2.42	
P(T<=t) one-tail	0.02	
t Critical one-tail	1.77	
P(T<=t) two-tail	0.03	
t Critical two-tail		2.16

Table 6: Post-Test Score of Experimental and Control Groups

Gain Score		Experimental Group	Control Group
N	Valid	14	14
	Missing	0	0
Mean		0.43	1.43
Std. Error of Mean		0.36	0.53
Median		0.00	1.00
Mode		0.00	1.00
Std. Deviation		1.34	1.99
Variance		1.80	3.96

Table 7: Gain Score of Experimental and Control Groups



Graph 1: Frequency Polygon of Gain Scores between Experimental and Control Groups

The frequency polygon (Graph 1) showed that more students who watched the video-cum-slides only lesson (Control Group) obtained a higher Gain Score than students who watched the video-cum-slides-plus-gesture lesson (Experimental Group).

	Paired Differences					t	df	Sig. (2-tailed)	
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		Mean	Std. Deviation		Std. Error Mean
	Lower	Upper	Lower	Upper	Lower	Upper	Lower		Upper
Experimental Group – Control Group	-1.00	2.57	0.69	-2.49	0.49	-1.46	13		0.17

Table 8: Table of Paired Sample T Test of Gain Score between Experimental and Control Group.

		Gain Score of Experimental Group	Gain Score of Control Group
Experimental Group	Pearson Correlation	1	-0.16
	Sig. (2-tailed)		0.58
	N	14	14
Control Group	Pearson Correlation	-0.16	1
	Sig. (2-tailed)	0.58	
	N	14	14

Table 9: Table of Pearson's Correlation of Gain Score between Experimental and Control Group.

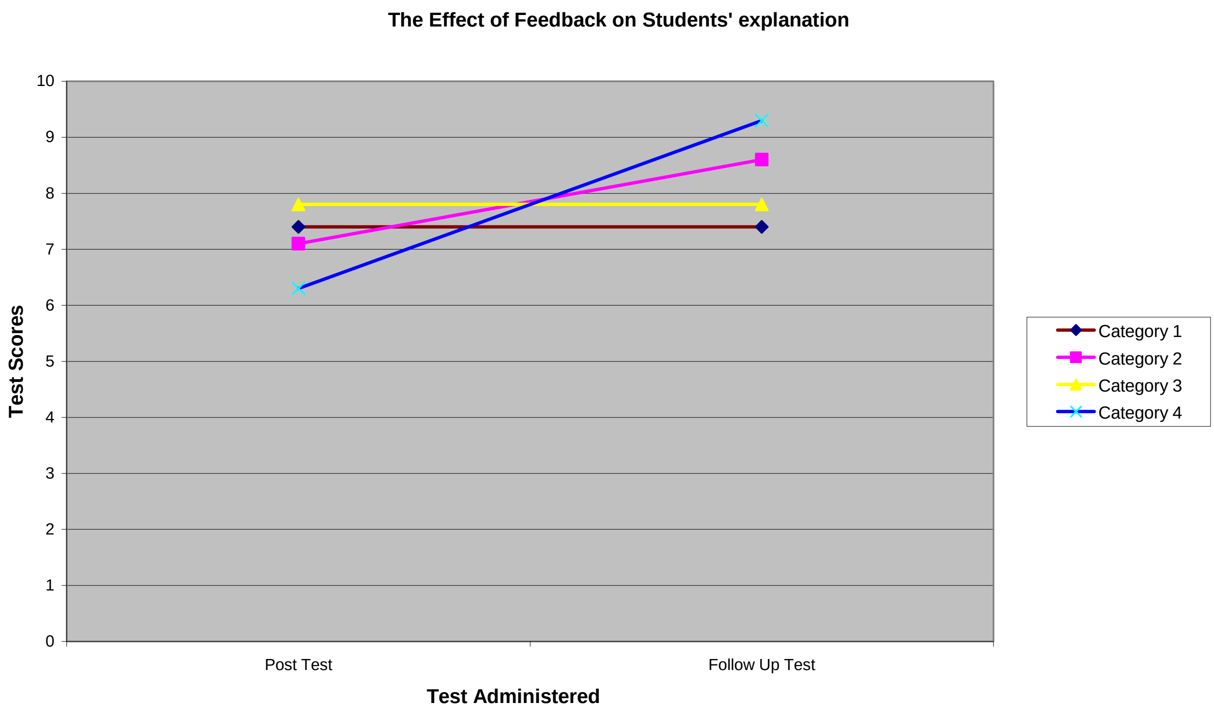
The Paired Sample Two Tail T-Test (Table 8) showed that the difference in Gain Score between the Experimental Group and the Control Group was insignificant while Pearson's Correlation (Table 9) highlighted that there was also no correlation in the use of gestures to bring about better understanding in the students.

Follow-Up Test Performance

In a follow up test attempted one week later, it was revealed that students who were given gesticulated accompaniment feedback on their explanations scored better (Graph 2) in the follow-test and progressed from a discordant stage of gesture-speech mismatch to the concordant stage of gesture-speech match of a right concept while those without feedback regressed from a discordant stage of gesture-speech mismatch to the concordant stage of gesture-speech match of a wrong concept as hypothesised earlier.

Categories	1	2	3	4
Training Experiences	PowerPoint Slides and **Talking Head** Solve and explain 10 questions with **no feedback**	PowerPoint Slides and **Talking Head** Solve and explain 10 questions with **feedback after each explanation**	PowerPoint Slides and **Video recording of lecturer**. Solve and explain 10 questions with **no feedback**	PowerPoint Slides and **Video recording of lecturer.** Solve and explain 10 questions with **feedback after each explanation.**
Post-Test	7.3	7.1	5.8	6.3
Follow-Up	7.4	8.6	7.8	9.3
Gain Score	+0.1	+1.5	+2.0	+3.0

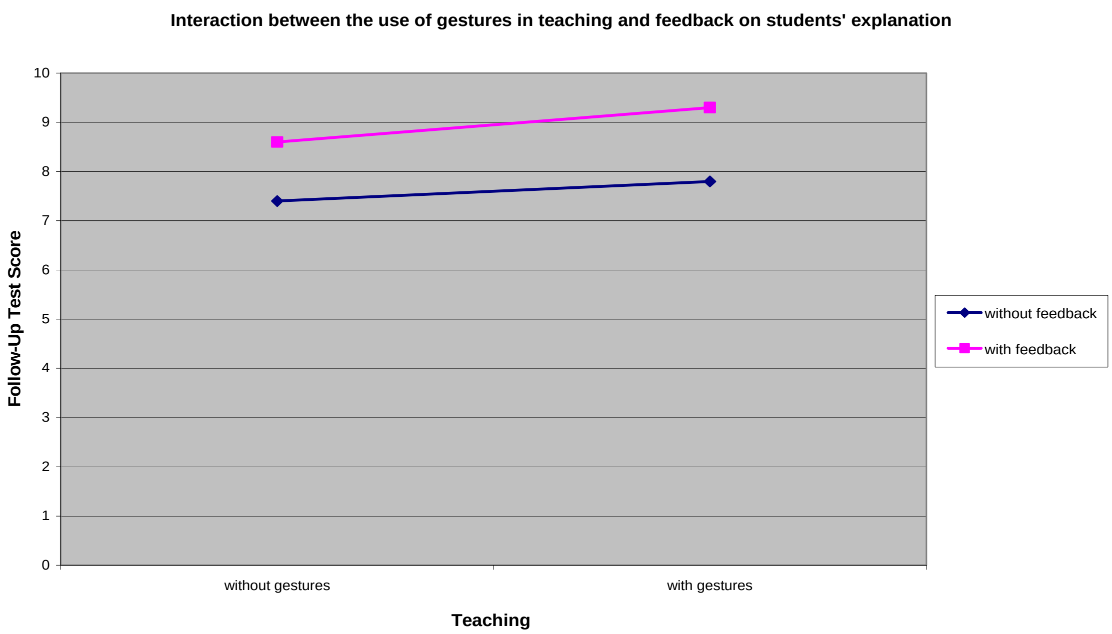
Table 10: Table of Test Score and Training Experiences of 4 categories



Graph 2: Graph of Test Scores among the Categories of 4 different training experiences

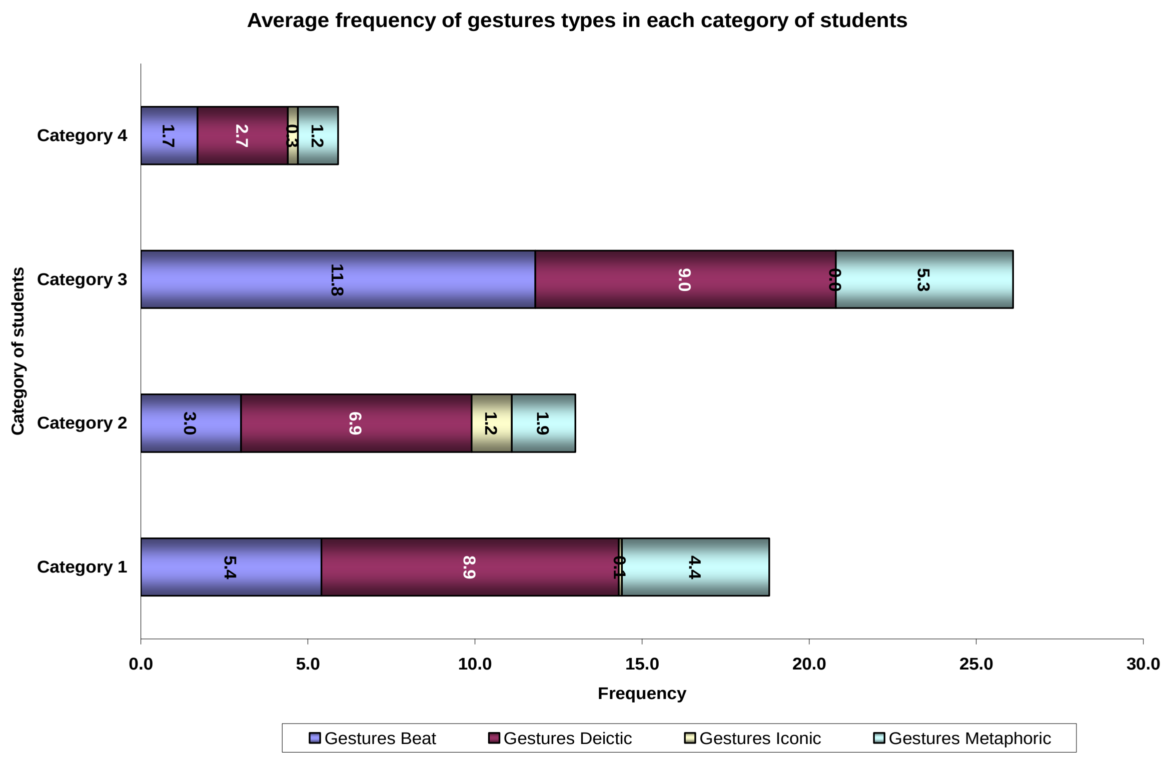
Further analysis showed that students who underwent the video-cum-slides-plus-gesture lesson with feedback (Category 4) have the highest Follow-Up Test score of 9.3 with a Gain Score of 3.0. This is followed by students who underwent video-cum-slides-only lesson with feedback (Category 2), obtaining a high Follow-Up Test score of 8.6 with a Gain Score of 1.5. This clearly supported the hypothesis that students from category 2 and category 4 progressed from a discordant stage of gesture-speech mismatch to the concordant stage of gesture-speech match of a right concept.

On the other hand, students who underwent video-cum-slides-plus gesture lesson with no feedback (Category 3) and those who underwent video-cum-slides only lesson with no feedback (Category 1) scored the lowest in the Follow up test, obtaining a Mean Score of 7.8, a Gain Score of 2.0 and a Mean Score of 7.4 and a Gain Score of 0.1 respectively. This also supported the hypothesis that students in category 1 and category 3 regressed from a discordant stage of gesture-speech mismatch to the concordant stage of gesture-speech match of a wrong concept.



Graph 3: Interaction between the use of gestures in teaching and gesticulated feedback in students learning.

Investigation into the possible relationship between the use of gestures in teaching and feedback in students learning revealed no interaction between these two factors (Graph 3).



Graph 4: Average frequency of gesture types in each category of students

On examining the frequency of gesture types each student displayed while explaining their understanding (Graph 4), it was noted that students who had feedback given (Category 2 and Category 4) produced fewer gestures than those who did not receive feedback (Category 1 and Category 3).

This is because students in Category 1 and 3 did not receive any feedback on their explanations; hence they are in a state of cognitive dissonance (evidence by the high level of beat and deictic gestures) where these students are constantly revising and integrating newly synthesised knowledge to existing ones. Furthermore these students employ the use of metaphoric gestures to aid in their explanation of biological concepts. This is because in areas where words failed to sufficiently clarify their mental representations of concepts, the use of gestures was employed to illustrate their explanations.

Chapter 4: Discussion and Conclusion

This study revealed that the use of gestures in a video recorded lesson did not bring about an increase in conceptual change in the students. This could possibly be due to the distraction that gestures bring in a video recorded lesson. Here students may possibly be too busy looking at the gestures of the teacher (Diagram 1) and ignore the content presented in the slides. Moreover, since these students do not have any supplementary notes with them whilst viewing these video recorded lessons, there is no way they could refer to any biological content once they have missed the information on the slides. This may explain the lower Post Test Scores and the distribution of students having lower Gain Score in the Experimental Group.

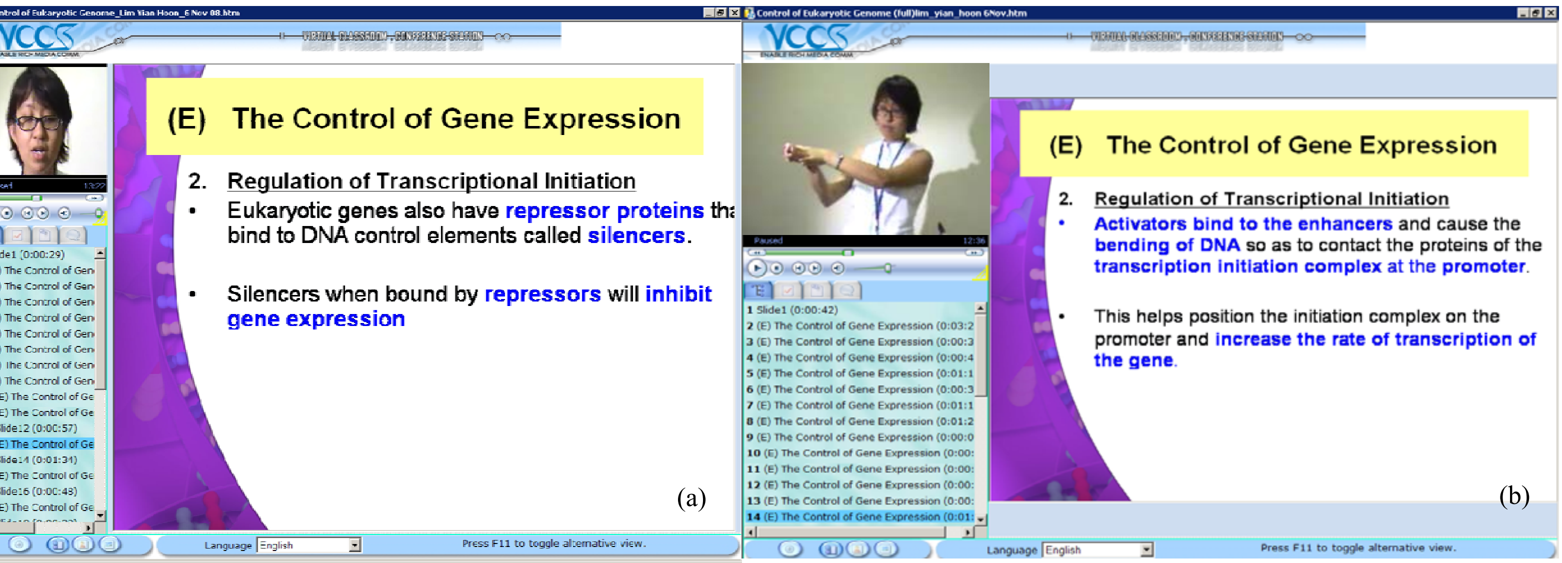


Diagram 1: (a) A video-cum-slides lesson and (b) A video-cum-slides plus gestures lesson

Therefore, a way to ascertain the above hypothesis is to extend this investigation to having two groups of students watch video recorded lessons. One lesson has a talking head incorporated while the other does not. Hence if the hypothesis that the gestures used in the video recording lesson is a form of distraction is true, the Post Test Score obtained by these two groups of students should be comparable.

On the other hand, this study also proves that students who had feedback given progressed from a discordant stage of gesture-speech mismatch to the concordant stage of gesture-speech match of a right concept and at the same time have a higher retention of knowledge (as seen in the higher Mean Gain Score of Follow Up Test in Table 10), while students who did not receive feedback regressed from a discordant stage of gesture-speech mismatch to the concordant stage of gesture-speech match of a wrong concepts. This is because the use of gestures in teachers' feedback help ground the difficult biological concepts of Organisation and Control of Eukaryotic Genome into concrete, physical examples (Valenzeno et al, 2003) which in turn enables students build a mental representation of the concept hence retaining their learning for a much longer period.

The purpose of this investigation is also to bring about increase awareness among Singapore's teachers in the propensity gestures have in scaffolding students' learning. This is because most teachers are not conscious of their hand movements as they teach, whether these gestures convey the same message as their speech or provide a second communicative channel needed to illustrate concepts which are difficult to explain in words. Therefore, it seems appropriate to employ the use of gestures as a daily resource in teaching, amidst the changing Pre-University education landscape where teachers are tasked to 'Teach Less and Learn More'. This is because the use of gestures requires no extra teaching resources, curriculum time in implementing and is a ready tool for all teachers to tap on.

Looking ahead, the use of gestures as means to assess students' mental representations and understanding, may play a pivotal role in assisting teachers' arrest student's alternative conceptions and determine students' readiness to learn new concepts in our current Education Landscape. Thus, it is paramount that the National Institute of

Education of the National Technological University looked into training Beginning Teachers' acumen in judging students' learning on the basis of non verbal cues and gestures (Jecker et al, 1965). This is imperative as more and more undergraduates from our local universities are turning to the Teaching Profession as means to obtain jobs through this Economy downturn without having the 'heartware and hardware' necessitated by this profession.

Such a move could distinctly increase the level of competency of Beginning Teachers' in assessing and keeping in pace with students' learning to bring about an increase in conceptual understanding in our students.

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