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Componential Differences and Varying Developmental Patterns Exhibited in Immersion Programmes

Sachiko Asano[a]*

[a] *Osaka University of Health and Sport Sciences, Department of Health and Sport Sciences, Osaka, Japan*

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Abstract

In bilingual literature, few studies have examined the processes of concept formation (CF); even fewer studies have discussed their developmental changes. This study explores language-cognition links and CF fractionation processes by comparing total and partial immersion programmes (TIPs and PIPs). Descriptive statistics (DS), correlational analysis (CA) and principal component analysis (PCA) are performed to investigate language-cognition relationships and similarities and differences in developmental aspects between TIPs and PIPs.

The DS and CA for PIPs demonstrate varying inter-individual differences depending on the courses and programmes. Moreover, despite the nearly equal ratio in the two languages used for the courses at the PIPs, the PCA results exhibit componential fractionations and time-sequential (developmental) changes similar to those for TIPs, suggesting unique language-cognition links. On one hand, the results for the two PIPs revealed a unique composition depending on the IP, and on the other hand, the extracted components mediated by the two languages demonstrated a similar developmental pattern.

The findings for PIPs, since they share common CF characteristics with TIPs, imply that the instructional and developmental significance of the CF process transcends time and educational systems. In particular, the fractionation and diversification processes of components cannot be accounted for within a constrained framework of independent model in existing research on bilingual education. Based on the statistical outcomes, an interactive/developmental model may be a more viable alternative educational model.

* Corresponding author. Tel.: +817244538895; fax: +81287487267.
E-mail address: asano@ouhs.ac.jp

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Keywords: Immersion programmes; language–cognition links; concept formation; interactive/developmental model.

1. Introduction

Although the effectiveness and significance of immersion programmes (IPs) have been well documented, some issues remain unresolved in the literature on bilingual education. One of them is the validity of the research paradigm on which most contemporary bilingual education programmes are based: the language-dominance framework primarily taken from the linguistic relativity hypothesis (LRH) (Cook, 2011). Bilingual educators in particular have customarily and traditionally focussed on linguistic properties while tacitly relying on the LRH and have accorded less attention to cognitive aspects in teaching settings. This widely accepted theme, however, is in distinct contrast to the anti-theme, which emphasises language-cognition links. Researchers who have focussed on these links have provided research evidence that questions the validity of the LRH paradigm and advances the anti-theme of an interaction of and interdependence between language and cognition (Evans, 2011; García & Náñez, 2011; Gathercole, 2011; Lucy, 2011). These findings have led them to recognise the significance of cognition in bilingual education (Cook, 2011).

In contrast to the LRH perspective, Vygotsky, as early as the 1930s, prioritised processes of concept formation (CF) as the core factor in language acquisition and explicated these processes in detail (Vygotsky, 1978, 1986, 1997). This theme is less discussed among Western applied linguists and bilingual education researchers. Directly related to CF processes, Vygotsky posited that ‘words play a central role as the minimal units governing the relationship between language and thought’ (1986). Contemporary bilingual education researchers also acknowledge the significance of CF as a determinant of second-language acquisition (Gathercole, 2011; Kroll & Sholl, 1992; Swoyer, 2011). However, only a few studies have referred to and explicated CF processes relative to bilingualism and bilingual education (Kroll & Sholl, 1992), and there are minimal reliable data on the developmental patterns manifested in IPs. The present study explores CF processes in IPs using a multi-year statistical analysis of total and partial immersion programmes (TIPs and PIPs) at the college level, with Vygotsky’s (1986) understanding of CF and the relationship between CF and words as its theoretical framework.

2. Research questions

The following research questions are proposed to investigate and determine how adult second-language learners differ from young second-language learners and what latent factors are present across different IPs by comparing TIPs and PIPs: (1) Are the statistics collected regarding TIPs in a previous study (Asano, 2014) parallel to outcomes in PIPs? (2) What factors of PIPs affect the academic performance of students attending these programmes?

2. 3. Purpose of the study

This study addresses two issues that bilingual education researchers and practitioners have seldom addressed. The first issue concerns the validity of the LRH premise that ‘language precedes cognition’, which has not been fully tested and verified (Swoyer, 2011). The LRH theme as the

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traditional basis for the teaching and learning of English as a foreign language contradicts bilingual education research findings involving cognition, social factors and students' personalities (Genesee, 1987). In particular, this theme by itself cannot fully account for the common characteristics underlying both first-language and second-language acquisition processes. To put it simply: if the native and target languages essentially differ from each other in their linguistic and cognitive aspects, does this mean that bilingual persons have two separate, parallel linguistic structures in their minds? As the antithesis to the legitimacy of language-dominant perspectives (Cook, 2011; García & Náñez, 2011), an interactive and interdependent relationship between language and cognition in bilingualism is proposed and investigated in this study.

The second issue concerns the use of IPs' developmental aspects and patterns to test and verify the interdependent model. Particularly in terms of the interdependence model for second-language sequential learners, the relationship between CF processing and language-cognition links deserves thorough investigation. In bilingual education research, however, target populations have generally ranged from pre-kindergarten to grade 12, with few participants in late adolescence and young adulthood (Genesee, 1987). This methodological choice reflects the trend in today's educational systems to incorporate bilingual education at earlier ages. The inclusion of college populations in a multi-year study has rarely been reported in the bilingual research literature as part of the testability of the interdependent model in second-language acquisition processes. To attain this research goal, it is proposed that a variety of linguistic and cognitive characteristics might be explored and demonstrated by applying appropriate statistical methods to unclassified academic records of IPs at Sapporo Agricultural College, the forerunner of the current Hokkaido University. Access to these records circumvents the barrier that usually prevents researchers from investigating IPs in higher education, namely, the inaccessibility of students' academic data due to privacy protections. More specifically, latent (confounding) factors underlying the links between language and cognition in second-language acquisition processes can be explored by principal component analysis (PCA) (Field, 2009).

3. 4. Research methods

Two approaches—nomothetic and idiosyncratic (Rourke, 1989)—were employed for two PIPs to identify how and to what extent interactions between CF and languages were demonstrated in college populations. The nomothetic approach was used to explore any latent factors in IPs, whereas the idiosyncratic one was used to investigate time-sequential changes of the individual students through analysis of the statistical results obtained by the nomothetic approach. In this study, as the nomothetic approach, three statistical methods—descriptive statistics (DS), correlation analysis (CA) and PCA—were conducted to address the two research questions stated above. Leont'ev (1997) criticised the nomothetic (cross-sectional) approach commonly employed by Western scientists in every research field. A combination of both nomothetic and idiosyncratic approaches may reinforce the strengths of each and compensate for each other's drawbacks so as to adequately verify the present theme under examination in this study. (However, due to space limitations, the statistical results for TIP 1 and PIPs 1 and 4 are discussed in the following sections. The outcomes of the idiosyncratic approach will be reported further at another opportunity.)

4. 5. Results of descriptive statistics and correlation analysis

4.1. 5-1. TIP 1 (Tables 1and 2)

TIP 1 was an IP with 91% of the courses taught in English and 9% in Japanese from 1876 to 1880
The DS clearly demonstrated distinctive inter-individual differences across the freshman (FM) courses

Table 1. Descriptive Statistics for TIP 1: Freshman Courses in 1876

	N	Range	Min	Max	Mean	Std. Error	Std. Deviation	Variance
English 1	18	40.0	37.5	77.5	64.30	2.87	12.18	148.32
Algebra	18	76.0	20.0	96.0	68.89	4.59	19.51	380.61
Botany 1	18	54.0	37.0	91.0	72.11	3.31	14.06	197.75
Chemistry 1	18	70.0	22.5	92.5	62.22	4.39	18.64	347.42
English 2	16	36.3	44.9	81.2	68.79	2.66	10.64	113.18
Geometry	16	41.0	47.0	88.0	62.50	3.62	14.48	209.60
Agriculture 1	16	25.0	58.1	83.1	71.86	2.12	8.49	72.05
Botany 2	16	56.9	32.5	89.4	64.78	4.03	16.10	259.30
Chemistry 2	16	52.1	38.7	90.8	68.44	3.60	14.41	207.55
Physiology	16	37.0	53.0	90.0	72.19	3.07	12.26	150.30

Notes: (1) **Boldfaced** courses were offered during the first term and light-faced courses during the second term.
(2) Courses in purple were taught in English.

in 1876 with a wide range of high and low scores (maximum scores of 100), large standard deviations (*SD*s)[*1] and variances (underlined in Table 1) with the exception of an Agriculture course during the second term (ST). In addition, the occurrence of highly correlated values between most of the courses explicitly suggests markedly linear inter-individual differences (Table 2). With regard to specific courses, English 1, taught during the first term (FT), had statistically significant correlations with four courses, including a very high correlation with FT Chemistry 1, whereas ST English 2 had varying levels of positive correlation with FT Botany 1 and four ST courses (Agriculture 1, Botany 2, Chemistry 2 and Physiology). Most interestingly, both the FT and ST English courses had no correlation with two mathematics courses, Algebra and Geometry, indicating clearly that the mathematics courses belongs to a different domain from the courses in English, with the exception of the moderately correlated FT Chemistry 2. Deduced from the first two statistical treatments, DS and CA suggest that individual differences might reside deeply in the statistical outcomes of TIP 1. (Similar findings were exhibited in the other TIPs.)

[*]1 A *T*-score with a standard deviation of 10 was used as a cut-off point in the study for differentiating significant values from less significant ones (Anastasi & Urbina, 1997).

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Table 2. Spearman Correlations for TIP 1: Freshman Courses in 1876

	Eng 1	**Algebra**	**Bot 1**	**Chem 1**	Eng 2	Geom	Agc1	Bot 2	Chem 2	Physiol
English 1	—									
Sig.(2-tailed)										
N	18									
Algebra		—								
Sig.(2-tailed)										
N		18								
Botany 1	0.616		—							
Sig.(2-tailed)	0.007									
N	18		18							
Chemisry 1	**0.754**	0.530	0.601	—						
Sig.(2-tailed)	0.000	0.024	0.008							
N	18	18	18	18						
English 2			**0.754**		—					
Sig.(2-tailed)			0.000							
N			16		16					
Geometry		**0.876**		0.596		—				
Sig.(2-tailed)		0.000		0.000						
N		16		16		16				
Agriculture 1			0.675	**0.789**	**0.824**		—			
Sig.(2-tailed)			0.004	0.002	0.000					
N			16	16	16		16			
Botany 2			0.639	**0.702**	**0.882**		**0.959**	—		
Sig.(2-tailed)			0.008	0.002	0.000		0.000			
N			16	16	16		16	16		
Chemistry 2	0.521			**0.911**	0.596	0.560	**0.779**	**0.759**	—	
Sig.(2-tailed)	0.038			0.000	0.015	0.024	0.000	0.001		
N	16			16	16	16	16	16	16	
Physiology	0.564		0.560	**0.790**	**0.748**	0.542	**0.898**	**0.913**	**0.801**	—
Sig.(2-tailed)	0.023		0.027	0.000	0.001	0.030	0.000	0.000	0.000	
N	16		16	16	16	16	16	16	16	16

Notes: (1) **Boldfaced** values in red are highly correlated; light-faced values in red are moderately correlated (2) **Boldfaced** courses were offered during the first term and light-faced courses during the second term.

4.2. 5-2. PIP 1 (Tables 3 and 4) and PIP 4 (Tables are omitted)

PIP 1 was implemented with 26 courses (54%) taught in English and 22 (46%) in Japanese within a four-year curriculum. Tables 3 and 4 demonstrated the results of PIP 1 for FM courses in 1880, indicating a marked difference from the configuration for TIP 1 (Tables 1 and 2). Most noticeably, PIP 1 reduced the number of courses with high variation among students as measured by the statistical features of range, *SD* and variance (underlined in Table 3). With regard to the CA, only five bivariate values exhibited high correlations between the related courses, with 20 mildly and moderately correlated values (Table 4). This outcome was in clear contrast with the correlational matrix of TIP 1, which had 16 highly correlated and 12 moderately correlated values (Table 2). No correlation of English 1 with the FT Algebra and ST Geometry courses was observed, regardless of the language differences in the courses (in PIP 1, Algebra was taught in English and Geometry in Japanese). This result is consistent with that for TIP 1, again suggesting that mathematics belongs to a different domain from FT English 1. However, the scores for ST English 2 were mildly correlated with FT Algebra, but not with ST Geometry. Also, the Military Drill (MD; present-day physical education) courses had no connection with any other courses, which strongly suggests that the two courses did not share any linguistic features with language-related courses and that they belong to a different domain (Table 4).

Table 3. Descriptive Statistics for PIP 1: Freshman Courses in 1880

	N	Range	Min	Max	Mean	Std. Error	Std. Deviation	Variance
English 1	20	35.6	50.4	86.0	68.22	2.11	9.44	89.10
Algebra	20	46.0	48.6	94.6	73.90	3.15	14.07	197.82
Chemistry 1	20	45.8	51.4	97.2	72.58	3.16	14.14	200.05
Military Drill 1	20	12.0	60.0	72.0	65.10	0.82	3.69	13.58
English 2	20	24.4	64.6	89.0	77.76	1.53	6.82	46.54
Agriculture 1	20	37.0	41.9	78.9	65.88	2.28	10.18	103.66
Chemistry 2	20	30.5	63.2	93.7	79.06	1.56	6.97	48.61
Geometry	20	49.2	48.0	97.2	80.23	3.31	14.78	218.55
Drawing 1	20	30.3	63.0	93.3	74.03	1.84	8.21	67.34
Military Drill 2	14	24.0	57.0	81.0	69.80	2.19	8.29	67.19

Notes: (1) Courses in purple were taught in English and courses in green in Japanese.
(2) **Boldfaced** courses were offered during the first term and light-faced courses during the second term.

PIP 4 was implemented with 26 courses (53%) taught in English and 23 (46%) in Japanese within the four-year curriculum (Table 7). Despite the unbalanced ratio of the courses (eight in English, three in Japanese) for the FM courses in 1884, PIP 4 yielded a totally different outcome in both the DS and CA (The tables are omitted due to space limitation). The DS exhibited a differential statistical feature of range, *SD* and variance from those of TIP 1 (Table 1 and 2) and PIP 1(Table 3 and 4). In particular, the MD courses for the FT and ST presented different characteristics not exhibited in TIP 1 and PIP 1, suggesting that some students of lesser physical strength had perhaps entered the programme. Thus, the DS configuration was distinctively projected to the CA with a smaller number of statistically significant values, resulting in five highly correlated values and nine moderately correlated ones.

4.3. 5-3. Summary and discussion of DS and CA

The DS of the three IPs can be summarised as follows. First, the DS results for the FM year for three IPs distinctively exhibited individual differences in varying degrees depending on the programme involved. TIP 1 markedly demonstrated a unique configuration of inter-individual differences from that of PIPs in that the highest- to lowest-achieving students were aligned in a linear fashion across all the courses but an Agriculture course (Table 1). It may be that the root cause of the differential statistical features could be ascribed to individualities of intellectual abilities in each programme, and that the approximately 50-50 percentage ratio of languages for the two PIPs might have resulted in the smaller statistical discrepancies exhibited between students.

Secondly, a comparison of the three CA tables showed that individual differences were involved in a complex way and contributed to the number of highly, moderately or mildly correlated values for the three IPs. Particularly for PIP 4, an unexpectedly small number of correlational values

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suggest that individual differences in students' factors might have strongly affected the correlations between the two MD courses and FT Algebra/Geometry regardless of the medium of instruction.

Considering the DS and CA results together, it can be concluded that individual differences in students' intellectual capabilities in each IP have affected the statistical variations in outcomes. It can also be inferred that latent factors might exist reflecting inter-individual differences to varying degrees in each IP. To identify these factors, PCA was performed on the academic records of the three IPs.

Table 4. Spearman Correlations for PIP 1: Freshman Courses in 1880

	Eng 1	**Algeb**	**Chem 1**	**Drill**	Eng 2	Agric	Chem 2	Geom	Draw	Drill 2
English 1	—									
Sig.(2-tailed)										
N	20									
Algebra		—								
Sig.(2-tailed)										
N		20								
Chemisry 1	0.565	**0.893**	—							
Sig.(2-tailed)	0.009	0.000								
N	20	20	20							
Military Drill 1				—						
Sig.(2-tailed)										
N				20						
English 2	**0.809**	*0.479*	0.547	0.517	—					
Sig.(2-tailed)	0.000	0.032	0.013	0.020						
N	20	20	20	20	20					
Agriculture	0.641	0.681	**0.717**		**0.749**	—				
Sig.(2-tailed)	0.002	0.000	0.000		0.000					
N	20	20	20		20	20				
Chemistry 2		0.516	0.517	*0.453*	*0.471*	0.611	—			
Sig.(2-tailed)		0.020	0.020	0.045	0.036	0.004				
N		20	20	20	20	20	16			
Geometry		**0.722**	0.657			0.540	0.586	—		
Sig.(2-tailed)		0.000	0.002			0.014	0.007			
N		20	20			20	20	20		
Drawing	*0.460*			0.571	0.504	0.620	*0.447*	*0.469*	—	
Sig.(2-tailed)	0.041			0.009	0.023	0.004	0.048	0.037		
N	20			20	20	20	20	20	20	
Military Drill 2										—
Sig.(2-tailed)										
N										14

Notes: (1) Courses in purple were taught in English and courses in green in Japanese.
(2) **Boldfaced** courses were offered during the first term and light-faced courses during the second term.
(3)**Boldfaced** values in red are highly correlated, light-faced values in red moderately correlated and
italicized values in red mildly correlated.

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5. 6. Results of principal component analysis

The PCA results for three IPs are reported in the following sub-sections separately; a componential (horizontal) analysis was made for each academic year, followed by a time-sequential and developmental (vertical) analysis across the four years for each IP.

5.1. 6-1. TIP 1 (Table 5)

The PCA extracted two components for the FM year. Component 1 was labelled 'Multiple Concepts' and included all the courses regardless of instructional contents. Component 2 was labelled 'Mathematical Concepts' with heavily loaded Algebra and moderately loaded Geometry courses, which were mildly and moderately loaded, respectively, for Component 1.

The sophomore (SM) year extracted three components. Component 1 included all the courses together with Chinese Classics taught in Japanese, and it was categorised as 'Multiple Concepts'. Component 2 was categorised as 'Visuospatial Concepts' and included heavily loaded Drawing 1 and mildly loaded Surveying courses. Component 3 was labelled 'Linguistic Concepts' with English 3 as the only heavily loaded course. Fractionation into three components for the SM year implies diversification of CF taking place in the processes of componential formation.

For the junior (JN) year, Component 1, labelled 'Multiple Concepts', included almost all the courses in English while excluding an MD course in Japanese. Although the two courses in Japanese, Chinese Classics and MD courses were implemented in separate years, the statistical exclusion of MD from the first component implied that the course assumed a totally different nature, with its focus on physical movement, and affected subsequent componential fractionation processes. Component 2 included English literature and English language courses with heavy loadings of a purely linguistic nature that shared a commonality of linguistic properties in their instructional contents; it was categorised as 'Abstract Thinking'. Component 3, consisting of moderately loaded English 4, moderately loaded MD 1 taught in Japanese and mildly loaded Zoology in English, was categorised as 'Perceptual Accuracy', despite the

Table 5. Components for TIP 1 (1876–1880)

	Component 1	Component 2	Component 3
FM 1876 N:15 E*:10	**Multiple Concepts:** **Agriculture 1, Chemistry 1 & 2, Botany 2, English 1 & 2, Physiology**, Geometry, Botany 1, *Algebra*	**Mathematical Concepts:** **Algebra**, Geometry	
SM 1877 N:14 E*: 8 J*: 1	**Multiple Concepts:** **Chemistry 3, Surveying, Conics/Trigonometry, Analytical Chemistry, Agriculture 2 & 3**, *English 3*, *Chinese Classics*, *Drawing 1*	**Visuospatial Concepts:** **Drawing 1**, *Surveying*	**Linguistic Concepts:** **English 3**
JN 1878 N:14 E*:11 J*: 1	**Multiple Concepts:** **Physics 1, Surveying, English 4, Astronomy**, Zoology, Drawing 2 & 3, Fruit Culture, Agriculture 4, English Literature, English Language; Military Drill 1 excluded	**Abstract Thinking:** **English Literature, English Language**	**Perceptual Accuracy:** Military Drill 1, English 4, *Zoology*

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SN 1879 N:13 E*:13 J*: 2	**Multiple Concepts:** **Agriculture 5 & 6**, **Geology**, **Veterinary Science**, **Microscopy**, **Political Economy**, **Physics 2**, **History of Civilization**, **Mental Science**, **Engineering**, Bookkeeping, Declamation, Agricultural Debate; Military Drill 2 & 3 excluded	**Visuospatial Accuracy:** **Military Drill 2 & 3**, Engineering, *Physics 2*, *Agriculture 6*	**Verbal Comprehension:** *Military Drill 2 & 3*, *Political Economy*, *Mental Science*, *History of Civilization*

Notes: (1) Courses in purple were taught in English and courses in green in Japanese.
(2) **Boldfaced** and underlined courses are loaded heavily for the component regardless of the languages.
(3) Light-faced courses are loaded moderately for the component regardless of the languages.
(4) *Italicised* courses are loaded mildly for the component regardless of the languages.
(5) E* indicates the number of courses in English and J* the number of courses in Japanese.
(6) All the notes (1)-(5) are also applied to Tables 6 and 7

difference in the language of instruction. The inclusion of MD 1 in the third component implied conceptual rather than linguistic significance in componential formation. The gradual increase in the number of components from the FM to the JN year partially attests to the significance of CF as claimed by the interdependence model (Gathercole, 2011; Kroll & Sholl, 1992; Swoyer, 2011).

For the SN year, Component 1 was categorised as 'Multiple Concepts' and included the courses taught in English except two MD courses in Japanese. Component 2 was labelled 'Visuospatial Accuracy', and it contained two MD courses that shared a common conceptual feature with one moderately and two mildly loaded courses in English, despite the language differences (Table 5). Component 3, labelled 'Verbal Comprehension', included two MD courses and three courses in English with mild loadings. The component was significant in terms of the PCA procedure extracting a linguistic commonality of the courses in both Japanese and English. Particularly inclusion of two MD courses in Japanese within both the second and third components suggests their significance in componential fractionation of CF.

To summarise, the PCA results for TIP 1 suggest that the languages did not play a predominant role in and of themselves in mediating the information delivered in science, agriculture, mathematics, language and literature courses; rather, the components were conceptually extracted across the categories of course contents. The composition of each component also suggests the interaction and interdependence of academic fields, instructional contents and the languages used, as these features were statistically exhibited in the componential fractionation process.

5.2. 6-2. PIP 1 (Table 6)

PIP 1 presented a unique componential pattern of fractionation. Despite the imbalance between the two instructional languages for the FM courses, three heavily loaded courses in English, four moderately loaded courses in Japanese and one mathematics course in English constituted Component 1, labelled 'Multiple Concepts'. The componential composition suggests that the common attributes of the eight courses in both English and Japanese including Geometry/Trigonometry interactively and interdependently affected CF processes. Component 2 included heavily and moderately loaded MD courses in Japanese, mildly loaded Drawing 1 in Japanese and mildly loaded English 2; it was labelled 'Visuoperceptual Accuracy'. All these courses shared a commonality of visuospatial nature across the courses, overriding language differences. Component 3, labelled 'Visuospatial Concepts', comprised three courses in Japanese.

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Particularly interesting from the componential point of view, two MD courses in Japanese were included in both Components 2 and 3 but were excluded from the first component due to the extraction process of PCA. Inclusion of the two MD courses in the residual two components implied the conceptual and linguistic roles that these courses played in the componential process.

For the SM year, Component 1 subsumed four courses in English and two courses in Japanese with heavy loadings while excluding three courses in Japanese, and it was categorised as 'Multiple Concepts'. One distinctive feature of its composition was the language dominance of the four English courses over the two in Japanese, despite the 50-50 overall ratio of the courses in both languages. The four mildly loaded courses in Japanese for the first component were projected to Component 2, which was labelled 'Visuospatial Concepts', reflecting the statistical extraction procedure of residual variance. Component 3, which consisted solely of two MD courses in Japanese, was categorised as 'Gross Motor Movement'. The common phenomenon of language dominance in Japanese for both the second and third components implied a unique characteristic of conceptual fractionation processes for PIP 1. The linguistic dominance of Japanese for the second and third components resembled the similar pattern of componential fractionation for the FM year.

The JN year produced four components with varying loadings in componential fractionation. Component 1 was categorised as 'Multiple Concepts' and included five courses in English and two courses in Japanese with heavy loadings. Component 2 included four courses solely in Japanese, representing a similar composition to the second component for the SM year. This component was labelled 'Visuospatial Concepts', denoting the inherent nature of visuospatial attributes that resided in the four courses. Component 3 was labelled 'Linguistic Sensitivity' as three courses in English shared a common characteristic of linguistic nature. The remaining variance was extracted for the fourth component within the acceptable eigenvalue of 1. Component 4, which included two MD courses in

Table 6. Components for PIP 1 (1880 - 1884)

	Component 1	Component 2	Component 3	Component 4
FM 1880 N:20 E*: 4 J*: 6	**Multiple Concepts:** **English 1 & 2**, **Agriculture 1**, **Geometry/Trigonometry**, Algebra, Drawing 1, Chemistry 1 & 2; Military Drill 1 & 2 excluded	**Visuoperceptual Accuracy:** **Military Drill 1** *& 2*, *Drawing 1*, *English 2*	**Visuospatial Concepts:** **Military Drill 2**, Chemistry	
SM 1881 N:21 E*: 6 J*: 6	**Multiple Concepts:** **Agriculture2 & 3**, **Botany1** & 2, **Physiology**, **Organic Chemistry**, **Trigonometry/Surveying**, English3, *Agricultural/Analytic Chemistry*; Military Drill 3 & 4, Drawing 2 excluded	**Visuospatial Concepts:** **Drawing 2**, Military Drill 3, Agric. /Anal. Chemistry, *Trigonometry/ Surveying*, *Organic Chemistry*	**Gross Motor Movement:** **Military Drill 4** *& 3*	
JN 1882 N:20 E*: 8 J*: 7	**Multiple Concepts:** **Botany 3**, **Declamation**, **Fruit Culture**, **Zoology**, **English Literature**, **Astronomy**, **Mechanics**, Agriculture 4, English 4, Drawing 4 *& 3*, *Topology*, *Military Drill 5 & 6*	**Visuospatial Concepts:** **Topology**, Drawing 4 & 3, Military Drill 5	**Linguistic Sensitivity:** English 4, Declamation, *English Literature*	**Visuospatial Sensitivity:** Military Drill 6 *& 5*, *Agriculture 4*

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SN	Multiple Concepts:	Perceptual Accuracy:	Verbal Manipulation:
1883 N:17 E*: 8 J*: 3	**Veterinary Science 1 & 2**, **Political Economy**, **Physics**, **Engineering**, Agriculture 5 & 6, Debate, Original Declamation, *Military Drill 7*; Microscopy excluded	**Military Drill 7**, Microscopy, *Original Declamation*	Debate, Agriculture 5

All the notes for Table 3 are applied to Table 6.

Japanese and one Agriculture course in English, was categorised as 'Visuospatial Sensitivity', bridging a commonality of concepts characteristic of the three courses. Thus, the alternately exhibited dominance of either language for the four components can only be accounted for in terms of CF processing through the componential fractionation.

Component 1 for the SN year included three courses in English and two courses in Japanese, both with heavy loadings, but Microscopy in English was excluded from the componential composition. Again, the composition demonstrated interdependence of cognitive attributes overriding language differences and instructional contents. Component 2, which included three courses in both languages, was categorised as 'Perceptual Accuracy' to share a common feature of the courses. Component 3 consisted of two courses in English of a purely linguistic nature but with no commonality in content areas except the medium of instruction; it was therefore categorised as 'Verbal Manipulation'. The componential fractionation pattern for the SN year had no resemblance to those for the preceding three years. The only logical explanation for the fractionation is that a conceptual and linguistic integration was manifested for the SN year. This particular phenomenon is further discussed in Section 6-4 in terms of the time-sequential order.

5.3. 6-3. PIP 4 (Table 7)

The same number of components was extracted for the three consecutive years for PIP 4 as for PIP 1, differing only for the SN year. However, the extracted components demonstrated a distinctive contrast to PIP 1 in componential configurations due to the disproportionate ratio of courses in the two languages. Component 1 for the FM year was categorised as 'Multiple Concepts', including three courses taught in English and two MD courses in Japanese with heavy loadings together with four moderately and mildly loaded courses in English while excluding a Drawing course in Japanese. Component 2, extracting the four courses in English was categorised as 'Verbal Reasoning', characterising a common feature of the courses. Component 3, although the two courses had no outward resemblance in either language or instructional contents, was arbitrary labelled 'Linguistic Sensitivity'.

For the SM year, Component 1, labelled 'Multiple Concepts', included an Agriculture course taught in English and five in Japanese with heavy loadings, despite the disproportionate number of courses in the two languages. For Component 2, PCA extracted two Chemistry courses, of which Chemistry 3 was excluded from the first component; it was thus labelled 'Chemical Concepts'. This extraction of Chemistry courses represents an analogous composition to that exhibited for the FM and JN years of TIP 1 in componential formation (Table 5). Component 3 was categorised as 'Graphic Representation', as it included two courses that shared a graphic nature. A comparison of the compositions between Tables 6 and 7 also displays a marked difference in the componential patterns of the two PIPs.

For the JN year, Component 1 subsumed six courses in English and four courses in Japanese with heavy loadings, two courses in English with moderate loadings and two courses in Japanese with

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mild loadings. Component 2 included MD 6 with a prioritised heavy loading and two courses in English with moderate loadings; it was labelled 'Visuospatial Concepts'. Component 3 was extracted as 'Geological Concepts' as it included only one course, Geology, taught in English. The extraction of a single course represents a unique pattern in componential formation within the programme. Component 4, categorised as 'Visuospatial Sensitivity', included two courses taught in English and one MD course in Japanese both with mild loadings.

The SN year extracted two components, with a fractionation pattern that differed remarkably from PIP 1 in its componential number. Component 1 included six heavily loaded courses in Japanese and two heavily loaded ones in English. Component 2 contained Civil Engineering in Japanese with a heavy loading and Agriculture 8 (in English) and an MD course (in Japanese), both with moderate loadings; it was labelled 'Perceptual Accuracy' to denote a common cognitive attribute of a perceptual nature, which overrode differences in instructional content and language. This lesser number of components extracted for the SN year was exhibited in neither TIP 1 nor PIP 1. This phenomenon may have resulted because
reorganisation or changes in intellectual capabilities took place developmentally through the four-year CF processes, which were affected by individual differences among the students enrolled in PIP 4.

To summarise PIP 4 results, the disproportionate number of courses in English and Japanese in each academic year linguistically and conceptually contributed to the unique componential pattern of conceptual fractionation despite the balanced ratio of the two languages in the four-year programme.

Table 7. Components for PIP 4 (1884-1888)

	Component 1	Component 2	Component 3	Component 4
FM 1884 N:16 E*: 8 J*: 3	**Multiple Concepts:** **Algebra & Geometry**, **Botany 1**, **Agriculture 2**, **Military 1 & 2**, Agriculture 1, Chemistry 1, History 1, Physiology, *English*; Drawing excluded	**Verbal Reasoning:** **English**, History 1, Physiology, *Agriculture 1*	**Linguistic Sensitivity:** *History 1*, *Military Drill 1*	
SM 1885 N:15 E*: 5 J*: 7	**Multiple Concepts:** **Agriculture 3** & 4, **Drawing 3** & 2, **Astronomy**, **Mathematics**, **Military Drill 3** & 4, **Surveying**, Chemistry 2, Microscopy, History 2; Chemistry 3 excluded	**Chemical Concepts:** **Chemistry 2** & 3	**Graphic Representation:** Chemistry 3, *Drawing 3*	
JN 1886 N:16 E*: 9 J*: 6	**Multiple Concepts:** **Agriculture 5 & 6**, **Fruit Culture**, **Physics 1**, **Geology 1** & 2, **Botany**, **Zoology**, **Mechanics**, **Topology**, **Topographic Drawing**, Analysis, Organic Chemistry, *Military Drill 5 & 6*	**Visuospatial Concepts:** **Military Drill 6**, Organic Chemistry, *Physics 1*	**Geological Concepts:** **Geology 2**	**Visuospatial Sensitivity:** *Analysis*, *Geology 2*, *Military 5*
SN 1887 N:17 E*: 4 J*: 7	**Multiple Concepts:** **Agriculture 7** & 8, **Physics 2**, **Political Economy**, **Entomology**, **Agricultural Law & Economy**, **Military Drill 7**, **Vet. Science 1 & 2**, *Agricultural Debate*, *Civil Engineering*	**Perceptual Accuracy:** **Civil Engineering**, *Agriculture 8*, *Military Drill 7*		

All the notes for Table 3 are applied to Table 7.

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5.4. 6-4. Summary and discussion of PCA

This section summarises the PCA results of three IPs from a time-sequential point of view, discussing similarities and differences demonstrated by each IP over the four-year period. TIP 1 typically exhibited an interactive and interdependent relationship between language and cognition underlying the formation process of scientific and agricultural concepts. The intertwining of language and cognition was developmentally fractionated from two to three components throughout the academic years. In other words, as the students advanced through the programme, the diversification trend became developmentally conspicuous in such a way that visuospatial and verbal features were differentially categorised in the CF processes.

For TIP 1, English necessarily played a major catalytic role as the dominant language for CF processes through the four years, whereas Japanese assumed a differential role for PIPs 1 and 4. Although the two PIPs both had an approximately 50-50 balance of languages over the four academic years, PIP 1 differed from PIP 4 in that the role of the two languages in CF fractionation composition varied across the academic years. For the FM year at PIP 1, courses in Japanese were dominant; for the SM and JN years, the two languages were used about equally; for the SN year, English was dominant (Table 6). Meanwhile, at PIP 4 an alternate dominance of one or the other language was exhibited (Table 7).

The varying proportions of instruction in the two languages during different years at PIPs 1 and 4 affected the composition of the first component, which in turn produced statistical differences and changes in both componential fractionation processes and time-sequential orders. The Japanese-dominant trend in PIP 1 was statistically demonstrated for the second and third components in both the FM and SM years, whereas the opposite trend was exhibited for the second and third components in PIP 4.

The JN year was a turning point for the two IPs in componential fractionation patterns. For PIP 1, despite the proportionate number of courses in both languages, the compositional dominance of heavily loaded English courses for Component 1 statistically determined subsequent componential fractionation, as was exhibited for the second through the fourth components. The alternate appearance of the two languages can be accounted for by the interactive and interdependent nature of the curriculum and the intellectual capabilities of individual students enrolled in the programme. In contrast to PIP 1, PIP 4, regardless of the disproportionate number of the courses in the two languages, was dominated by the heavily loaded courses in English, which determined the nature of subsequent compositions of componential fractionation patterns that differed significantly from those of PIP 1. This phenomenon was causatively rooted in CF processes through the intertwining of language and cognition.

For the SN year, a clear demarcation of components took place in the two PIPs. The integrated composition of the first component statistically affected the subsequent components exhibited for the PIPs, which encompassed the two languages for conceptual synthesis. PIP 1 demonstrated a componential fractionation as in the preceding three years, whereas PIP 4 converged into two components. The difference in the outcomes may have been affected by the differing language ratios for the two SN-year programmes. Here the languages developmentally took their own paths and played a dominant role in CF processes in the fourth year, which testifies partially to the legitimacy of the LRH.

It can be concluded from this summary that (1) the three IPs offered a similar curriculum for the academic years, but divergent phenomena occurred between programmes in the more advanced years; (2) the different progressive compositions possibly resulted from students' varying intellectual capabilities rather than from pure differences in the languages used and the course contents delivered in each year. The gradual diversification from comprehensive to specific components implies that human intellectual capabilities become transformed with an evolving, dynamic propensity parallel to and in conjunction with students' personality traits and teacher factors, curriculum, methodology and external physical conditions (Genesee, 1983).

6. 7. General summary of the three IPs

The extraction of two to four components throughout the three four-year curricula, regardless of the languages used and the differences in the number of language ratio between the programmes, supports the view that language and cognition interact in intertwining ways (Vygotsky, 1986; Swoyer, 2011). Additionally, the developmental statistical changes strongly suggest that concepts mediated by different languages were divergently transformed in time-sequential order; this process was affected by the interaction, interdependence and integration between concepts and languages that eventually diversified into multiple components. This phenomenon was clearly evidenced by the extraction of the third and fourth components as statistically significant residuals in the CF processes. In other words, human academic activities may have resulted from reciprocal interactions between language and cognition, regardless of the instructional contents and languages used.

7. 8. Conclusions

First, the present study has explored the CF processes and patterns of componential formation that are exhibited in IPs for the students at late adolescent age. Second, scientific and agricultural concepts mediated by both English and Japanese became statistically fractionated into multiple components. The divergence phenomenon (in other words, the gradual separation of concepts) became distinguished in the components bearing varying labels that were not included in Component 1. Third, on the basis of the identified components, this longitudinal study investigated developmental (time-sequential) changes for students pursuing agricultural or scientific education. This statistical examination determined that language per se did not affect cognition even in the later stages of learning, but that the relationship between language and cognition became reciprocally interdependent and integrated over time, to the extent that both languages contributed differentially and in parallel to the process of CF. The findings do not generally favour the LRH theme, and they represent the first step towards proposing an interdependent/developmental model, in line with the proposition that learning processes do not follow a linear path (Vygotsky, 1978, 1986, 1997).

8. 9. Implications

The statistical analyses suggest that optimal learning can result from a balanced interaction of and interdependence between cognitive and linguistic factors even in late adolescence and young adulthood, as was verified by the three statistical approaches. The statistical outcomes can be transposed to the present framework of education in varying instructional aspects. The findings may also apply to present-day bilingual education, not only from pre-kindergarten to grade 12 but also at the postsecondary level. Furthermore, the application of these findings may contribute to the development of students' intellectual capabilities in different educational systems. Specifically, the findings may cast significant light on remedial programmes for students with learning problems and difficulties who need specific instructional care in order to foster and enhance their cognitive skills, which the prevalent language-dominant instruction cannot necessarily and satisfactorily do.

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