

Precision education: A new challenge for AI in education

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*New Challenges for **AI in education** (AIED)

- From Single domain to Multi-disciplinary
- From Computation to Cognition
- From Personalized to Individualized
- From Knowing to Unknown
- From Technology to Humanity
- **From One-size-fits-all to Precision**

*Stephen J.H. Yang @ Kyoto University, March 23, 2019

From One-size-fits-all to Precision

- One-size-fits-all
 - One kind of
 - Average
- Precision
 - One of a kind
 - Specific
 - Precision medicine, Precision education

We were inspired by Precision medicine

- The Precision Medicine Initiative
 - <https://obamawhitehouse.archives.gov/precision-medicine>
- Obama, 2015 State of the Union address
 - “President Obama announced that he's launching the Precision Medicine Initiative — a bold new research effort to revolutionize how we improve health and treat disease.”

Precision medicine

- “Most **medical treatments** have been designed for the “average patient.” As a result of this “**one-size-fits-all-approach**,” treatments can be very successful for some patients but not for others.”
- “This is changing with the emergence of precision medicine, an innovative approach to disease prevention and treatment that takes into account **individual differences in people’s genes, environments, and lifestyles**.”

Comparison of **Medicine** & **Education**

Disease	At-risk students
Genes	IQ
Living style	Learning style
Living environment	Learning environment
Living philosophy	Learning strategy (SRL)

Research goal & steps

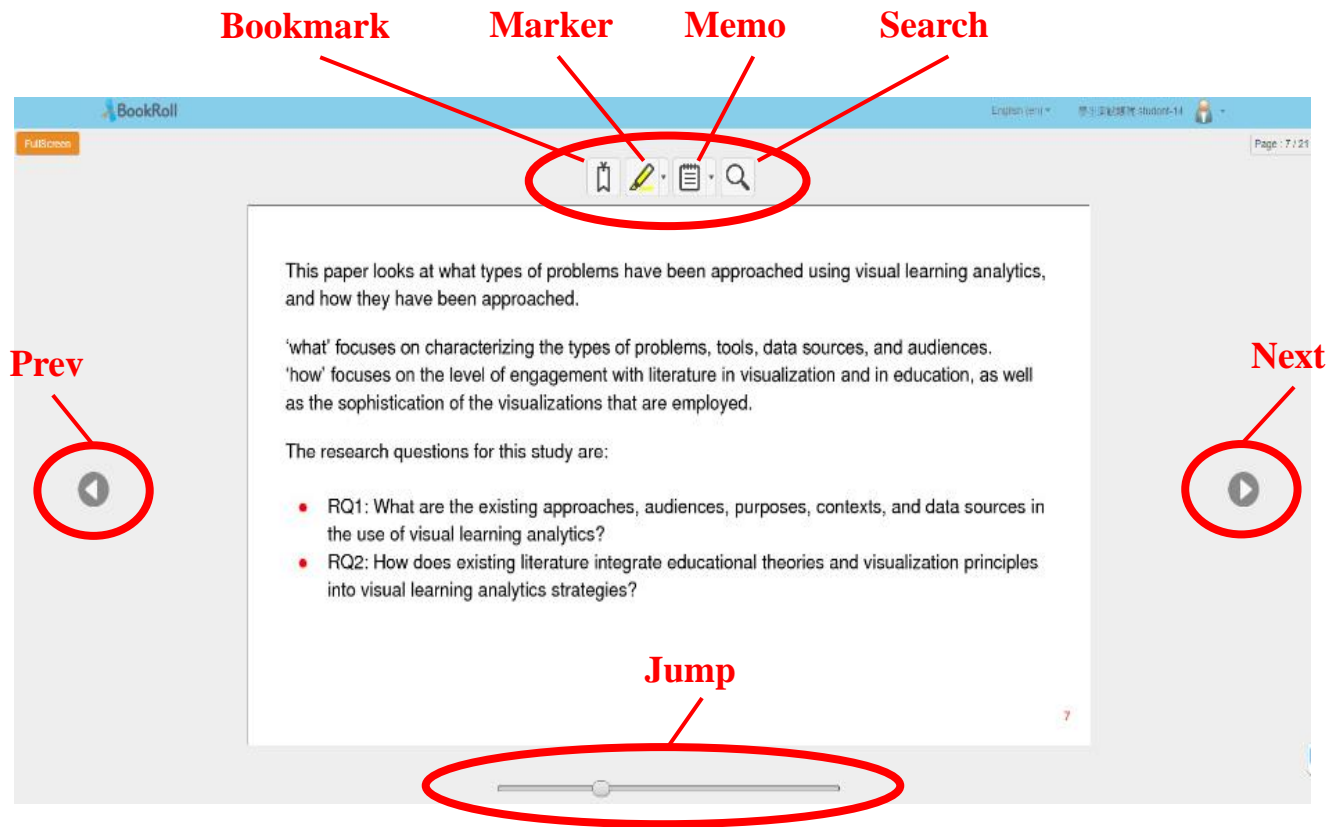
- **The goal** is to identify **at-risk students** as early as possible and provide **timely intervention**.
- **Knowing** the correlation between students' learning **patterns & outcome**
- **Research steps**
 - **Diagnosis** of students' learning patterns
 - **Prediction** of students' learning outcome
 - **Treatment** with teachers' timely intervention (learning activities)
 - **Prevention** with students' SMART mind

Knowing the correlation between students' learning **patterns** & **outcome**

	Diagnosis (Patterns)	Prediction (Outcome)	Treatment (learning strategy)	Treatment (learning activities)
}	Disengaged	Fail	Motivation	More Next, Prev (draw attention)
	Surfing	Fail	Motivation	More Marker (help focus)
}	Reflective	Pass	Goal setting Time management	Improve quality of Preview/Reflection reports
	Targeting	Pass	Self-evaluation Critical Thinking	More Memo/Change_memo, More Bookmark_jump
	Comprehensive	Pass	Elaboration	Improve quality of Preview/Reflection reports

The following empirical study is based on **my own class**

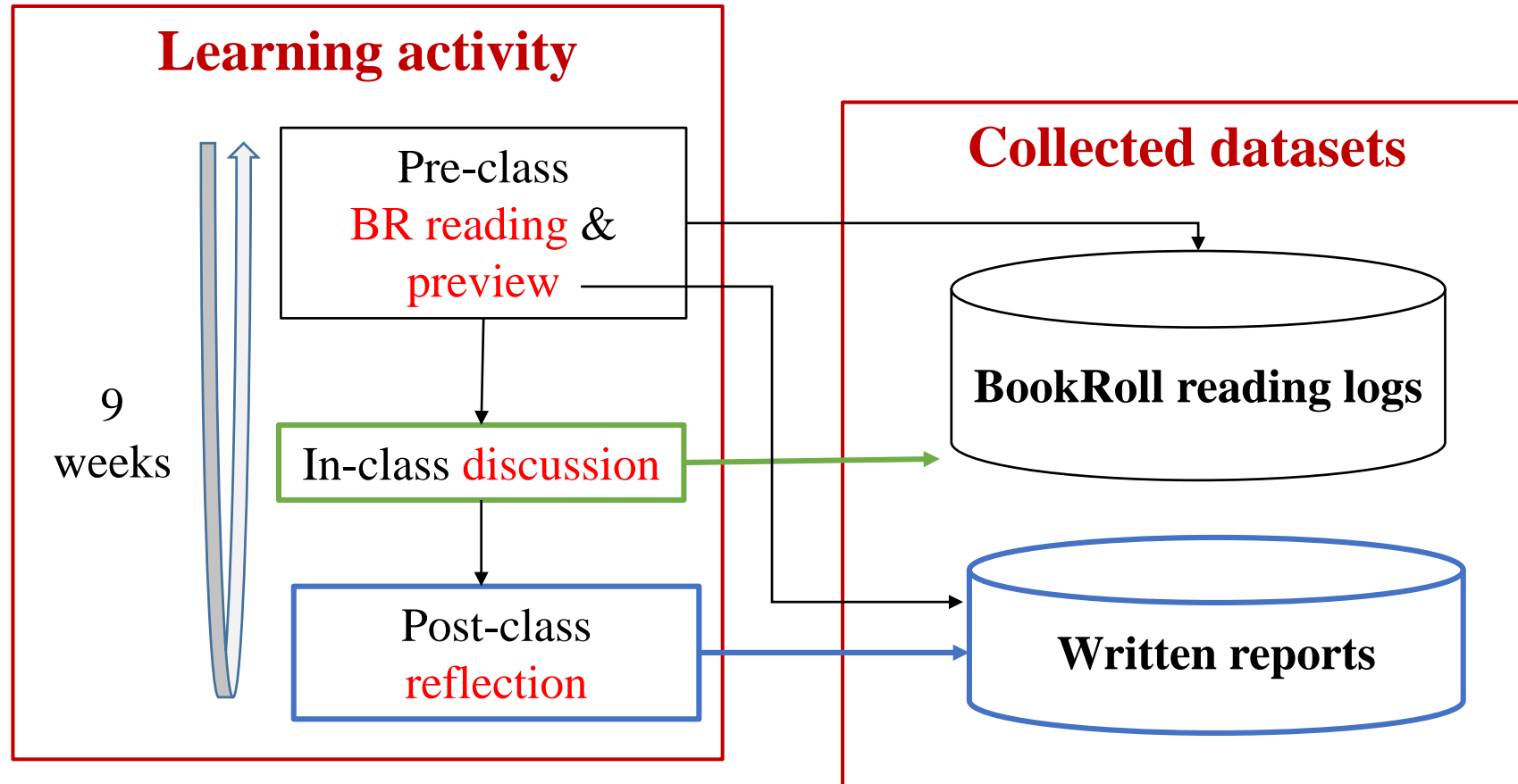
- Course: Creative Learning, NCU, **Fall 2018**
- Participants: **21 graduate students**
- Reading log: **Kyoto University, BookRoll**



Based on **Yamada, M.**, Oi, M., & Konomi, S. I. (2017).
 Are Learning Logs Related to Procrastination? From the Viewpoint of Self-Regulated Learning.
 14th International Conference on Cognition and Exploratory Learning in Digital Age (CELDA 2017)

Kyoto Univ. BookRoll	
5 Categories	15 Features
File	Open
	Close
Bookmark	Add Bookmark
	Delete Bookmark
Marker	Add Marker
	Delete Marker
	Marker
Memo	Add Memo
	Delete Memo
	Change Memo
	Memo
Page	Next
	Prev
	Jump
	Search

Flipped classroom & self-regulated learning activities to improve students' engagement with BR



Step 1. **Diagnosis** of students' learning patterns

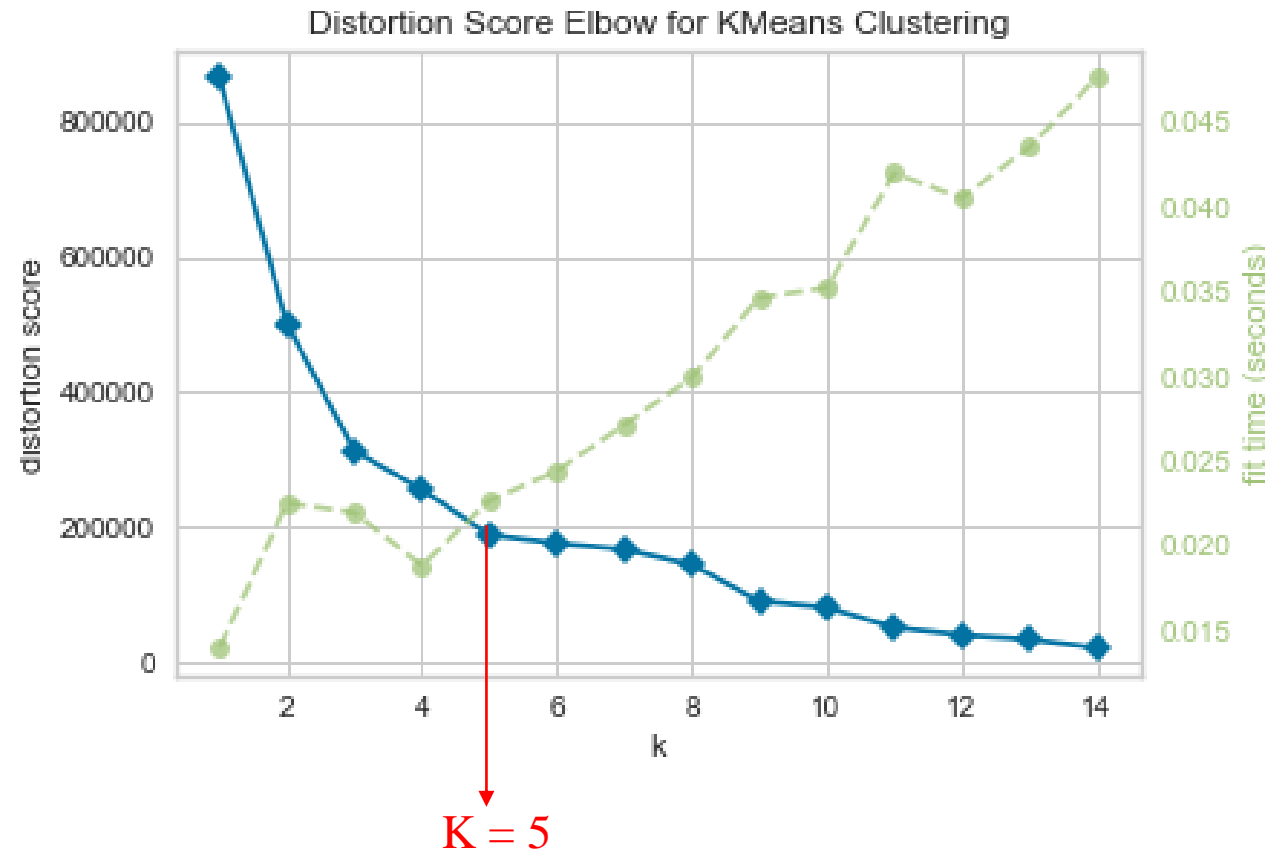
Detection of reading behavior & reading patterns

Detection of students' BR reading patterns

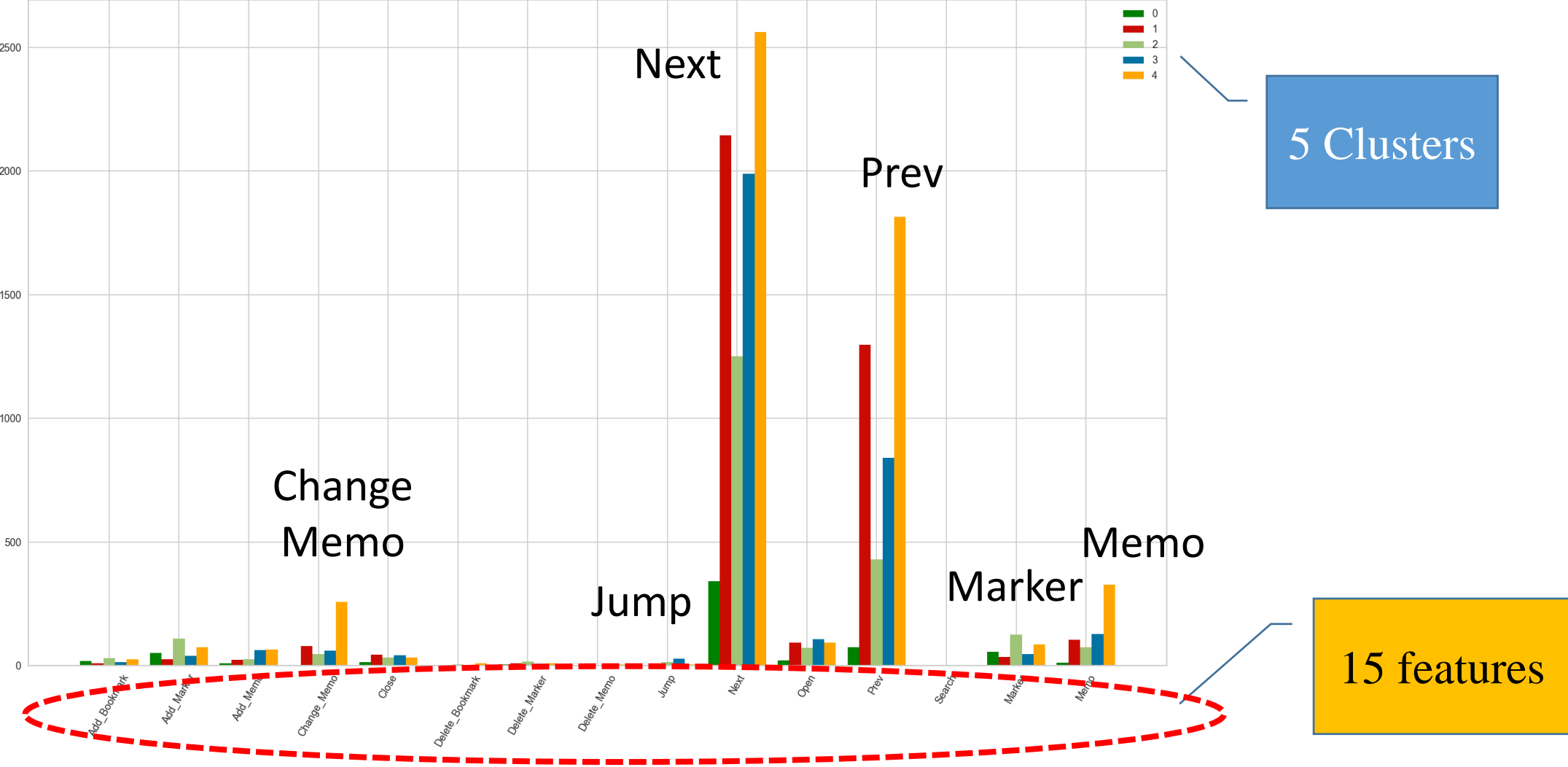
1. Clustering based on features
2. Clustering based on reading sequences
3. Sequence mining based on Motif, EFA

1.1 Clustering based on BR features (K-means)

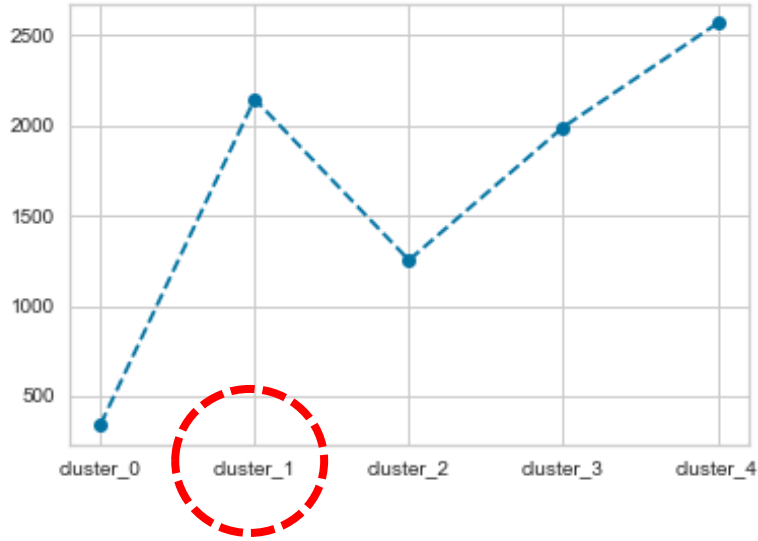
BR 15 Features
Add_Bookmark
Add_Marker
Add_Memo
Change_Memo
Close
Delete_Bookmark
Delete_Marker
Delete_Memo
Jump
Next
Open
Prev
Search
Marker
Memo



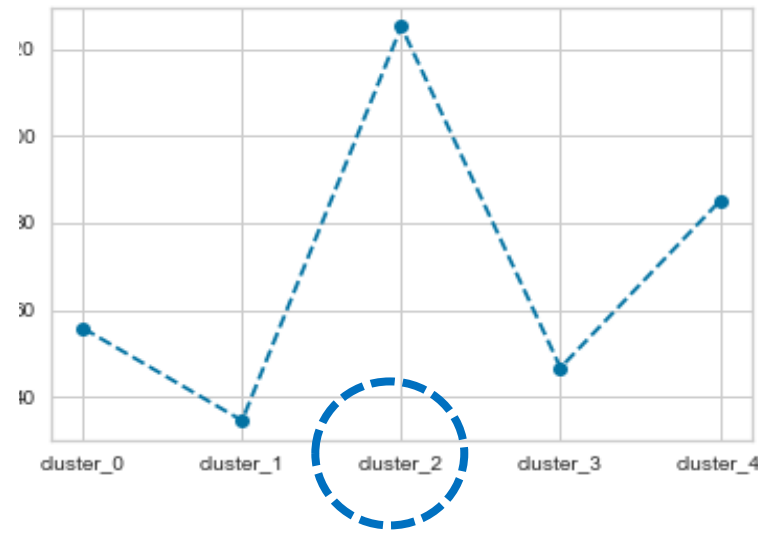
Distribution of 15 features of 5 clusters



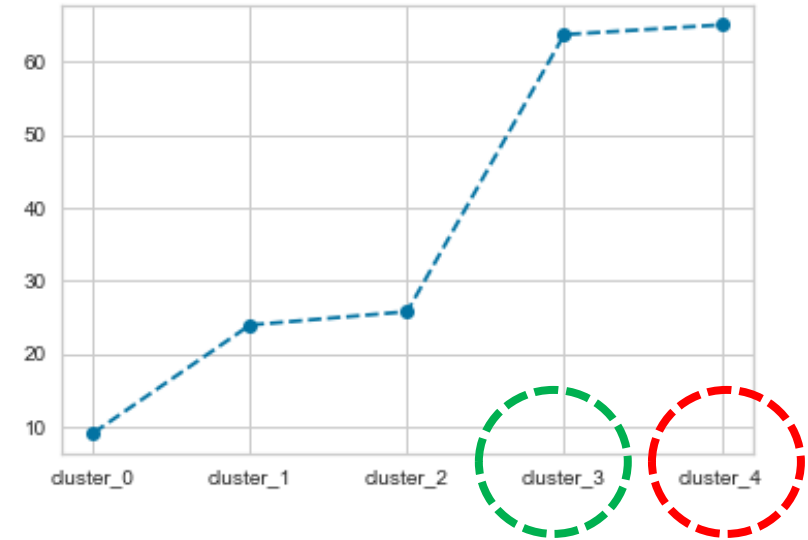
Next



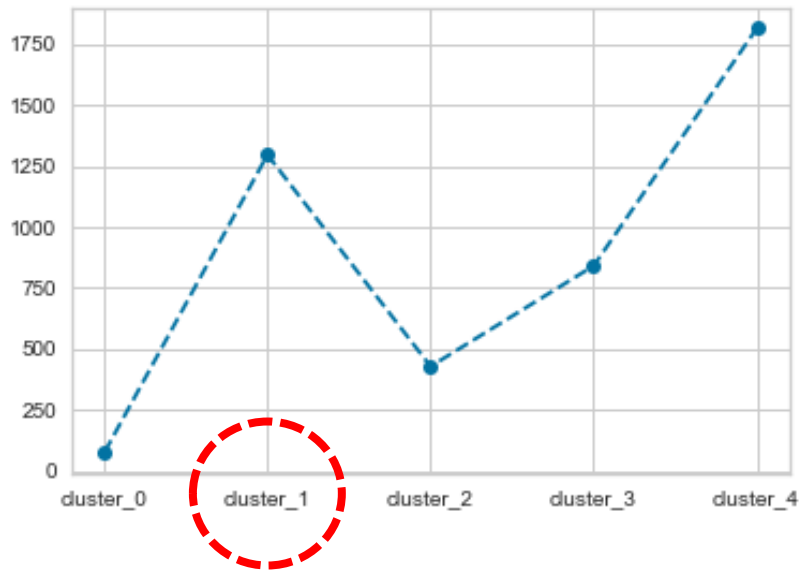
Marker



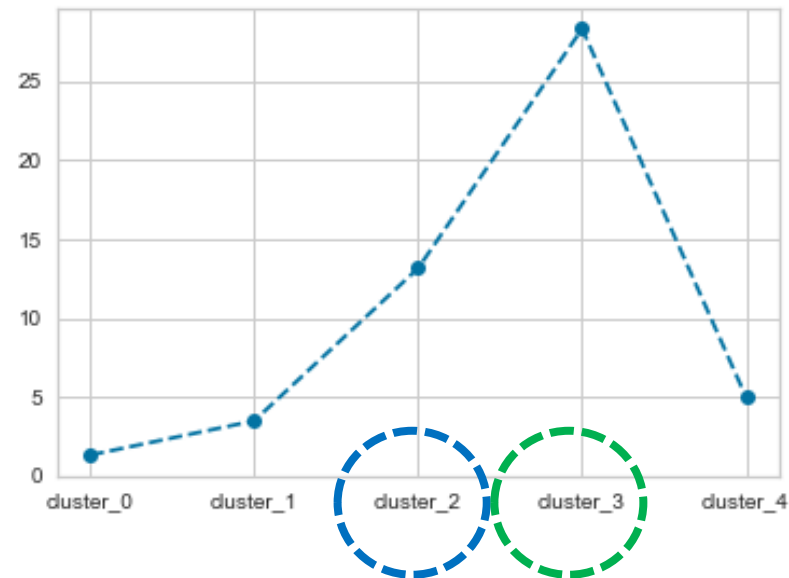
Change Memo



Prev



Jump



Description of 5 clusters based on BR features

Cluster	description	Reading pattern
0	Least activities	Disengaged
1	More page turning, less other activities	Surfing – turning page
2	Most markers, more jump	Targeting - seeking keywords, concepts
3	More change_memo, most jump	Reflective - Critical thinking
4	Most memo, most activities	Comprehensive - Note & annotation taking, hardworking

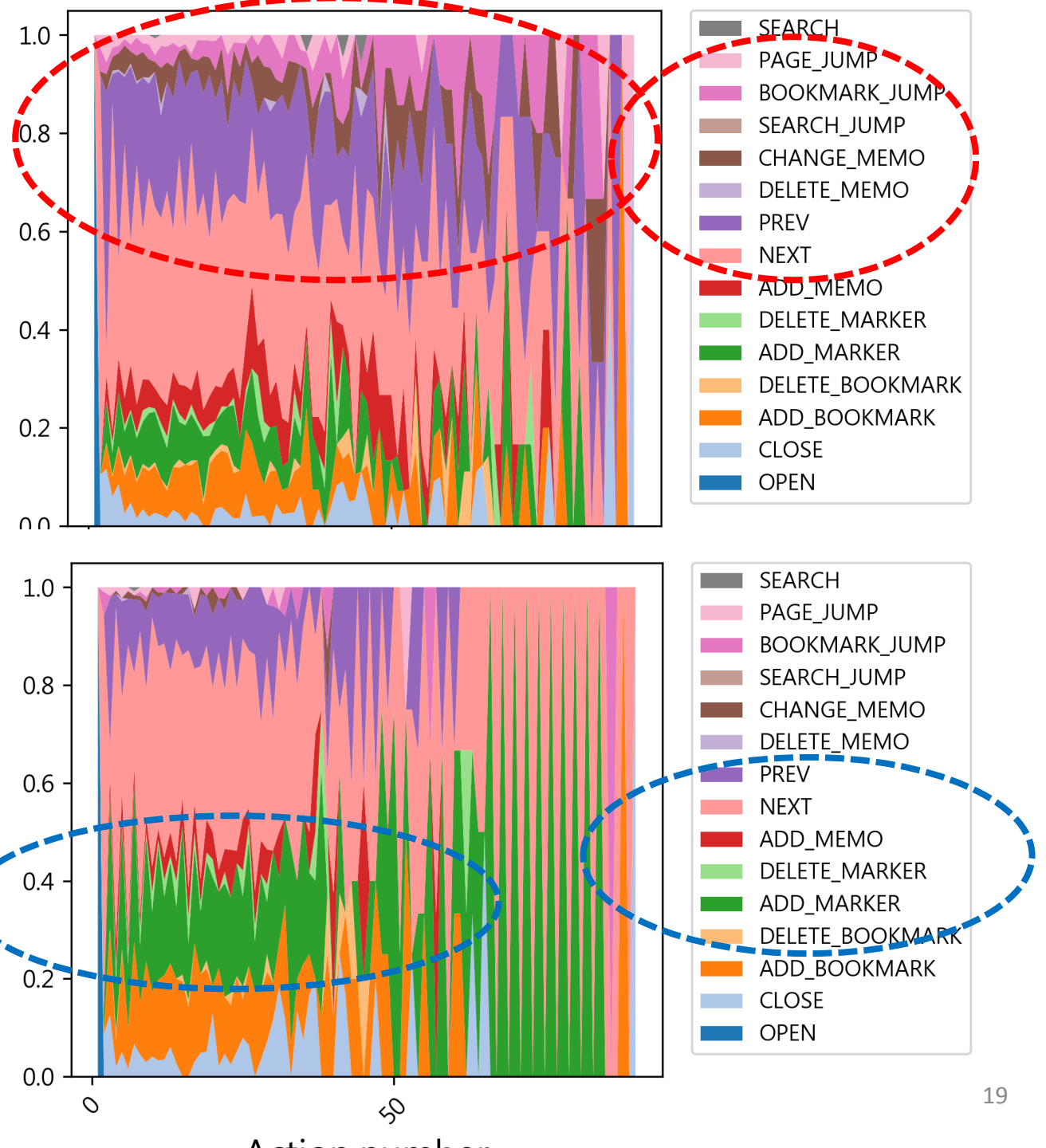
1.2 Clustering based on BR reading sequences

- A reading sequence is series of actions (BR-based)
 - Next page, add marker*, add memo*, bookmark this page, next page*, prev page*, jump_bookmark, chang memo
- Distribution of BR actions in all reading sequences
- Clustering of reading sequences

Jovanović, J., Gašević, D., Dawson, S., Pardo, A. & Mirriahi, N. (2017). Learning analytics to unveil learning strategies in a flipped classroom. *The Internet and Higher Education*, 33, 74-85.

Distribution of BR actions in all reading sequences $50 < \text{length} < 100$

- **High score (top 20%)**
 - More **bookmark_jump**
 - More **prev_page**
 - More **change_memo**
 - More variety of actions
- **Low score (lower 20%)**
 - More **add_marker**
 - More **next_page**



Clustering of reading sequences, 50 < length < 100

- **Type 1**

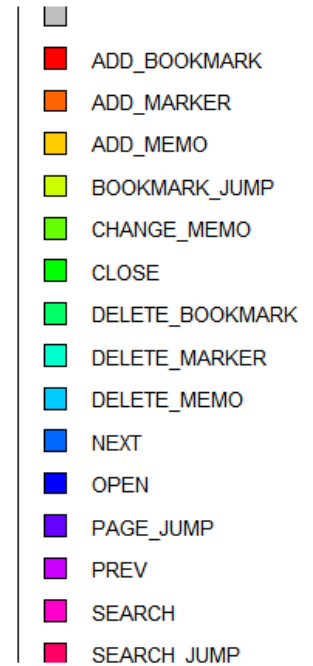
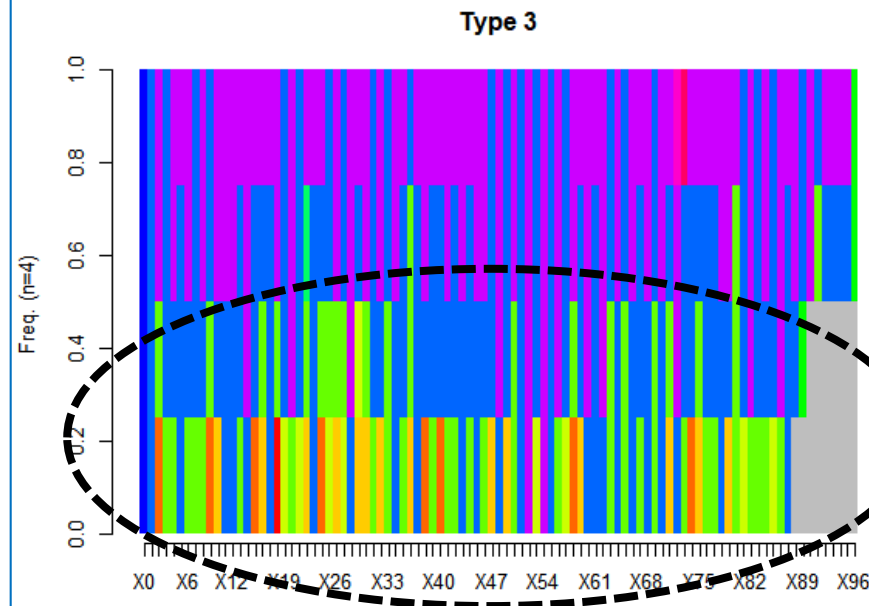
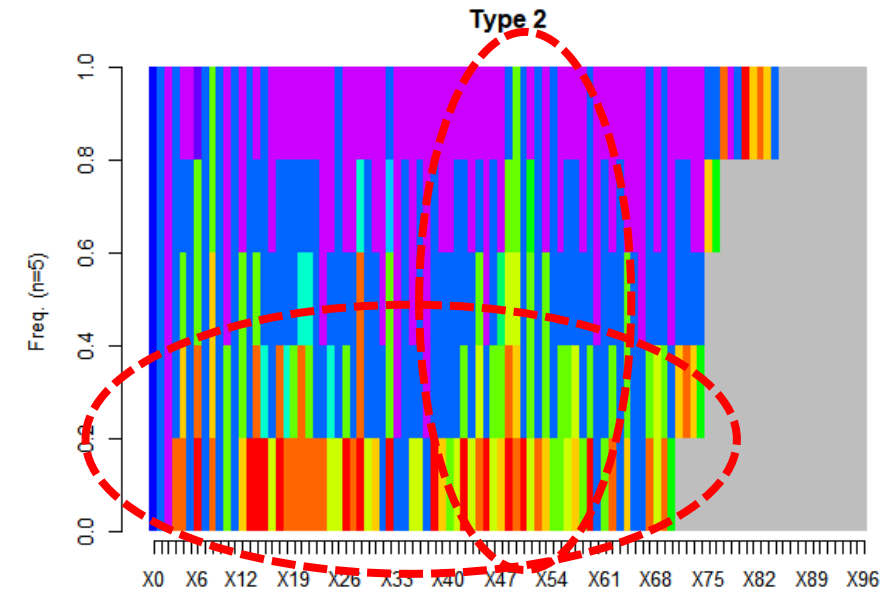
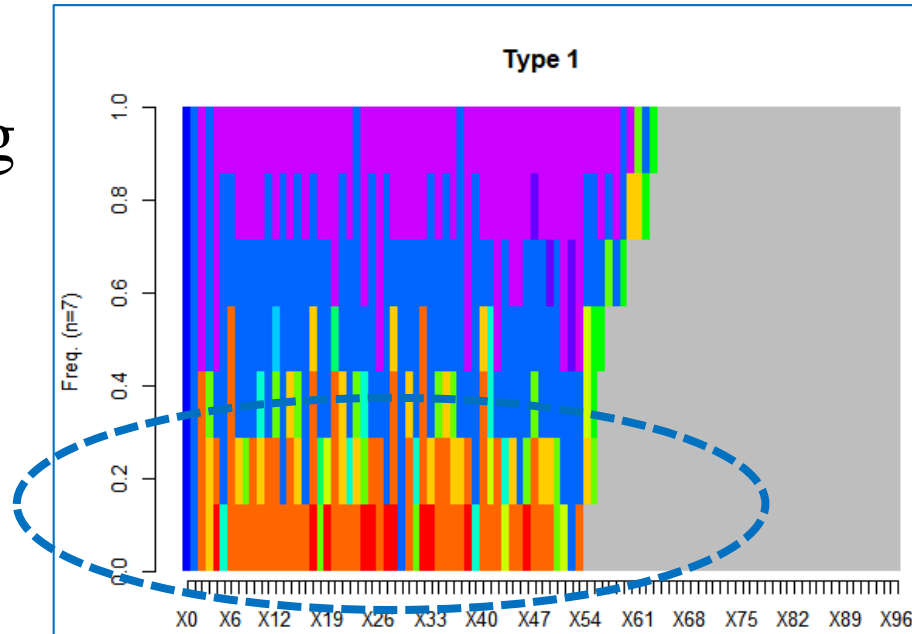
- More marker,
- More jump

- **Type 2**

- More memo,
- More activity

- **Type 3**

- More change_memo,
- More prev_page



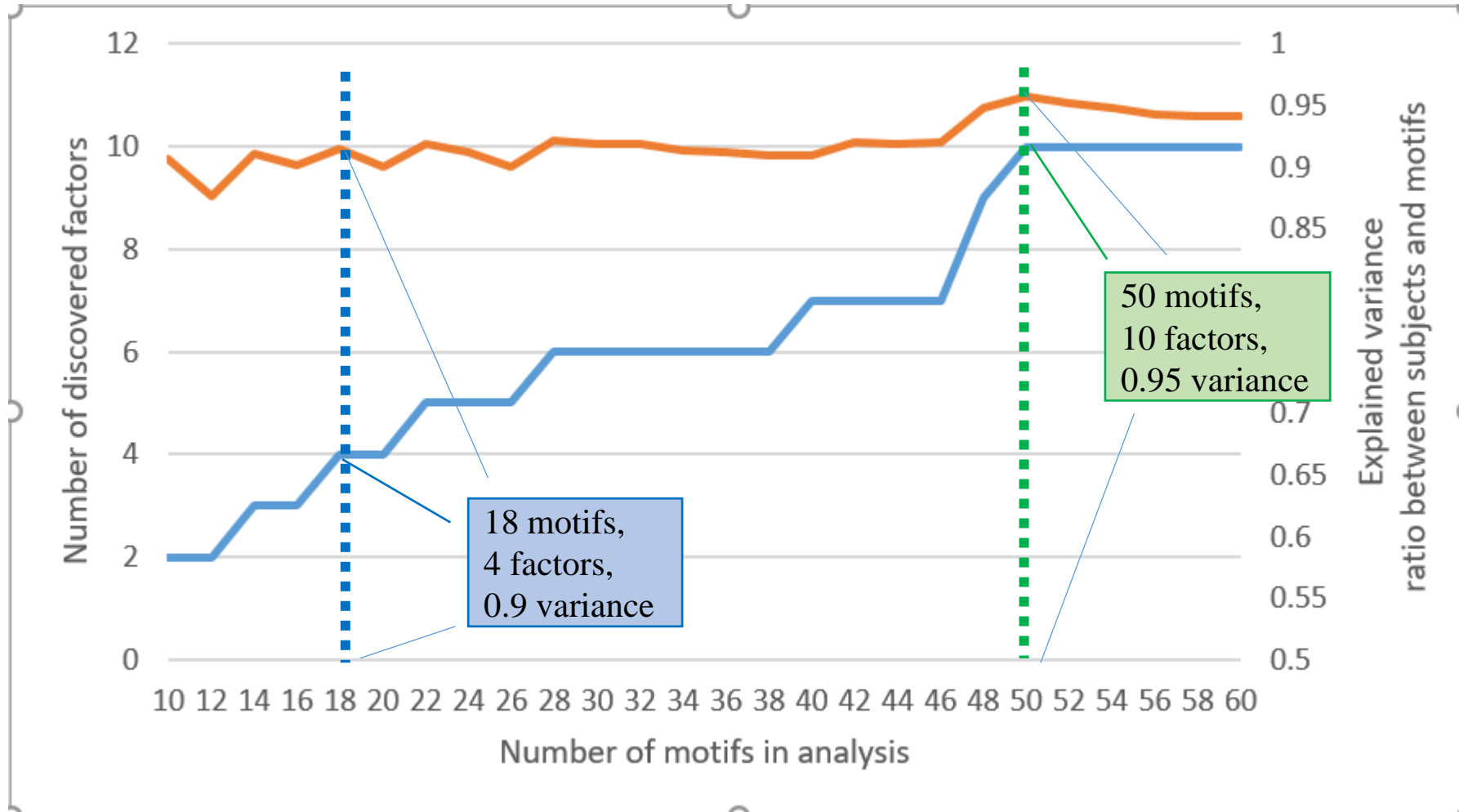
Clustering of 3 types based on BR reading sequences

Type	description	Reading pattern
1	Least activities	Disengaged
2	More page turning, less activities	Surfing — turning page
1	More markers, more jump	Targeting - seeking keywords, concepts
2	More memo, more activities	Comprehensive - Note & annotation taking, hardworking
3	More change_memo, more prev_page	Reflective - Critical thinking

1.3 Sequence mining (Motif)

- Reading sequence (Motif) is used to denote a sequence of actions
- A sliding window of size W is used to define sequences of actions with a length of W . ($W = 3$)
- Exploratory factor analysis (EFA)
 - EFA using the most frequent motifs as input.
 - The output of the EFA is a set of constructs (factors) that represent user behavior patterns.

Minimal number of motifs & factors to explain the maximum variance (EFA)



Motif & factor that explain the maximum variance (EFA)

Maximum variance in factors

Top 18 most frequent Motif in 4 factors

Top 50 most frequent Motif in 10 factors

	元件									
	1	2	3	4	5	6	7	8	9	10
NNN	.563	.226	-.040	.556	-.054	-.003	.501	-.099	.223	.044
PPP	.699	.098	-.184	.625	-.091	-.066	.164	-.086	.091	-.047
NNP	.482	.191	-.114	.791	-.100	.129	.148	.019	.170	.015
PNN	.457	.175	-.096	.843	-.110	.075	.099	.037	.102	-.014
NPP	.543	.146	-.165	.790	-.099	.019	.071	.003	.111	-.018
PPN	.563	.132	-.129	.792	-.097	.021	.012	.052	.025	-.022
NPN	.448	.179	-.054	.840	-.111	.177	.065	.044	.044	.020
ONN	.336	.215	.025	.436	-.031	.064	.702	-.100	.308	.185
PNP	.600	.051	-.100	.742	-.098	.052	-.175	.089	-.126	.007
NNAMa	.110	.341	.772	-.108	.113	-.135	.159	.417	.007	.067
AMaNN	.193	.213	.859	-.049	.272	-.102	.058	.193	.079	.134
CMeNN	.920	.071	.084	.240	.004	.213	.026	.125	.112	-.027
NNCMe	.958	.014	.112	.234	.018	.068	.069	-.009	.038	.000
NNC	-.032	.354	.189	.000	-.016	.321	.759	.256	-.264	.060
NAMaN	-.055	.165	.946	-.146	.080	-.020	.096	-.061	-.022	.027
NCMeN	.939	.042	.048	.264	-.006	.164	-.040	.068	.012	-.048
AMaAMaN	.039	.106	.913	-.022	.266	.054	-.082	.009	.005	.153
JJJ	.139	.845	.086	.224	.035	-.073	-.111	-.058	.031	.094
AMaAMaAMa	-.134	.261	.455	-.118	.655	-.028	-.129	.357	-.040	-.168
NAMaAMa	.066	.167	.907	-.093	.302	-.053	-.029	.108	-.029	.027
ABNN	.022	.089	.327	-.102	.912	-.043	.039	.114	.084	.057
NNAB	-.016	-.038	.127	-.129	.959	-.016	-.061	-.101	-.049	-.109
NABN	-.031	-.200	.212	-.100	.933	-.015	.030	-.067	-.015	.094
JNN	.074	.961	.097	.102	.006	.042	.166	.012	.085	.012
NNAMe	.671	.152	-.068	.328	.007	.577	-.024	.162	.020	.115
CMeCMeCMe	.861	.009	.295	.234	.086	.078	.032	.045	-.025	.185
AMeNN	.572	.153	-.105	-.027	.044	.750	.191	.054	.136	-.022
AMaNAMa	-.164	.167	.830	-.074	-.081	.048	-.007	-.366	-.047	-.229
NNJ	-.115	.903	.072	.064	-.020	.018	.276	-.128	.099	-.082

Motif & factor
that explain the
maximum
variance (EFA)

Top 50 most
frequent Motif
in 10 factors

NAMEN	.533	.119	-.186	.122	-.095	.776	.130	.003	.043	.053
CMeCMeN	.838	.088	.039	.151	.020	.353	.327	.039	.048	-.013
CMePP	.950	.023	.029	.255	-.024	-.077	-.102	.034	-.009	-.048
NPAMa	.309	.637	.301	-.007	-.009	.087	-.192	.453	.309	.057
NMeCMe	.943	-.059	.012	.133	.012	.169	.223	-.064	.025	-.030
JJN	.059	.947	.167	.040	-.008	-.045	.010	.059	-.094	.017
PCMeN	.809	.081	-.040	.274	-.039	.392	-.101	.232	.000	-.048
NJN	-.116	.866	.091	.127	-.006	.115	.262	-.133	.136	.010
PABN	.115	.469	.553	.106	.437	-.127	.217	.169	.297	.031
AMaNP	-.014	.729	.445	-.064	.093	.180	-.210	.202	.149	-.030
PPCMe	.901	.026	-.091	.063	-.015	-.139	.134	-.011	.205	-.131
PPJ	.320	.768	-.007	.109	.029	.335	.092	.188	.051	-.019
PPAMa	.501	.234	-.086	.147	.053	.091	.049	.028	.772	-.060
JPP	.049	.841	.146	.101	-.075	.245	.044	.330	-.154	.133
NJJ	.075	.946	.212	.069	-.045	-.033	-.033	-.030	-.101	.055
NPCMe	.820	.124	.014	.242	-.026	.371	-.130	.242	.019	.000
PNCMe	.910	.033	-.029	.253	-.033	.235	-.137	.113	-.076	-.049
NCN	-.122	.153	.126	.018	-.021	-.010	.103	-.131	.070	.905
NPAMe	.534	.171	.060	.108	-.105	.793	.057	-.082	-.044	-.090
AMaPP	.374	.110	.139	.128	.033	.055	.113	.708	.051	-.255
CNN	-.181	-.080	.184	.538	-.051	.026	-.042	.087	.692	.313

4 Factors that explain reading patterns (EFA)

factor1	NNN	PPP	CMeNN	NNCMe	NCMeN	NNAMe	CMeCMeCMe	CMeCMeN	CMePP	NCMeCMe	PCMeN	PPCMe	NPCMe	PNCMe
factor2	JJJ	JNN	NNJ	NPAMa	JJN	NJN	AMaNP	PPJ	JPP	NJJ				
factor3	NNAMa	AMaNN	AMaNAMa	PABN										
factor4	NNP	PNN	NPP	PPN	NPN	ONN	PNP	NAMaN	AMaAMaN	NAMaAMa				
factor5	AMaAMaAMa	ABNN	NNAB	NABN										
factor6	AMeNN	NAMeN	NPAMe											
factor7	NNC													
factor8	AMaPP													
factor9	PPAMa	CNN												
factor10	NCN													

Description of 4 factors based on EFA

Factor	description	Reading pattern
1	Least activities	Disengaged
2	More page turning, less activities	Surfing—turning page
1	Most change_memo+prev+change_memo , more activities	Comprehensive - Note & annotation taking, hardworking
2	More jump+prev+marker	Reflective - Critical thinking
3, 4	Most markers , more page turning	Targeting - seeking keywords, concepts

Remarks of BR reading pattern detection

- The results of **three methods are consistent**, leading to **five BR reading patterns**
 - Disengaged, Surfing, Targeting, Reflective, Comprehensive
- With good-designed **learning activity**, it will guide students to
 - Targeting, Reflective, and Comprehensive
- The result of reading patterns is confined to **BR only**
 - Different systems could result in different patterns

Step 2. **Prediction** of students' learning outcome

based on BR learning log

Assessment metrics for measuring students' performance

- Teachers' Assessment metrics (**labels**)
 - **BR log score (behavior engagement)**
 - Counts of 15 feature's (**auto ranking**)
 - Quality of markers & memos (**auto grading**)
 - **Written reports (Preview & reflection)**
 - Quality of written report (**auto grading**)
 - Procrastination of report submission (**auto ranking**)
 - **Paper exams**
 - Mid-term & final exam (**human grading**)

Eight Classification methods

1. Gaussian Naive Bayes (GaNb)
2. Linear-SVC
3. Support Vector Classification (SVC)
4. Logistic Regression (LR)
5. Decision Tree (DT)
6. Random Forest (RF)
7. Neural Network (NN)
8. Extreme Gradient Boosting (XGBoost)

Evaluation metrics for prediction performance

- Accuracy

- $Accuracy = \frac{TP+TN}{TP+TN+FP+FN}$

- Recall

- $Recall = \frac{TP}{TP+FN}$

- Precision

- $Precision = \frac{TP}{TP+FP}$

- F1-score

- $F1 = 2 \cdot \frac{Precision \cdot Recall}{Precision+Recall}$

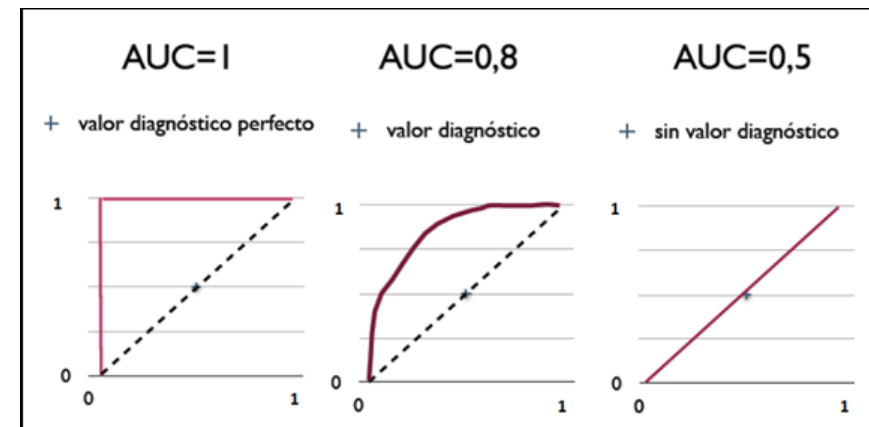
Evaluation metrics for prediction performance

- AUC
 - The area under the ROC curve
 - The higher, the better

- $TPR = \frac{TP}{TP+FN}$

- $FPR = \frac{FP}{FP+TN}$

- $AUC = \int_{\infty}^{-\infty} TPR(T)FPR'(T)dT$



2.1 Which **classification** methods are best for predicting students' performance (e.g. **log score**)?

- **LR** has the best prediction performance on **AUC**.

Method	Accuracy	Precision	Recall	F1-score	AUC
	80-20 / 50-50 / 20-80 (Grading policy)				
GaNB	.81 / .75 / .79	.66 / .81 / .78	.81 / .75 / .79	.72 / .73 / .78	.50 / .74 / .64
Linear-SVC	.91 / .91 / .78	.93 / .91 / .79	.91 / .91 / .78	.91 / .91 / .79	.90 / .91 / .67
SVC	.94 / .90 / .83	.94 / .90 / .82	.94 / .90 / .83	.94 / .90 / .82	.91 / .90 / .69
LR	.94 / .93 / .82	.95 / .93 / .85	.94 / .93 / .82	.94 / .93 / .83	.95 / .93 / .78
DT	.84 / .81 / .81	.86 / .82 / .83	.84 / .81 / .81	.84 / .81 / .82	.79 / .81 / .73
RF	.89 / .87 / .83	.89 / .87 / .80	.89 / .87 / .83	.89 / .87 / .81	.81 / .87 / .65
NN	.91 / .92 / .78	.92 / .92 / .80	.91 / .92 / .78	.91 / .92 / .79	.86 / .92 / .68
XGBoost	.87 / .83 / .79	.87 / .84 / .74	.87 / .83 / .79	.84 / .83 / .76	.67 / .83 / .56

2.2 How **assessment metrics** affect predictive model?

Assessment metrics

Log is the best

Preview is better than

Reflection is better

than **Exam**

Grading policy

80-20 is the best

Leniency is better

than **Moderate** is

better than **Stringency**

Method	AUC			
	Log	Preview	Reflection	Mid-term
	80-20 / 50-50 / 20-80 (Grading policy)			
GaNB	.50 / .74 / .64	.50 / .74 / .54	.50 / .74 / .64	.50 / .76 / .55
Linear-SVC	.90 / .91 / .67	.90 / .90 / .59	.90 / .77 / .67	.90 / .65 / .78
SVC	.91 / .90 / .69	.91 / .90 / .63	.90 / .77 / .70	.91 / .64 / .76
LR	.95 / .93 / .78	.95 / .92 / .62	.95 / .82 / .78	.95 / .73 / .74
DT	.79 / .81 / .73	.80 / .82 / .67	.79 / .79 / .74	.79 / .71 / .62
RF	.81 / .87 / .65	.81 / .86 / .59	.82 / .82 / .65	.82 / .74 / .55
NN	.86 / .92 / .68	.86 / .92 / .56	.86 / .82 / .67	.86 / .72 / .73
XGBoost	.67 / .83 / .56	.67 / .83 / .55	.67 / .79 / .56	.67 / .78 / .57

2.3 What are the **critical factors** affecting predictive model? (Spearman)

Feature Category	Feature name	Grades			
		Log	Preview	Reflection	Exam
eBook file	Open	0.855***	0.889***	0.894***	0.742***
	Close	0.712***	0.646**	0.680**	0.594**
Bookmark	Add Bookmark	0.622**	0.429	0.472*	0.553**
	Delete Bookmark	0.707***	0.559**	0.629**	0.491*
Marker	Add Marker	0.639**	0.361	0.385	0.235
	Delete Marker	0.629**	0.265	0.281	0.143
	Marker	0.654**	0.369	0.385	0.224
Memo	Add Memo	0.811***	0.741***	0.749***	0.627**
	Delete Memo	0.490*	0.342	0.318	0.219
	Change Memo	0.874***	0.747***	0.745***	0.625**
	Memo	0.921***	0.801***	0.787***	0.695***
eBook page	Next	0.789***	0.719***	0.689**	0.726***
	Prev	0.657**	0.492*	0.458*	0.498*
	Jump	0.865***	0.742***	0.773***	0.725***
	Search	0.126	0.133	0.183	-0.115

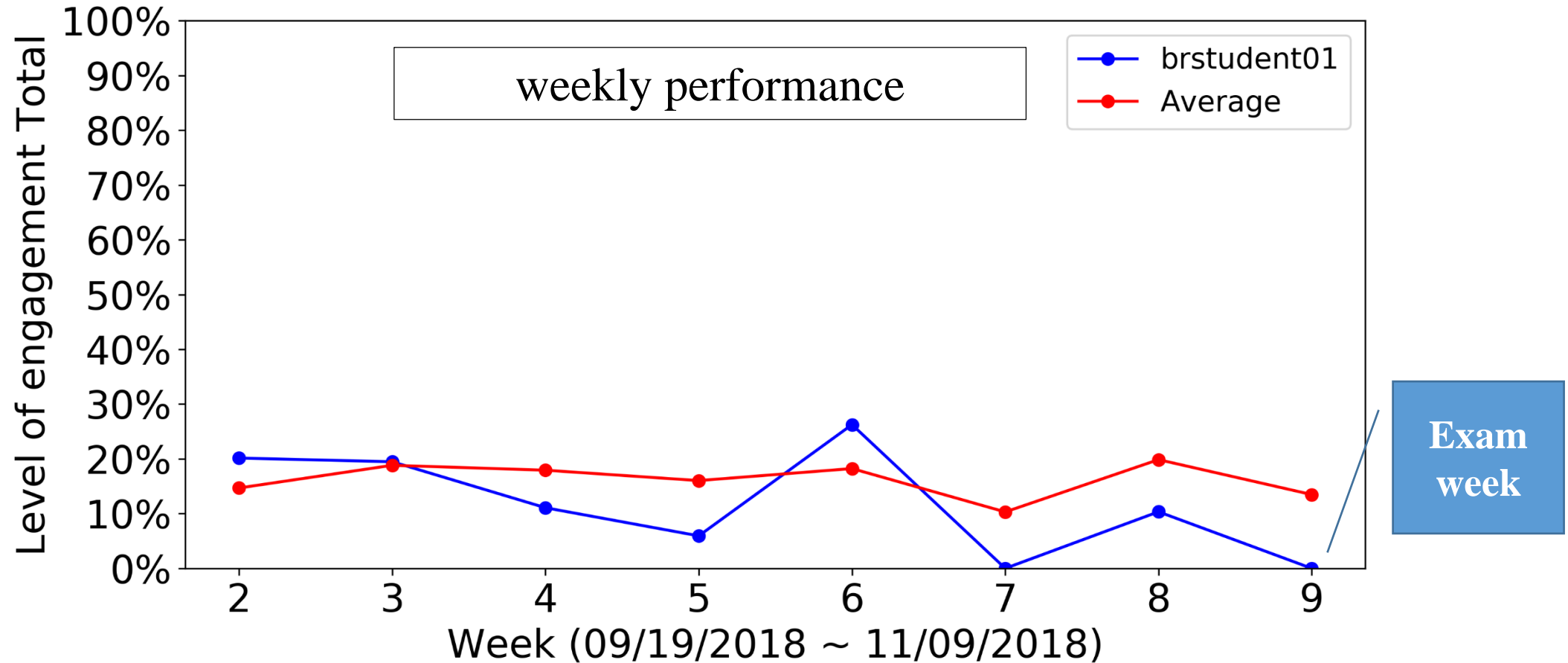
Step 3. **Treatment** by timely intervention

Improving engagement with
BR-based learning activities design and evaluation

Knowing the correlation between students' learning **patterns** & **outcome**

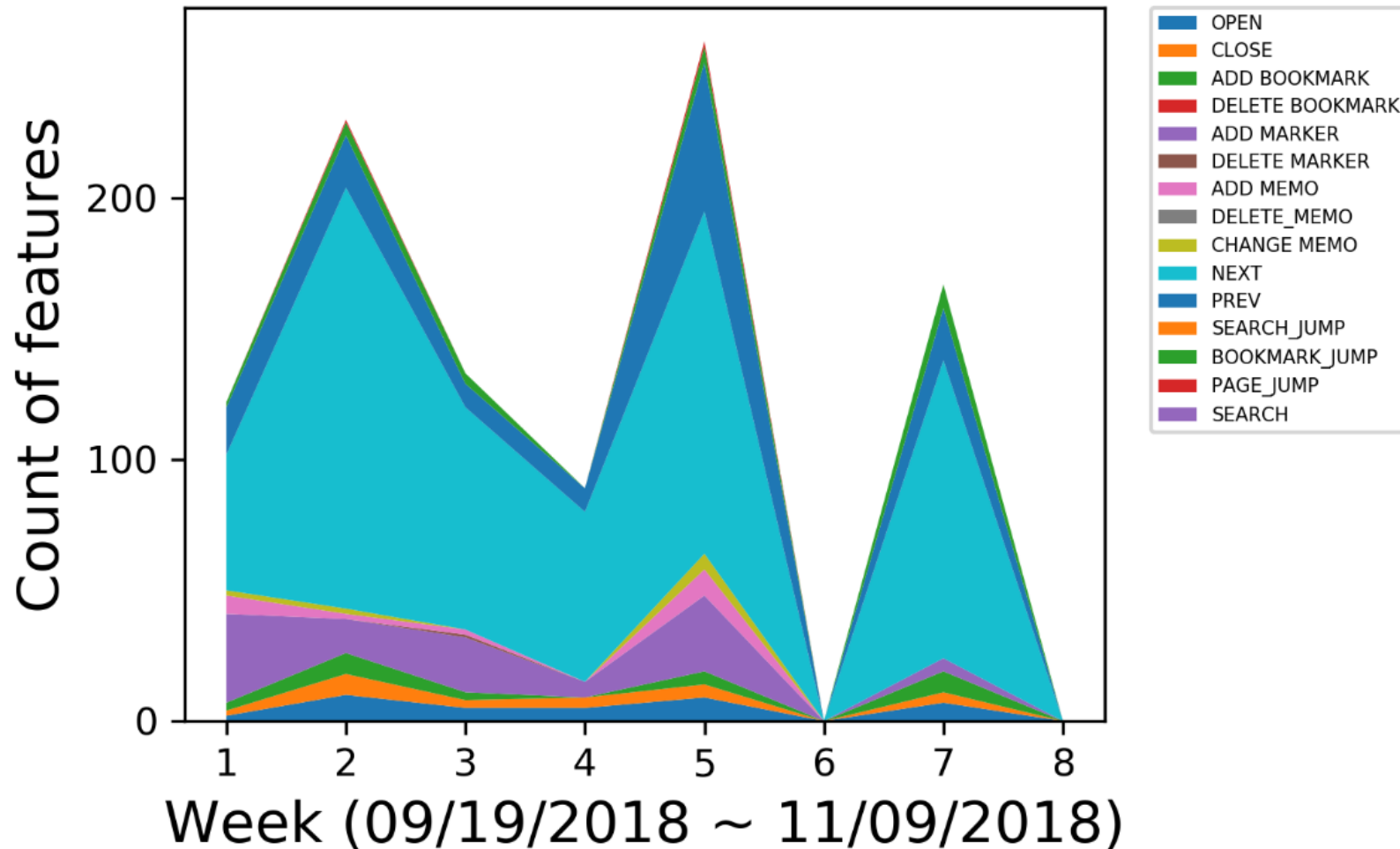
	Diagnosis (Patterns)	Prediction (Outcome)	Treatment (learning strategy)	Treatment (learning activities)
}	Disengaged	Fail	Motivation	More Next, Prev (draw attention)
	Surfing	Fail	Motivation	More Marker (help focus)
}	Reflective	Pass	Goal setting Time management	Improve quality of Preview/Reflection reports
	Targeting	Pass	Self-evaluation Critical Thinking	More Memo/Change_memo, More Bookmark_jump
	Comprehensive	Pass	Elaboration	Improve quality of Preview/Reflection reports

Evaluation of **feature counts** between **individual** and **class average**
Diagnosis : below average, unstable, decreasing; non-hardworking before exam

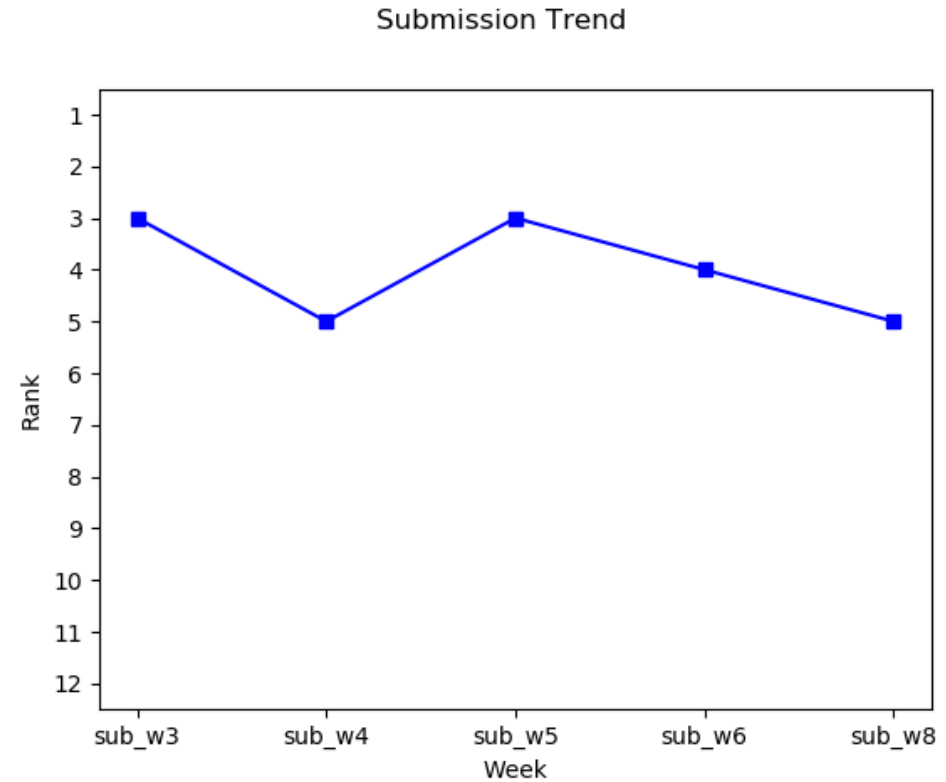
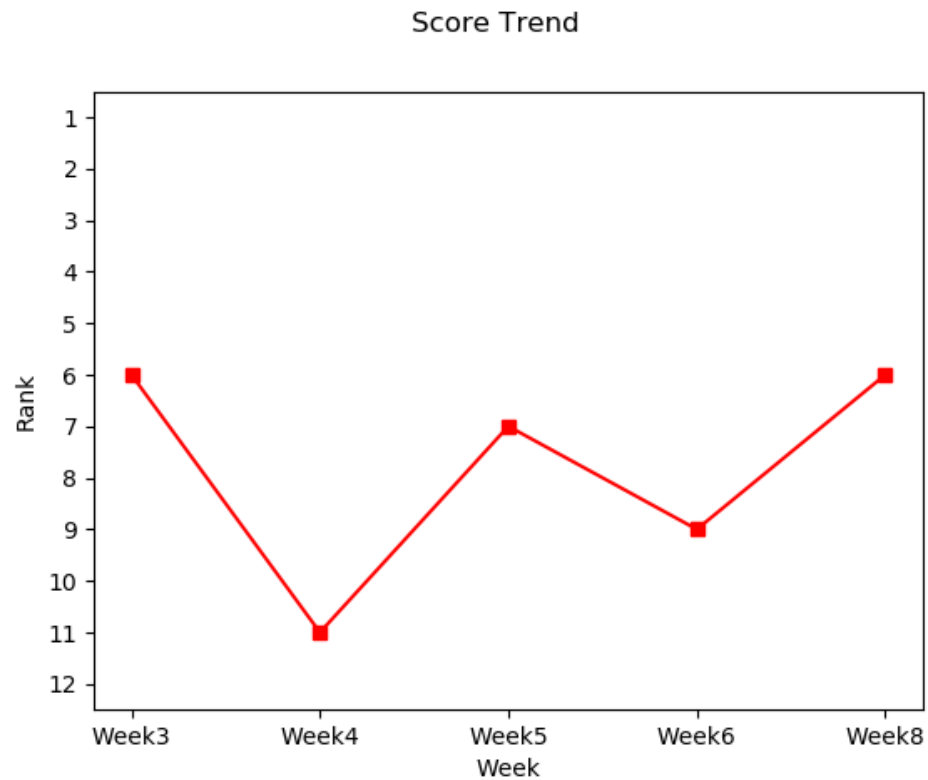


Evaluation of **individual** student's **distribution of 15 features**

Diagnosis : unstable, decreasing, balanced, non-hardworking before exam



Evaluation of individual student's **Quality of Preview** & **Procrastination** of written report submission



3.1 Activity for improving students' engagement by identifying **keywords/concept** with **Marker & Memo**

- Pre class activities
 - Use **Marker** to highlight the important issue (**red**) and those you don't know (**yellow**).
 - Use **Memo** to write down your comments or questions next to the Marker
- In class activities
 - **Raise comments/questions** based on marker/memo
 - **Delete marker** if it no longer important
 - **Delete memos** if you get answers
 - **Add new marker or memo** if you find something interesting in class

3.2 Activity for improving students' engagement by locating **pages of reminder** with **Bookmark**

- Pre class activities
 - **Bookmark** the pages you think they are important and as a **reminder of reflection**.
 - **Bookmark** the pages you **put questions**
- In class activities
 - Let teacher know **which page** you mentioned when you raise question in class
 - Easy to **flash back** those important pages

3.3 Activity for improving students' engagement by following **teacher's presentation** with **Marker & Memo**

- Pre class activities
 - Are teacher's **red highlight** the same as yours **red marker**?
 - Do you and teacher have the same **important connect/keywords** about this article?
 - Will you write down your thoughts in **Memo**?
- In class activities
 - Can you follow teacher's **presentation**?
 - Can you **comment** teacher's presentation and raise questions and opinion?

3.4 Activity for improving students' engagement by inspiring Q&A discussion with embedded questions

- Pre class activities
 - Teacher raise questions and embed into certain pages to draw students' attention
 - Request students to answer questions by Memo
- In class activities
 - Teacher encourage discussion of those embedded questions
 - Students take notes about the discussion

3.5 Activity for improving students' engagement by writing **preview & reflection** with **marker & memo**

- Pre class activities
 - Use **marker & memo** to **take notes** from your own perspective
 - Copy the maker and memo in preview as your **pre-class preview report**
- In class activities
 - Use marker and memo to take notes what **teacher said** and what **classmates' discussion**, and your own **inspiration, reflection** in class discussion
 - Copy the maker and memo in class as your **post-class review report**

Step 4. **Prevention** by

SMART mind

SMART (mind)

Specific

Measurable

Agreement

Realistic

Time

Specific

Point to the right direction

Self-paced, Self-regulated learning

Measurable

Pick battles big enough to matter, small enough to win

Individualized learning

Agreement

Be alert, Catch on, Refocus

Adaptive learning

Realistic

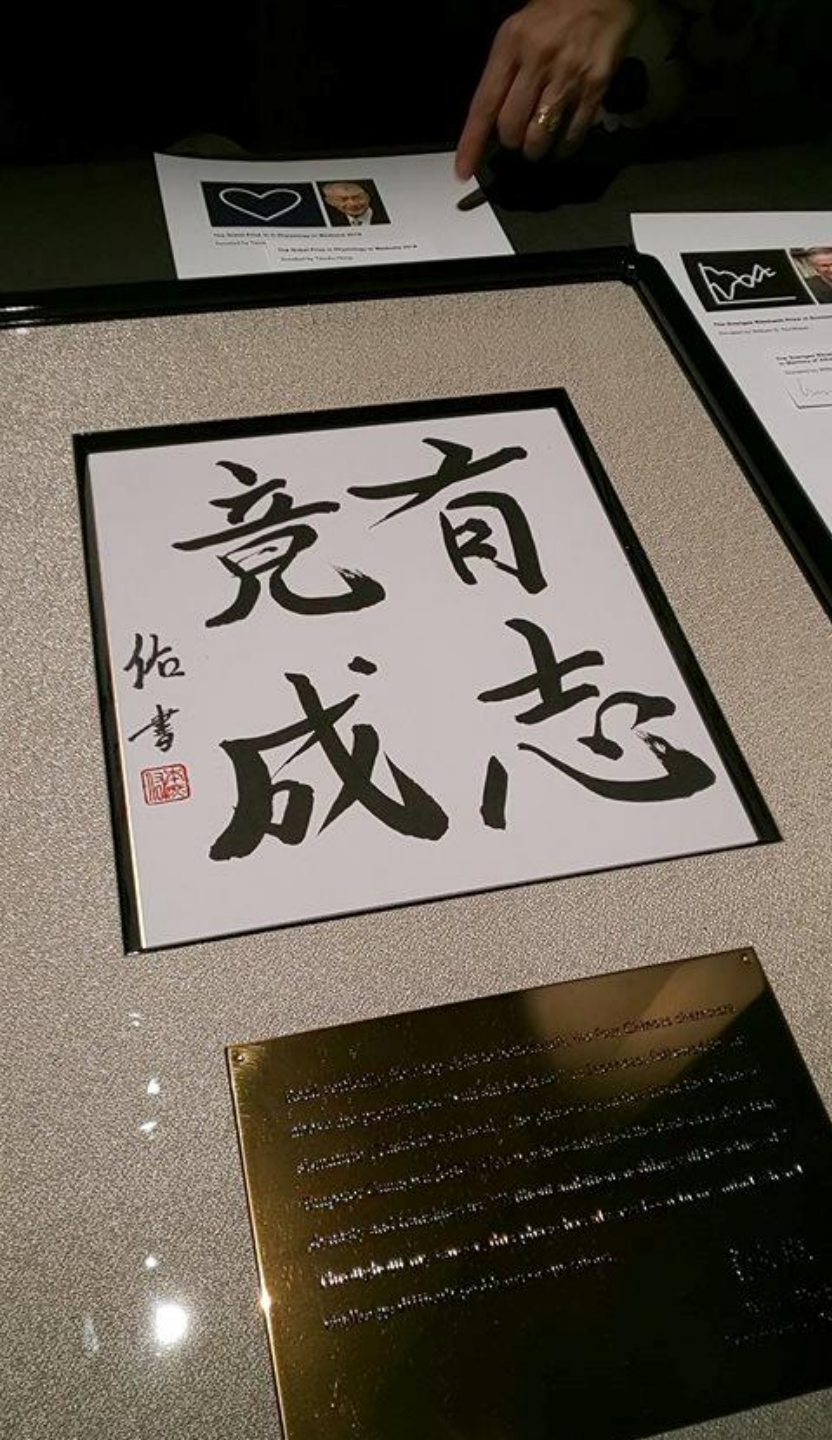
Enjoy yourself. If you can't enjoy yourself,
enjoy somebody else

Collaborative learning

Time

Time is not measured by a watch, but by moments!

Just-in-time learning



With Will, You Succeed

2018 Nobel laureate in Physiology/Medicine
Kyoto University

Prof. Tasuku Honjo (本庶佑)



Thanks very
much

Stephen J.H. Yang

楊鎮華