Methods and tools for learning behavior and interactive pattern analysis

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Learning analytics

- Using the data produced by learners to discover information and social connections in order to offer advice for learning (Siemens, 2010).
- Who could be benefited from learning analytics?
  - learners
  - teachers
  - educational policy makers

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Why learning analytics is important to e-learning research?

- Most e-learning studies report the effectiveness of the proposed system/strategy by using tests and questionnaires.
- More convincing evidences could be provided via analyzing students' learning process
  - What happen during the learning process?
  - Why the experimental group had better learning outcomes than the control group?
  - What are the differences between the behavioral patterns or interactive content of the students learning with personal characteristics (e.g., low- and high-achievements)?
- Provide in-depth interpretations of the findings

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Coding scheme

- A coding scheme is a set of codes
  - Transfer **learning behaviors, interactive contents (ill-structured)** into unified and **meaningful categories (structured).**

Behavior: talk to NPC in gaming process
→
Code: Seeking help

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Behavior: go to the library and read supplementary materials
→
Code: Reading learning materials

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Data to be coded (1)

- **Interactive content** or **learning behaviors recorded on videos**
  - Need to be coded manually by two persons based on the coding scheme for verifying the consistency of the coded results

Kappa value	Consistency degree
< 0.4	poor
0.4 ~ 0.6	acceptable
0.6 ~ 0.8	good
> 0.8	Very good

Cohen, J. (1960). A coefficient of agreement for nominal scale. *Educational and Psychological Measurement*, *20*(1), 37–46. doi:10.1177/001316446002000104

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Interactive content in a discussion forum on "Global Warming" (5 students A, B, C, D, E)1/2

A: Why is global warming important?
B: The temperature of the earth is rising.
A: What does that have to do with us?
C: It's mainly because the ozone layer is being destroyed because of too much exhaust.
D: It seems to be because of the emissions from cars and factories.
E: The barbecue in the Dragon Boat Festival barbecue should also be a reason.
A: But the barbecue of the festival occurs only once in a year, so it should not have much effect.
B: Yes, I also think barbecue is not the main reason.
A: A new barbecue restaurant opened near us, very good; a lot of meat, called “Meat Duo Duo".
C: It is a hot pot restaurant.
D: Is it very expensive?
A: The cost is around 299 for one person, and you can take the food home if you can't finish it.
E: I know this one, and you can exchange your vegetable plate for a meat plate.
D: It's great! I'm going to eat there next time too.
B: Shouldn't we think about the problem of global warming. Is there some other reason?

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Interactive content in a discussion forum on "Global Warming" (5 students A, B, C, D, E)2/2

E: The worship is also the reason. We need to burn a lot of gold paper.
D: That's right, every time there's smoke around our house on Ching Ming Festival.
A: Do you live in a cemetery?
C: I think cars and factories are a bigger factor.
D: Compared with cars, factories should be the main culprit.
A: Why don't factories want to deal with the exhaust?
B: I think the technology for dealing with the exhaust does not exist.
C: I think the cost is too high, not the problem of technology.
E: I also think it is the cost problem, businessmen are to make money.
A: Anyway, the main problem of global warming should be factories, followed by cars; in addition, barbecue or worship should be avoided as much as possible.
B: But factories have to consider the cost, otherwise they will not be able to operate.
D: I think we should give priority to environmental protection, otherwise it will be impossible to live here in the future.
C: I agree, the living environment is still more important.
A: So the conclusion is that we should control the emission of waste gas from factories and cars, and we should reduce the way of barbecue and worship.
B: Yes, that's right.
C: OK.

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Coding results of the interactive content in a discussion forum on "Global Warming" (5 students A, B, C, D, E)

A: Why is global warming important? →**raising a question**
B: The temperature of the earth is rising. →**Providing an answer**
A: What does that have to do with us? →**raising a question**
C: It's mainly because the ozone layer is being destroyed because of too much exhaust. →**Providing an answer**
D: It seems to be because of the emissions from cars and factories. →**Providing an answer**
E: The barbecue in the Dragon Boat Festival barbecue should also be a reason. →**Providing an answer**
A: But the barbecue of the festival occurs only once in a year, so it should not have much effect. →**Raising an objection**
B: Yes, I also think barbecue is not the main reason. →**Proposing an agreement**
A: A new barbecue restaurant opened near us, very good; a lot of meat, called “Meat Duo Duo". →**Irrelevant content**
C: It is a hot pot restaurant. →**Irrelevant content**
D: Is it very expensive? →**Irrelevant content**
A: The cost is around 299 for one person, and you can take the food home if you can't finish it. →**Irrelevant content**
E: I know this one, and you can exchange your vegetable plate for a meat plate. →**Irrelevant content**

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Coding results of the interactive content in a discussion forum on "Global Warming" (5 students A, B, C, D, E)

D: It's great! I'm going to eat there next time too. →**Irrelevant content**
B: Shouldn't we think about the problem of global warming. Is there some other reason ? →**raising a question**
E: The worship is also the reason. We need to burn a lot of gold paper. →**Providing an answer**
D: That's right, every time there's smoke around our house on Ching Ming Festival. →**Proposing an agreement**
A: Do you live around a cemetery? →**Irrelevant content**
C: I think cars and factories are a bigger factor. →**Providing an answer**
D: Compared with cars, factories should be the main reason. →**Raising an objection**
A: Why don't factories want to deal with the exhaust? →**raising a question**
B: I think the technology for dealing with the exhaust does not exist. →**Providing an answer**
C: I think the cost is too high, not the problem of technology. →**Raising an objection**
E: I also think it is the cost problem, businessmen are to make money. →**Proposing an agreement**
A: Anyway, the main problem of global warming should be factories, followed by cars; in addition, barbecue or worship should be avoided as much as possible. →**Making a conclusion**
B: But factories have to consider the cost, otherwise they will not be able to operate. →**Questioning the conclusion**

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Coding results of the interactive content in a discussion forum on "Global Warming" (5 students A, B, C, D, E)

D: I think we should give priority to environmental protection, otherwise it will be impossible to live here in the future. →**Supporting the conclusion**
C: I agree, the living environment is still more important. →**Proposing an agreement**
A: So the conclusion is that we should control the emission of waste gas from factories and cars, and we should reduce the way of barbecue and worship. . →**Making a conclusion**
B: Yes, that's right. →**Proposing an agreement**
C: OK. →**Proposing an agreement**

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Data to be coded (2)

- Learning behavior logs recorded by the learning system based on the pre-defined coding scheme
  - No manual coding process is required **if the coding scheme is defined when developing the learning system** (e.g., seek helps, reading learning materials, accepting challenges, avoiding challenges, correctly answer a question, fail to correctly answer a question)

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Other usages of developing a coding scheme

- Analyze and evaluate students' **higher order thinking** performances based on the data collected from
  - Students' learning diaries
  - Students' reports
  - Students' feedback to open-ended questions
- For example: how to evaluate students' critical thinking by analyzing their interactive contents or reports?

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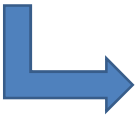
What are the features of a student with critical thinking competence?

"have reasonable criticizes"
"make comparisons on other opinions"
"provide in-depth opinions or inferences"
"provide simple opinions"



Coding Scheme

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Rubrics for Critical Thinking

Score	5	4	3	2	1
# of reasonable criticizes	> 8	5-8	3-4	2	1
# of comparisons	> 8	5-8	3-4	2	1
# of in-depth opinions or inferences	>= 5	4	3	2	1
# of simple opinions	>10	7-8	5-6	3-4	1-2

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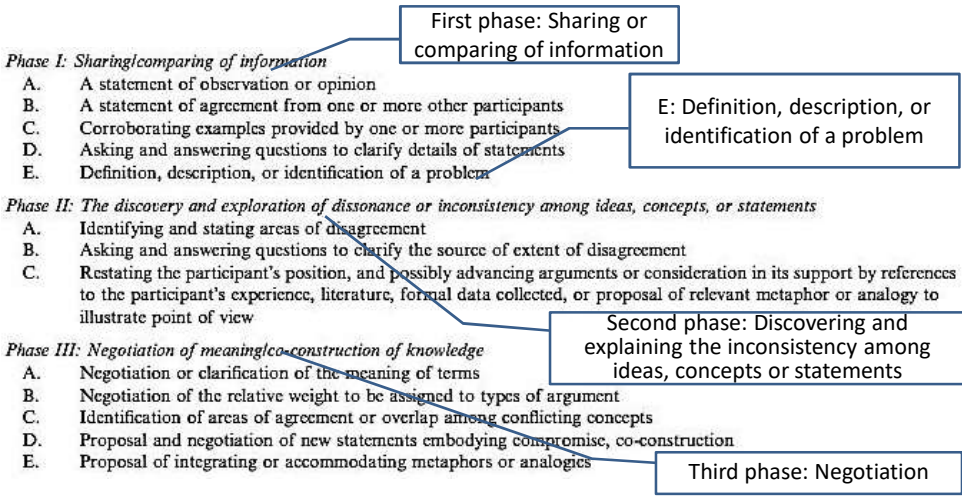
Interaction Analysis Model (IAM)- a coding scheme proposed in 1997 for online interactions



Gunawardena, C. N., Lowe, C. A., & Anderson, T. (1997). Analysis of a Global Online Debate and the Development of an Interaction Analysis Model for Examining Social Construction of Knowledge in Computer Conferencing. *Journal of Educational Computing Research*, *17*(4), 397-431.

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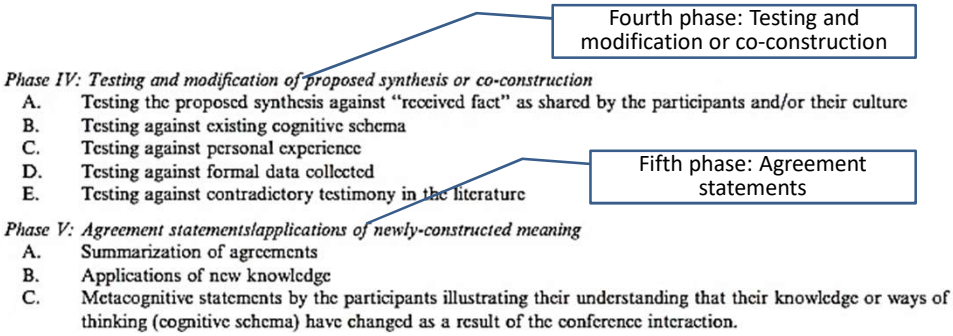
Interaction Analysis Model(IAM)



Phase IV: Testing and modification of proposed synthesis or co-construction

A. Testing the proposed synthesis against "received fact" as shared by the participants and/or their culture
B. Testing against existing cognitive schema
C. Testing against personal experience
D. Testing against formal data collected
E. Testing against contradictory testimony in the literature

Phase V: Agreement statements/applications of newly-constructed meaning

A. Summarization of agreements
B. Applications of new knowledge
C. Metacognitive statements by the participants illustrating their understanding that their knowledge or ways of thinking (cognitive schema) have changed as a result of the conference interaction.

Gunawardena, C. N., Lowe, C. A., & Anderson, T. (1997). Analysis of a Global Online Debate and the Development of an Interaction Analysis Model for Examining Social Construction of Knowledge in Computer Conferencing. *Journal of Educational Computing Research*, *17*(4), 397-431.

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Simplified coding scheme modified from Phase 1 of IAM for problem-solving-based online discussion patterns

Code	Phase	Description
P1	Propose, define, and clarify problem	Propose problem or clarify the definition of the problem
P2	Provide solutions or information for possible answers	Provide information or propose solutions to the problem (provide information for partial or full solution)
P3	Compare, discuss, and analyze	Analyze, compare, and comment on others' opinions, solutions, or collected information
P4	Organize and form conclusions	Organize proposed solutions or comments and form conclusions for solutions
P5	Others	Messages not related to the subject of discussions

Hou, H. T., Chang, K. E., & Sung, Y. T. (2008). Analysis of Problem-Solving-Based Online Asynchronous Discussion Pattern. *Educational Technology & Society*, *11*(1), 17-28.

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Coding scheme for peer discussion in an AR-based collaborative inquiry learning activity

P1: Raising or defining a question.
P2: Proposing a solution to the question or offering information relevant to the question.
P3: Comparing or discussing the solutions proposed for the question.
P4: Reaching a conclusion regarding the various solutions proposed for the question.
P5: Sharing statements or comments **unrelated to the discussion topic.**

Chiang, Tosti H.C, Yang, Stephen J.H., & Hwang, G. J. (2014). Students' online interactive patterns in augmented reality-based inquiry activities. *Computers & Education, 78*, 97-108.

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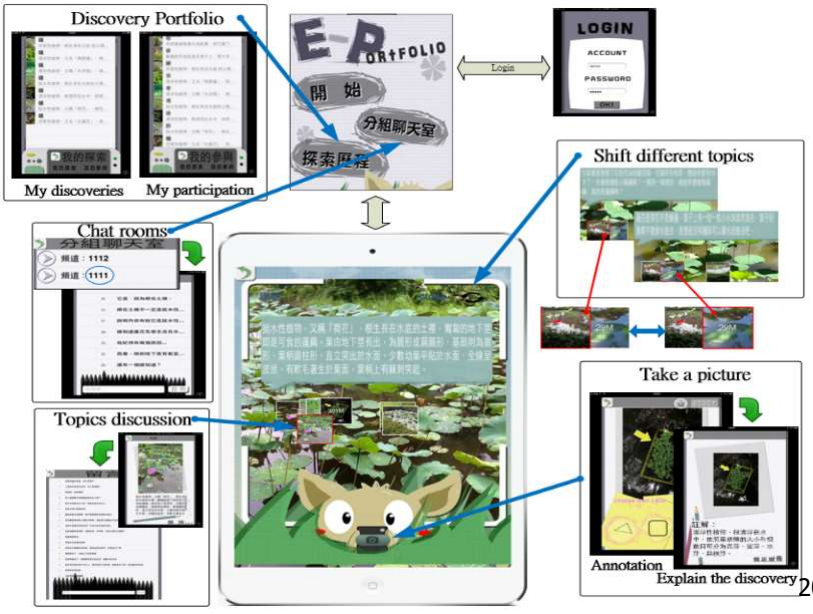
Design of the AR-based collaborative inquiry tasks in the field (Ecological area)



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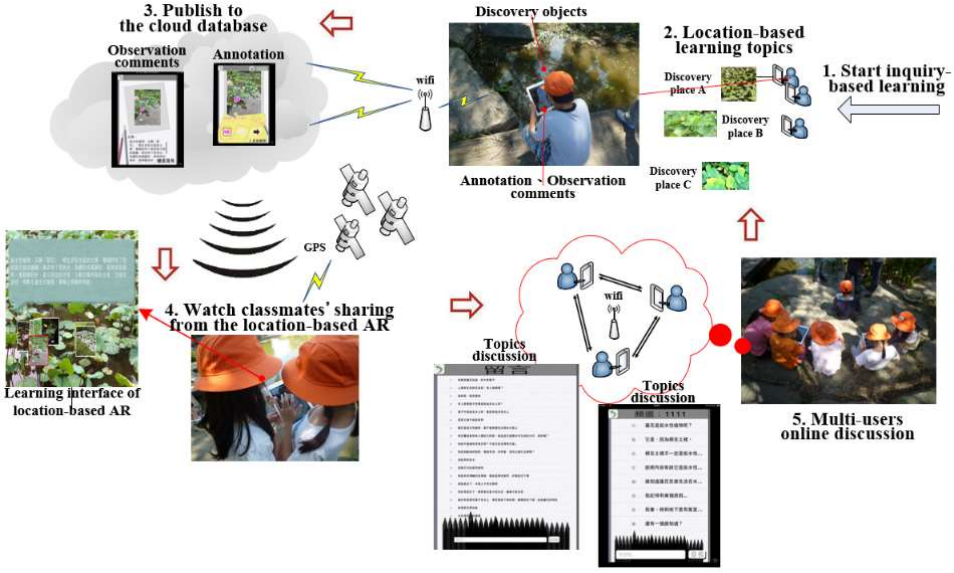
3. Publish to the cloud database
Observation comments
Annotation
wifi
Discovery objects
2. Location-based learning topics
Discovery place A
Discovery place B
Discovery place C
1. Start inquiry-based learning
Annotation ~ Observation comments
GPS
4. Watch classmates' sharing from the location-based AR
Learning interface of location-based AR
wifi
Topics discussion
Topics discussion
5. Multi-users online discussion

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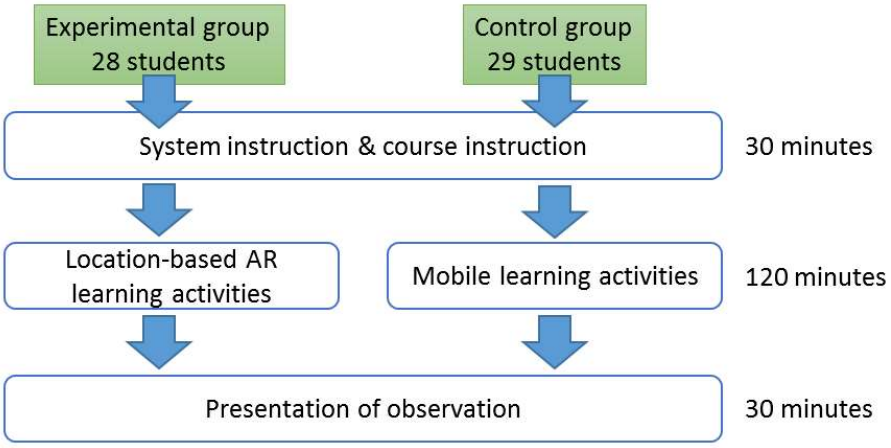
Experimental group
28 students
Control group
29 students
System instruction & course instruction
30 minutes
Location-based AR learning activities
Mobile learning activities
120 minutes
Presentation of observation
30 minutes

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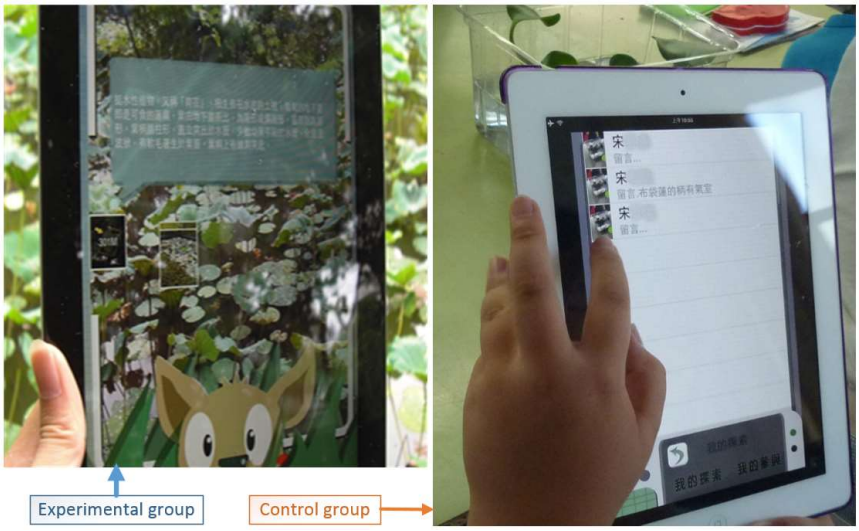

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Examples of coded interactive contents

"Why the leaf shape of this plant is flat and round?"

→P1 (Raising or defining a question)

"I think it is because the plant requires more water."

→P2 (Proposing a solution to the question)

"I think it is because the plant requires more sunshine."

→P2 (Proposing a solution to the question)

"I think Tom's answer is better than John's."

→P3 (Comparing or discussing the solutions)

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Table 2. Frequency transition table of the two groups

Experimental group						Control group					
	P1	P2	P3	P4	P5		P1	P2	P3	P4	P5
P1	488	193	0	0	9	P1	585	107	12	17	48
P2	2	51	52	13	4	P2	21	10	5	2	15
P3	6	4	103	18	5	P3	8	5	1	3	9
P4	33	0	14	0	0	P4	0	0	0	0	20
P5	5	0	4	1	3	P5	36	0	5	5	145

The number of occurrences of P4→P1 in the experimental group is 33.

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Table 3. Adjusted residuals table (z-scores) of the two groups

Experimental group						Control group					
	P1	P2	P3	P4	P5		P1	P2	P3	P4	P5
P1	*16.63	*3.66	-21.29	-8.47	-2.55	P1	*15.99	*3.97	-2.22	-1.14	-20.52
P2	-12.12	*4.70	*7.96	*5.03	0.99	P2	-3.34	1.72	*3.72	0.58	1.06
P3	-12.20	-6.31	*19.48	*7.19	1.40	P3	-3.25	1.25	0.59	*2.94	1.52
P4	*2.42	-4.01	*2.35	-1.27	-1.02	P4	-5.69	-1.63	-0.67	-0.73	*8.41
P5	-1.06	-2.07	1.31	0.94	*5.33	P5	-13.33	-5.51	0.47	0.07	*19.61

*The sequential relationship P4→P1 is significant (i.e., Z-score > 1.96)

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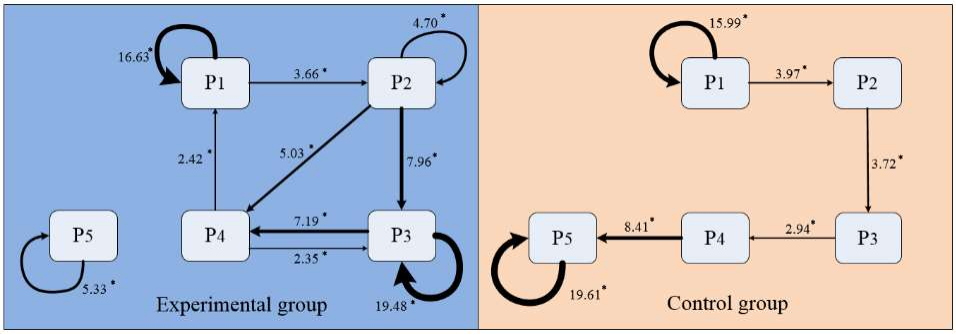

P1: Raising or defining a question.
P2: Proposing a solution to the question or offering information relevant to the question.
P3: Comparing or discussing the solutions proposed for the question.
P4: Reaching a conclusion regarding the various solutions proposed for the question.
P5: Sharing statements or comments unrelated to the discussion topic.

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Sequence	Experimental group	Control group
P1→P1	71%	76%
P1→P2	28%	14%
P2→P3	**43%**	9%
P3→P4	13%	12%
P5→P5	23%	**76%**

P1: Raising or defining a question.
P2: Proposing a solution to the question or offering information relevant to the question.
P3: Comparing or discussing the solutions proposed for the question.
P4: Reaching a conclusion regarding the various solutions proposed for the question.
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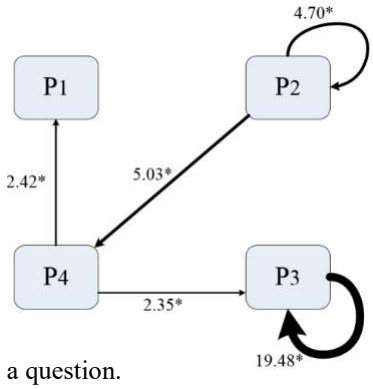
Behavioral transition diagram of sequences in the experimental group only



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P2: Proposing a solution to the question or offering information relevant to the question.
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P4: Reaching a conclusion regarding the various solutions proposed for the question.
P5: Sharing statements or comments unrelated to the discussion topic.

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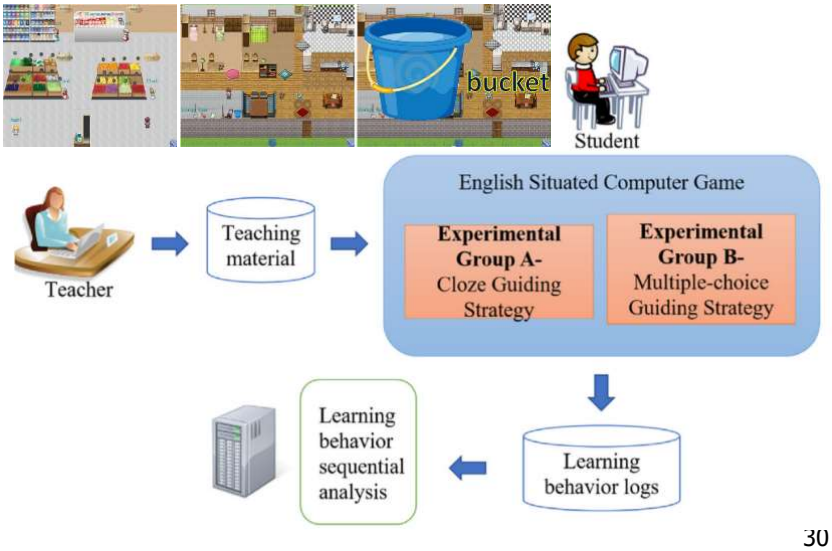
Designed of the English vocabulary learning game



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Interfaces of the cloze and multiple-choice guiding strategies

Hwang*, G. J., & Wang, S. Y. (2016). Single loop or double loop learning: English vocabulary learning performance and behavior of students in situated computer games with different guiding strategies. *Computers & Education*, *102*, 188-201. (SSCI)

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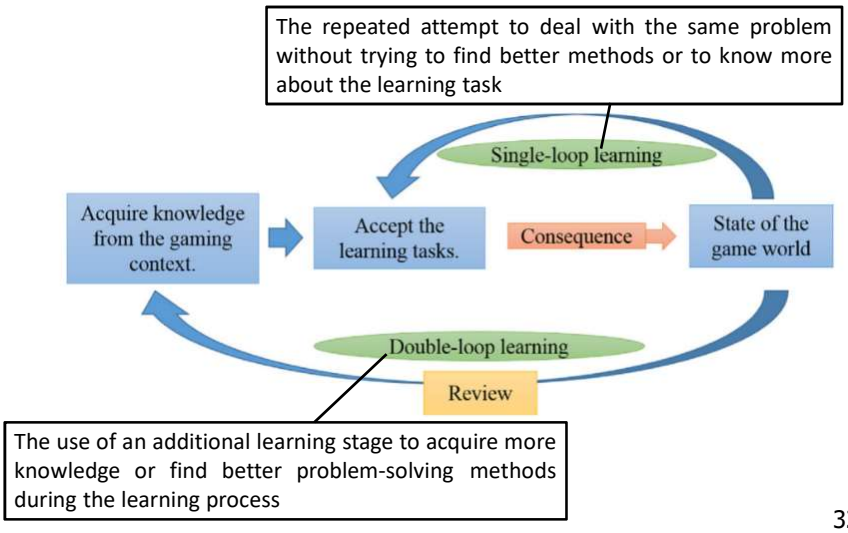
Theoretical background: Single and Double loop learning

Kiili, K. (2007). Foundation for problem-based gaming. *British Journal of Educational Technology*, *38*(3), 394-404.



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Coding scheme for English vocabulary learning game

Code	Phase	Description
L	Read the learning contents	Students learn the vocabulary from the corresponding contexts.
I	Read the gaming information	Students read the information about how to play the game.
A	Accept the learning missions.	Students agree to answer the question.
S	Reject the learning missions.	Students reject to answer the question.
O	Complete the learning missions.	Students correctly answer the question.
X	Fail the learning missions.	Students give the wrong answer
G	Look for gaming hints.	Students ask and read how to play the game.
H	Look for learning help.	Students read the summary of the learning contents.
T	Change the scenes.	Students go to another scene.
M	Take the props in the game.	Students fetch those props needed in the game.

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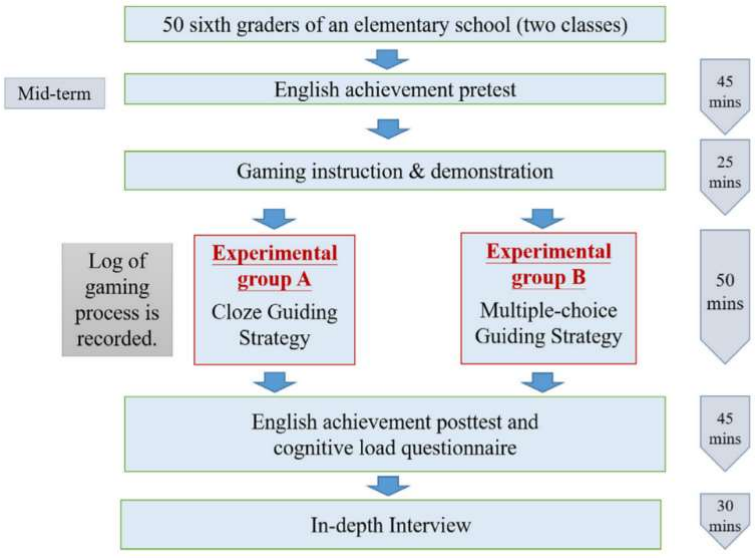
Experimental procedure



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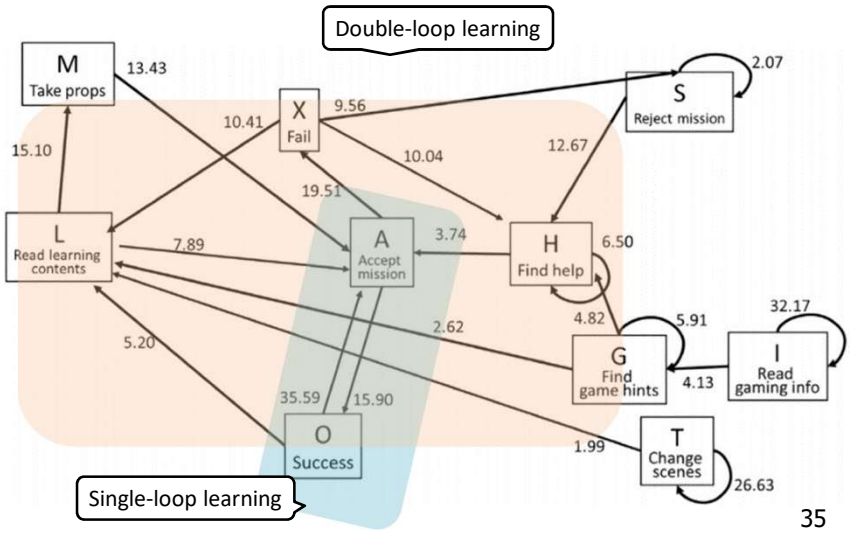
Behavioral transition diagram of the students learning with the cloze guiding strategy.



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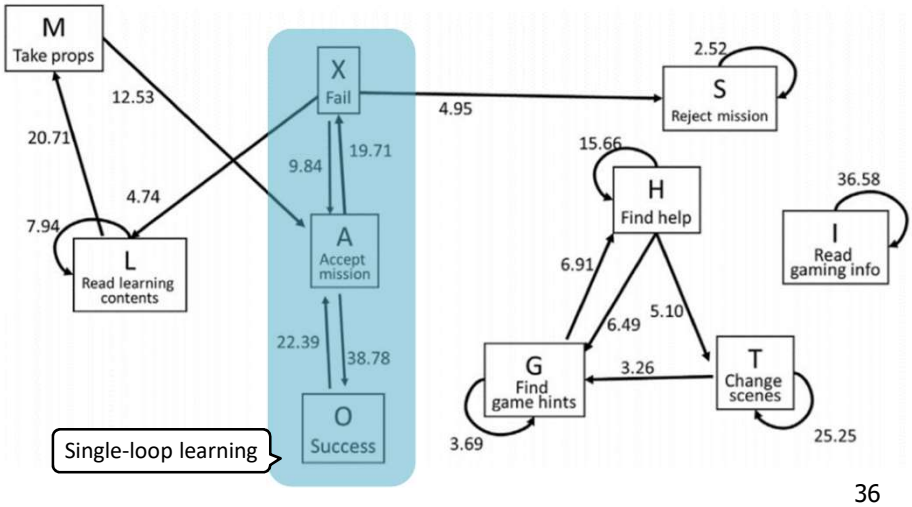
Behavioral transition diagram of those learning with the multiple-choice guiding strategy.



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Conclusion of the cloze and multiple-choice guiding strategies

- Students learned with cloze guiding strategy
  - Reviewed the learning contents after they failed to correctly answer the learning tasks
  - Tended to learn in a double-loop cycle
- Students learned with multiple choice guiding strategy
  - Kept guessing the answers if they did not give the correct one
  - Seldom reviewed the learning contents again
  - Tended to learn in a single-loop cycle
- Conclusion:
  A situated computer game for language learning with the cloze guiding strategy might be able to produce better learning achievement due to the feature of the test item guiding strategy.

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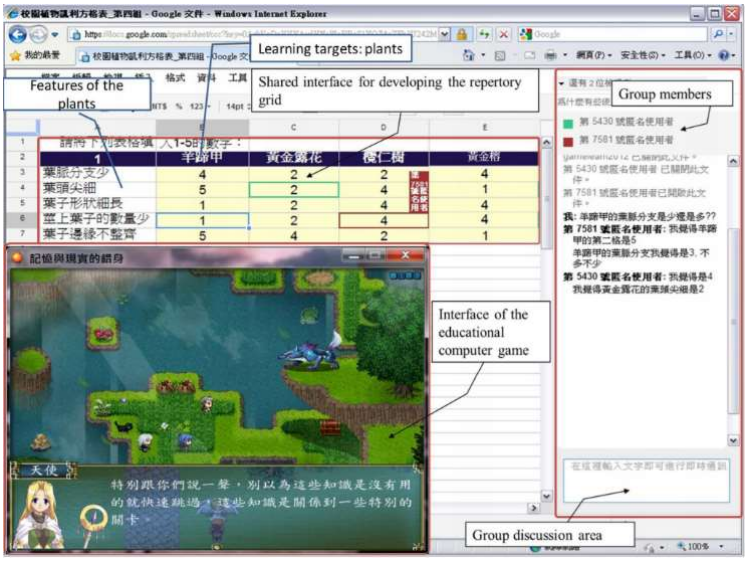
Design of a collaborative knowledge construction game



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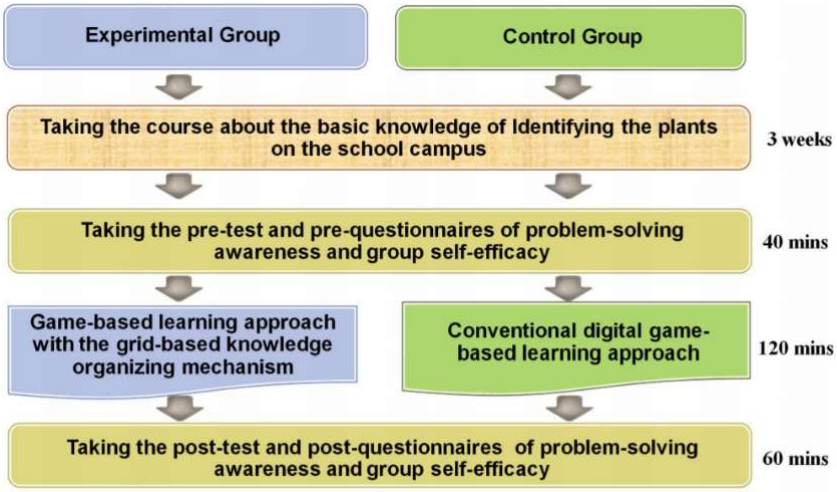
Coding scheme for collaborative knowledge construction game

Code	Phase	Description
S1	Selection of a task	Choose or start a new gaming mission
S2	Observation	Go to the location of the learning target
S3	Comparison	Observe two learning targets by switching the player's location from one target to another
S4	Reading materials	Read additional materials
S5	Clue search	Obtain some key clues.
S6	Correctly comparing a learning target	Correctly answer a multiple-choice question of the comparative test
E1	Reject challenges	Refuse to accept the opportunities to win treasures in the game
E2	Decline assistance	Refuse to follow the hints provided by the gaming character
E3	Incorrectly identifying a learning target/environment	Incorrectly answer a multiple-choice question of the basic test
E4	Incorrectly comparing a learning target/environment	Incorrectly answer a multiple-choice question of the comparative test

Experimental design for the learning activities



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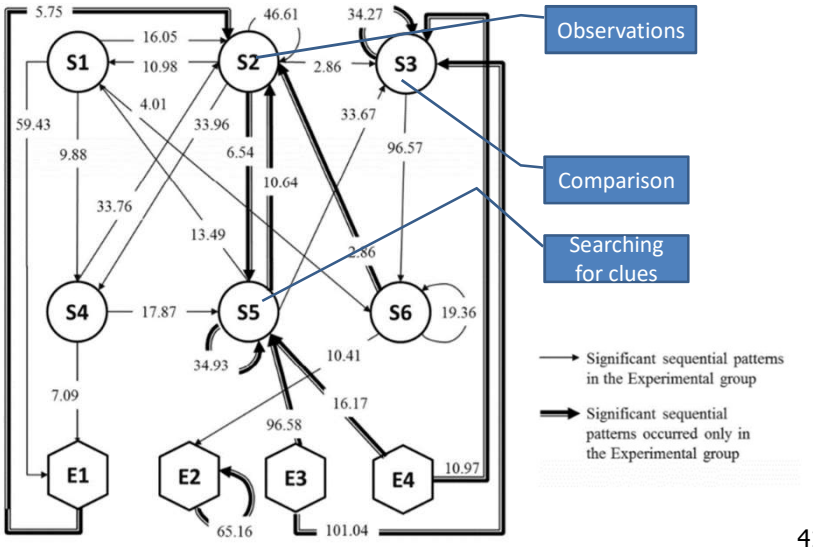
Behavior transition diagram for the experimental group students



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Conclusion of collaborative knowledge construction game

- The experimental group had better learning performance than the control group
  - They learned **more behavioral patterns of comparing and observing the learning targets**.
  - They tried to **seek clues when observing the learning targets**.
  - The experimental group would like to deal with the learning tasks on their own.

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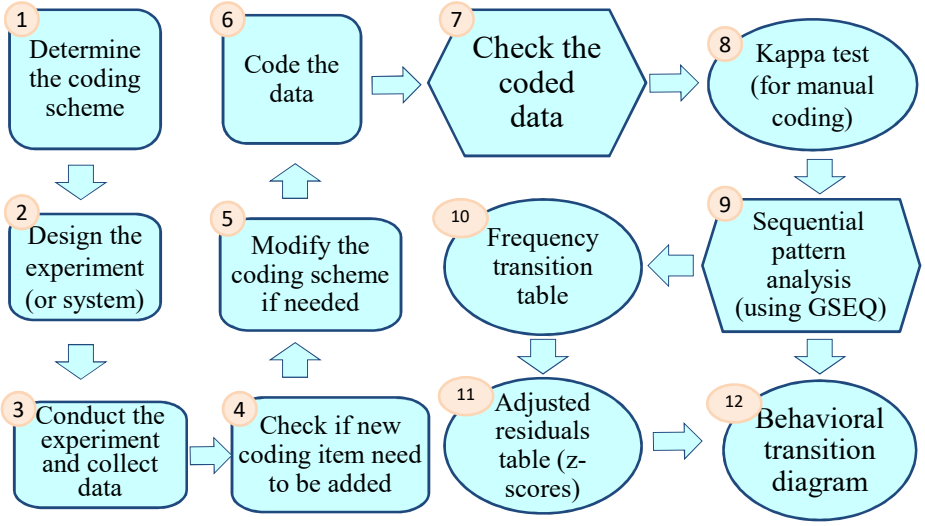
Procedure for designing a study of behavioral sequential pattern analysis



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Analyze sequential behavioral patterns using GSEQ

- GSEQ **(Generalized Sequential Querier)** is a computer program for analyzing **sequential observational data**.
- The data are presented using the **Sequential Data Interchange Standard** (SDIS), a language for describing sequential data obtaining from direct observation of individuals or groups.
- GSEQ includes a compiler for SDIS-formatted data files that converts them into MDS files (modified SDS files).

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GSEQ Version 5.1

- A version runs in Windows 95 or later.
- References:
  - Bakeman, R., Quera, V., & Gnisci, A. (2009). Observer agreement for timed-event sequential data: A comparison of time-based and event-based algorithms. *Behavior Research Methods, 41* (1), 137-147.
  - Quera, V., Bakeman, R., & Gnisci, A. (2007). Observer agreement for event sequences: Methods and software for sequence alignment and reliability estimates. *Behavior Research Methods, 39* (1), 39-49.

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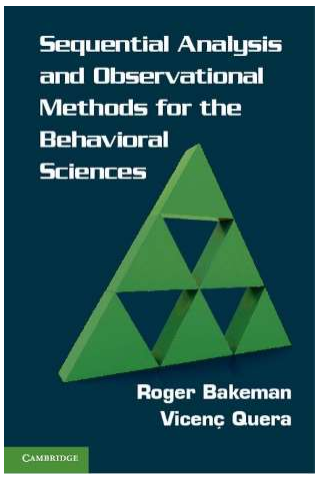
More about GSEQ and SDIS

- More information of GSEQ and SDIS can be found in:

"Bakeman, R., & Quera, V. (2011). *Sequential Analysis and Observational Methods for the Behavioral Sciences*. Cambridge, UK: Cambridge University Press. ISBN: 9781107001244 (hdcv), 9780521171816 (ppbk)"

Bakeman, R., & Quera, V. (1992). SDIS: A sequential data interchange standard. Behavior Research Methods, Instruments, and Computers, 24, 554–559.



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GSEQ web site

http://www2.gsu.edu/~psyrab/gseq/Download.html

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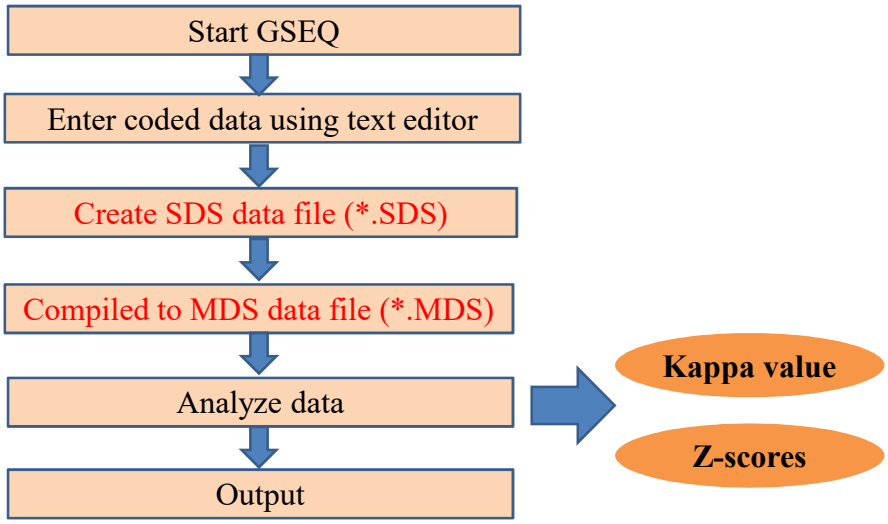
Procedure of using GSEQ



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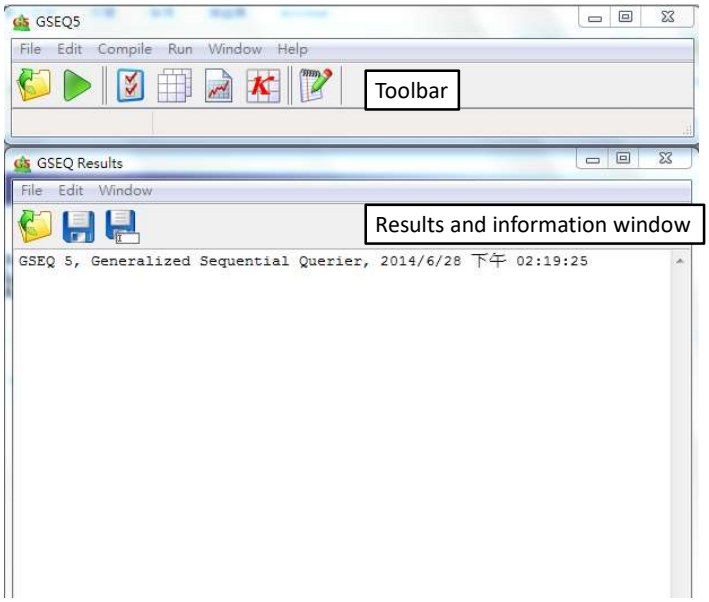
GSEQ interface



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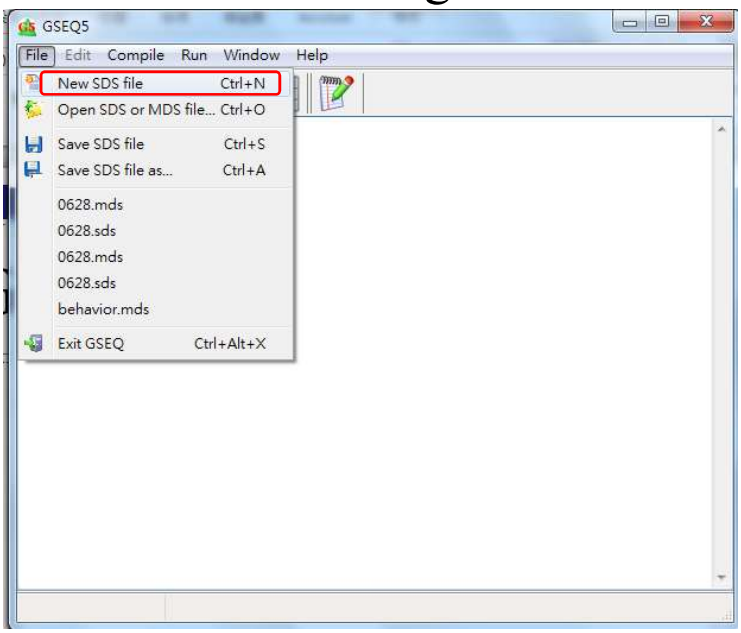
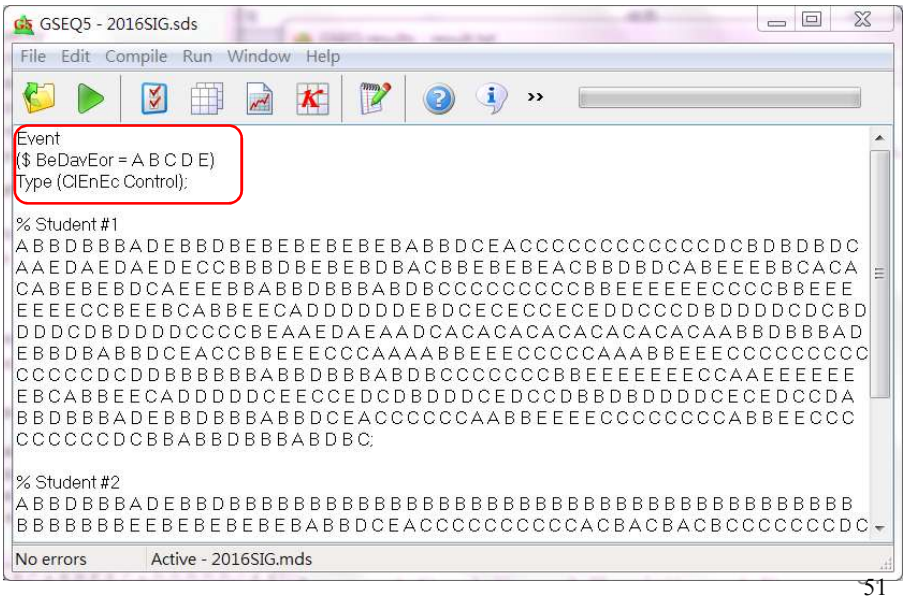
Create SDS file using the text editor



50

Enter commands and behavioral codes (1/3)



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Enter commands and behavioral codes (2/3)

Event ◂Start of a new task

($ Behavior = A B C D E)

▲Define the coding items: 5 behaviors are included

Type (Clinic Control);

Note: It is necessary to leave a space between the characters

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Enter commands and behavioral codes (3/3)

% Student #1 ◂sequential behaviors of student #1

A D E A C A C C A D E C C A C D E B D C E D
E E E A C A C A D E E D B E E E E; ◂ ";" means there are more data to be entered

▲leave a space between the characters

% Student #2

D E A A C C A C C A D E A F D A C E D E D B
C B E B E E A D E B E E E E E B F/

◂"/" means the end of data

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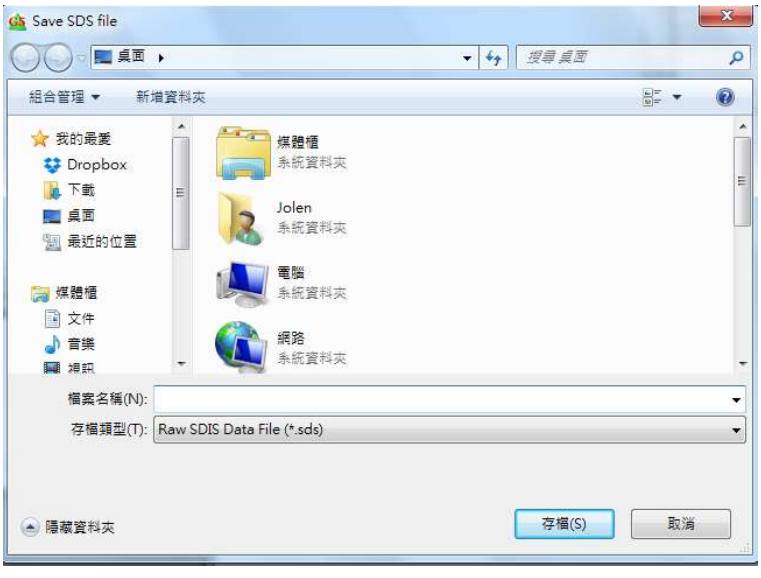
Save the SDS File



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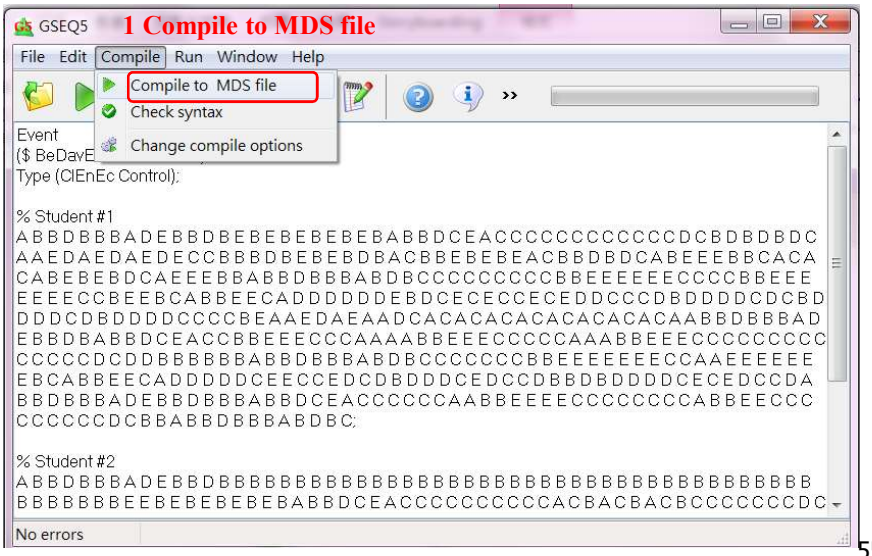
Create MDS File



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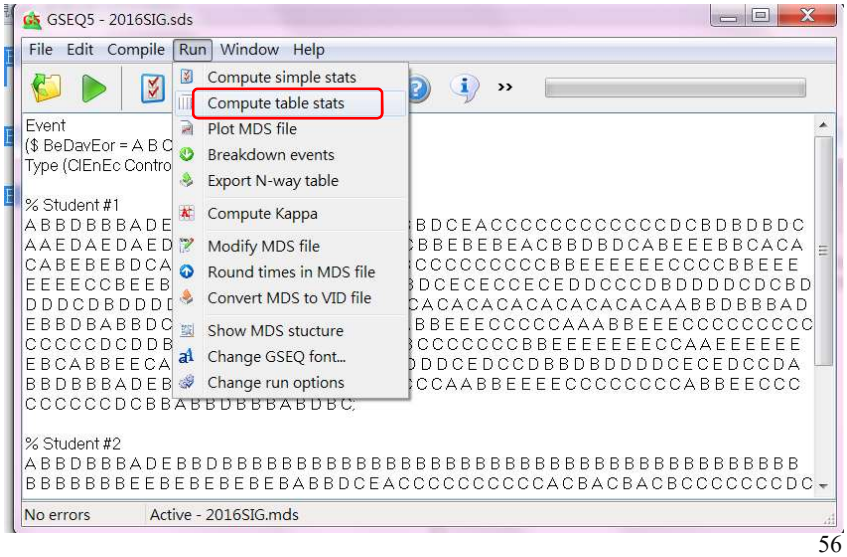
Compute table status



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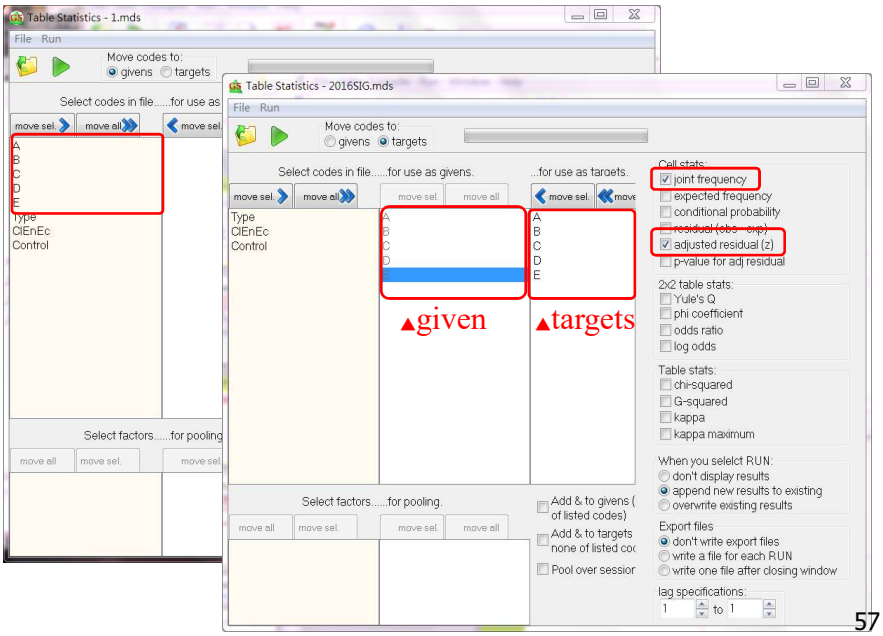
Define target behaviors and patterns



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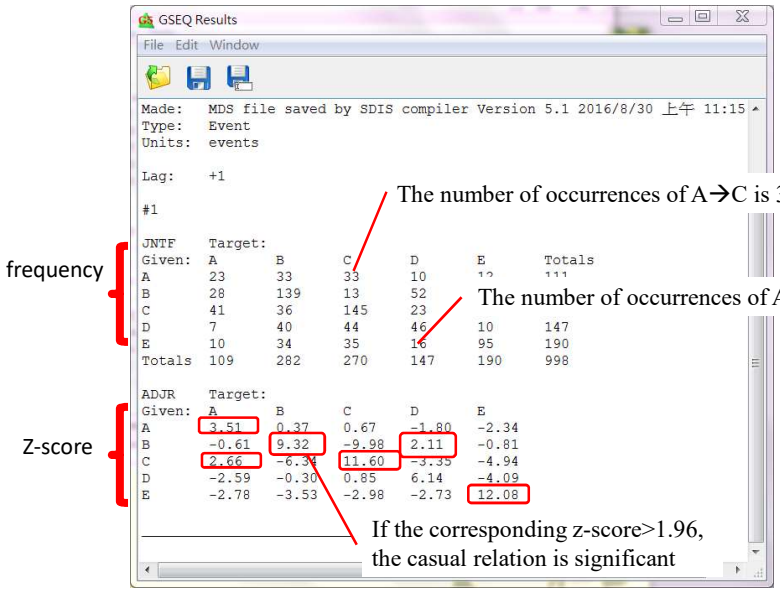
Analysis results using GSEQ



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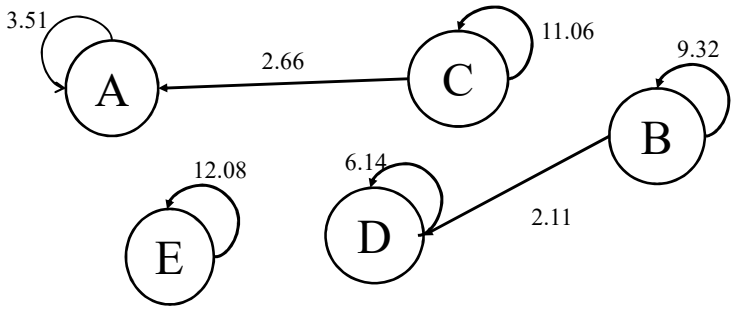
Draw the behavior transition diagrams



Code	Phase
A	Stat a learning task
B	Explore (find another learning target)
C	Observe the learning target
D	Make comparisons
E	Skip the hints given by the learning system

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Other Tools for Learning Analytics

- Learning management systems
  - e.g., 1know.et, COSCI.tw
- Data mining systems
  - e.g., SQL server
- Statistical analysis systems
  - e.g., SPSS

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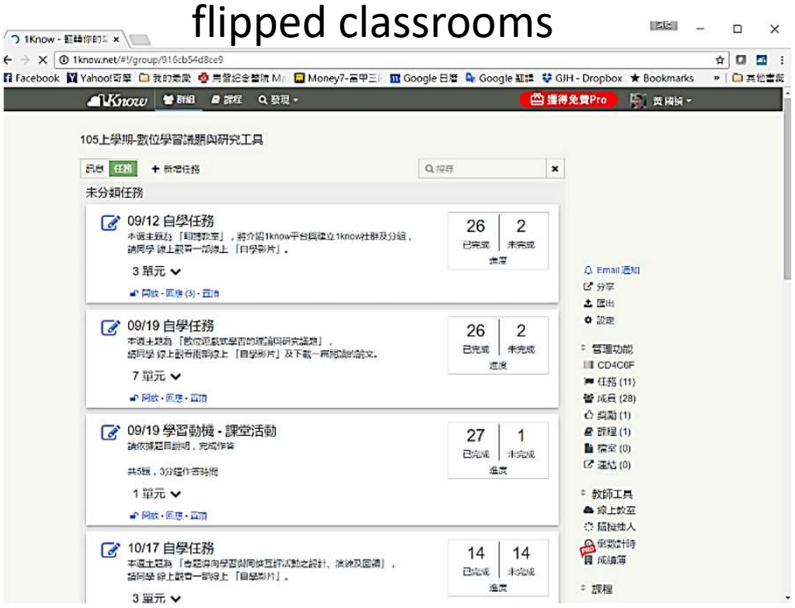
1know.net: Learning Management system for flipped classrooms



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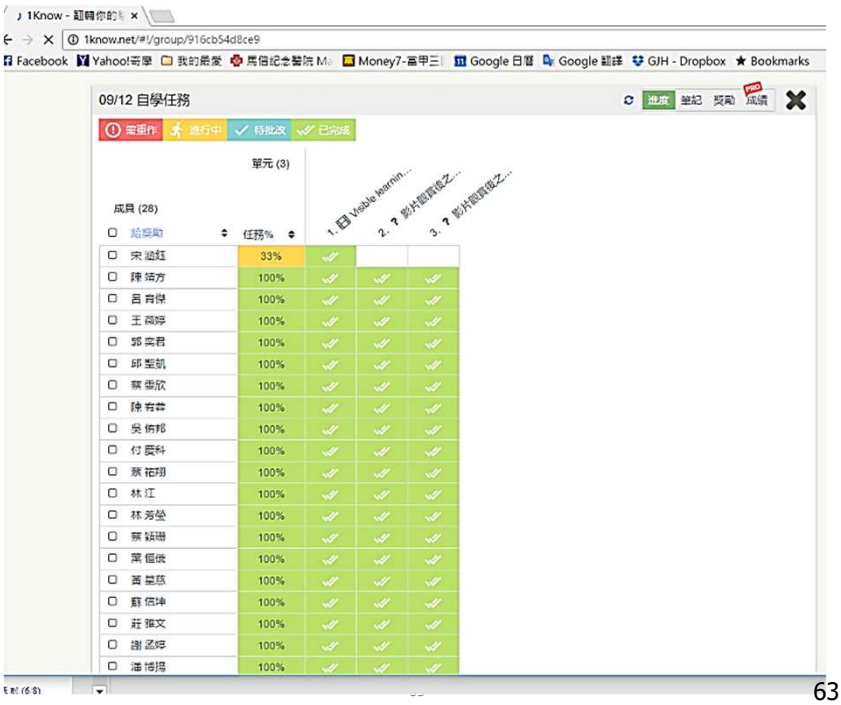
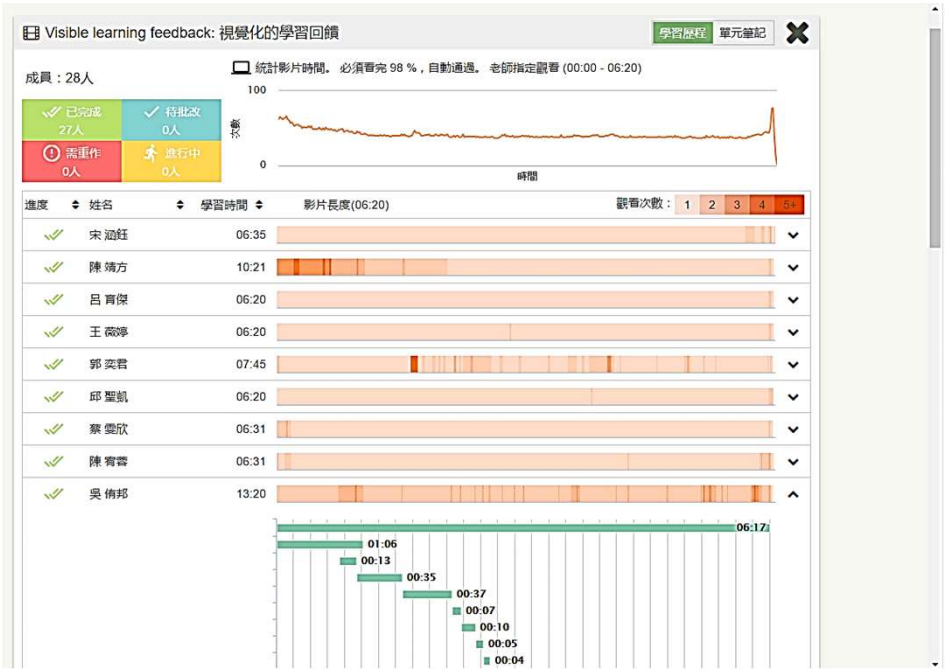

1Know - 翻轉你的
1know.net/#!/group/916cb54d8ce9
Facebook
Yahoo!奇摩
我的最愛
馬偕紀念醫院
Money7-富甲三
Google 日曆
Google 翻譯
GJH - Dropbox
Bookmarks
09/12 自學任務
進度
筆記
獎勵
成績
需重作
進行中
待批改
已完成
單元 (3)
成員 (28)
給獎勵
任務%
1. Visible learnin...
2. 影片觀賞後之...
3. 影片觀賞後之...
宋 涵鈺 33%
陳 婧方 100%
呂 育傑 100%
王 薇婷 100%
郭 奕君 100%
邱 聖凱 100%
蔡 雲欣 100%
陳 宥霈 100%
吳 侑邦 100%
付 庭科 100%
蔡 祐翔 100%
林 江 100%
林 芳瑩 100%
蔡 穎珊 100%
葉 恒佐 100%
黃 皇慈 100%
蘇 信坤 100%
莊 雅文 100%
謝 孟婷 100%
潘 博揚 100%

63


Visible learning feedback: 視覺化的學習回饋
學習歷程
單元筆記
成員：28人
統計影片時間。 必須看完 98 %，自動通過。 老師指定觀看 (00:00 - 06:20)
已完成 27人
待批改 0人
需重作 0人
進行中 0人
100
0
次數
時間
進度
姓名
學習時間
影片長度(06:20)
觀看次數：
1
2
3
4
5+
宋 涵鈺 06:35
陳 婧方 10:21
呂 育傑 06:20
王 薇婷 06:20
郭 奕君 07:45
邱 聖凱 06:20
蔡 雲欣 06:31
陳 宥霈 06:31
吳 侑邦 13:20
06:17
01:06
00:13
00:35
00:37
00:07
00:10
00:05
00:04

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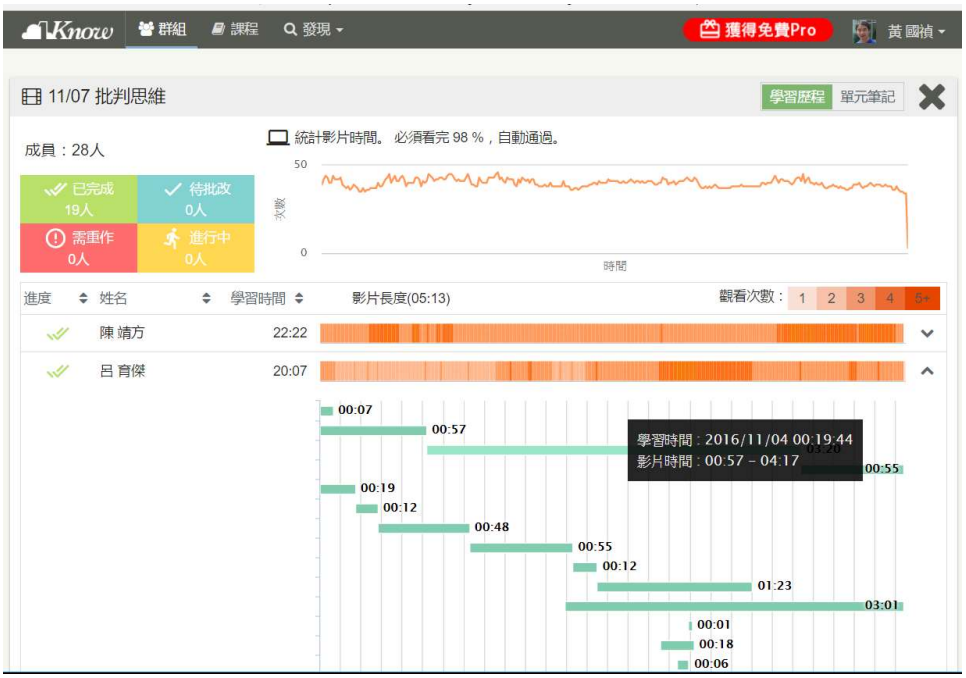
Know
群組
課程
發現
獲得免費Pro
黃國禎
11/07 批判思維
學習歷程
單元筆記
成員：28人
已完成 19人
待批改 0人
需重作 0人
進行中 0人
統計影片時間。必須看完 98 %，自動通過。
50
0
次數
時間
進度
姓名
學習時間
影片長度(05:13)
觀看次數：
1
2
3
4
5+
陳 靖方 22:22
呂 育傑 20:07
00:07
00:57
學習時間：2016/11/04 00:19:44
影片時間：00:57 – 04:17
00:55
00:19
00:12
00:48
00:55
00:12
01:23
03:01
00:01
00:18
00:06

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陳 靖方
2016/09/15 @04:37
繳交 1 次
通過這個影片發現：1.老師與學生這樣的互動，能讓學生更親近老師，學生更願意主動提出自己的想法，這樣的上課氛圍是很舒服的。2.原來透過視覺化的回饋，對於重新建構一個人的觀念，竟有如此大的幫助，這是我從未想像過的。
結論：這樣的上課方式以及回饋，是適合運用在每一個科目的教學上。
呂 育傑
2016/09/12 @22:34
繳交 1 次
看完影片後，可以看到很多視覺化學習的優點，如增進師生互動、讓學生更加投入、訓練觀察和思考力、學習聆聽他人意見等等。我認為最重要的是這樣的教學方式大大地增進了學生對於學習的信心。舉我自己的例子來說，我小時候很討厭上美術課。原因是，老師上課的方式是給我們一個主題讓我們去畫，有些人很快就能畫出很好看的東西，而本來對於畫畫就不在行的我，常常連怎麼開始畫都不知道，想當然爾成品也不會好看到哪去，最後就獲得不好的分數和評語，到了下一次還是一樣會不知道該怎麼畫，且越來越沒自信。
我覺得學習動力的來源有很大一部份是來自信心。從自己的觀察和自身經驗，很多人在某些方面學不好或是還沒開始學就放棄了，常常是因為把它們想得太困難了。就像影片中，如果老師一開始就拿出 Austin 最後的成品，對於某些不搭長畫畫的小孩可能會是個打擊，但如果是從比較不好的畫一直秀到最後的成品，會讓很多不會畫畫的人覺得他們也能辦得到，進而增加學習的動力。不只是畫畫，例如英文好了，可以讓學生觀察好的句子和不好的句子的差別，一步步修改，這樣也許比起老師單純講解枯燥的文法還要好吸收多了。
我們從小到大的教育都太著重於最終的正確答案，教學的內容都是如何得到答案的技巧，而沒有教導學生如何去學習。影片中的教學方式跟傳統的方式比起來看似比較花時間，但學生們所獲得的自信與獨立思考的能力，在未來不管要學什麼都會是很大的助力。
王 薇婷

Frequently adopted methods for learning analytics

- **Time sequence analysis: behavioral pattern analysis**
- Decision Tree
- Clustering
- Association rules
- Visualization techniques

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Research issues of learning analytics

- Proposing new approaches of learning analytics and educational data mining
- Investigating the impacts of the personalized supports provided based on educational data mining on students' learning performances
- Making predictions regarding students' learning performances based on the analysis results of their learning behaviors
- Investigating the potential applications and effectiveness of the visualization of educational data

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- Analyzing students' behavioral patterns to explain their performance in learning with different strategies, tools, or technologies
- Comparing the behavioral patterns of the students with different personal factors, such as learning achievements, cognitive styles, learning styles or motives
- Developing learning models or assessment models based on learning analytics results
- Proposing effective data integration, cleansing methods and management tools for processing educational data
- Investigating privacy and security management for open educational data

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Recommended readings

- Chiang, Tosti H.C, Yang, Stephen J.H., & Hwang, G. J. (2014). Students' online interactive patterns in augmented reality-based inquiry activities. *Computers & Education, 78*, 97-108.
- Hwang, G. J., Tsai, P. S., Tsai, C. C., & Tseng, Judy C. R. (2008). A novel approach for assisting teachers in analyzing student web-searching behaviors. *Computers & Education, 51*(2), 926-938.
- Lai, C. L., & Hwang, G. J. (2015). A Spreadsheet-based visualized Mindtool for improving students' learning performance in identifying relationships between numerical variables. *Interactive Learning Environments*, *23*(2), 230-249.
- Hwang, G. J., & Wang, S. Y. (2016). Single loop or double loop learning: English vocabulary learning performance and behavior of students in situated computer games with different guiding strategies. *Computers & Education, 102*, 188-201.
- Hwang, G. J., & Chen, C. H. (2016). Influences of an inquiry-based ubiquitous gaming design on students' learning achievements, motivation, behavioral patterns, and tendency towards critical thinking and problem solving. *British Journal of Educational Technology*. doi: 10.1111/bjet.12464
- Wu, C. H., Hwang, G. J., Kuo, F. R., Huang, I. (2014). Collab-Analyzer: an environment for conducting web-based collaborative learning activities and analyzing students' information-searching behaviors. Australasian Journal of Educational Technology, 30(3), 356-374.

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