**Table S1.** *Sample prompt sheet for using KBDeX*

Date: Group Members:

|  |  |  |
| --- | --- | --- |
| Inquiry topic: | | |
| **Our Analysis**  Analyzing our KB using KB visualizations and data | 1. What do you think about your inquiry process by analyzing the KBDex idea-network map of keywords? | Growth curve of cumulative degree centrality and idea-network map of ideas/keywords generated by |
| 2. Which aspects have your groups discussed, which aspects have discussed more with help of KBDex idea-network map of keywords? |  |
| **Our Problems**  What problems have we discovered? | 1. Do you have made your inquiries progressively be deepened? And why? |  |
| 2. Which aspects do you think you need to deepen but have discussed less by analyzing KBDex idea-network map of keywords? And why? |  |
| **Our Plan**  Action plans for further developing our inquiry | 1. Which aspects are you going to deepen your inquiry with the help of KBDex idea-network map? And why? |  |
| 2. What is your specific action plan for extending and deepening your further inquiry? |  |

Table S2. *Coding framework for characterizing competencies in knowledge building and data sciences*

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| --- | --- | --- | --- |
| Competencies | Dimensions | Sub categories | Description |
| Knowledge building competencies | Questions | Fact-seeking questions | Questions on definition of the terms or concepts or seeking factual information |
|  |  | Explanation-seeking questions | Questions seeking open-ended responses with elaborative explanations |
|  | Scientificness of ideas | Prescientific | Poor and contains misconceptions, or opinions irrelevant to the topic |
|  |  | Hybrid | Reveals some misconceptions and includes irrelevant information, but shows some understanding of ideas or concepts related to the topic |
|  |  | Basically scientific | Basically scientific ideas/explanations related to the topic and contains no or few evidence of misconceptions and irrelevant information |
|  |  | Scientific | Clear and scientific ideas/explanations related to the topic |
|  | Collaborative interaction | Creating inquiry awareness | Team members pose problems, identify focus, and/or a lack of knowledge |
|  |  | Alleviating lack of knowledge | Team members alleviate lack of knowledge and inconsistencies in their knowledge by using authoritative sources |
|  |  | Negotiating a fit | Teams present and discuss alternative opinions/claims/ideas and explore these alternatives before taking a position or making a decision, or they elaborate on or add to other member's contributions in order to ensure that ideas introduced by any member are not ignored or accepted without discussion |
|  |  | Co-directing collective inquiry | Teams make efforts to ensure that people are fully understanding the ideas people present by taking time to reword, rephrase, or push for further clarification |
|  |  | Engaging problem-centred uptake | Members progressively and coherently develop ideas to problematize and to address previous ideas through collaborative efforts |
|  |  | Summarizing community ideas | Summarizing and coordinating collective ideas from previous discussion. |
|  |  | Synthesizing and rising above community ideas | Synthesizing and integrating collective ideas with reflecting on inquiry goals, contributing higher-level inquires or conceptions or ideas, and generating action plans for deepening further inquiry |
| Data science competencies |  | Analyzing analytic data and tasks | Analyzing data and using data to monitor inquiry process and/or understanding and to identify missing knowledge or inconsistencies |
|  |  | Making data-informed decisions | Interpreting data, using data effectively to make data-informed decision, and engaging in data-informed process of inquiry, including but not limiting to data-informed analysis of inquiry and ideas, and data-informed action planning to deepen inquiry. |

Table S3. *Connection coefficients of Phase 1 (before* *AsRA) and Phase 2 (during ASRA) of high-performing group*

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Connection | Phase 1 | Phase 2 | Connection | Phase 1 | Phase 2 | Connection | Phase 1 | Phase 2 |
| CIA & ALK | 0.019 | 0.106 | NAF & SCI | 0.000 | 0.067 | CDI & AAT | 0.048 | 0.044 |
| CIA & NAF | 0.390 | 0.216 | CDI & SCI | 0.000 | 0.034 | EPU & AAT | 0.121 | 0.053 |
| ALK & NAF | 0.051 | 0.072 | EPU & SCI | 0.000 | 0.026 | SCI & AAT | 0.000 | 0.131 |
| CIA & CDI | 0.027 | 0.103 | CIA & SRI | 0.000 | 0.028 | SRI & AAT | 0.000 | 0.258 |
| ALK & CDI | 0.000 | 0.101 | ALK & SRI | 0.000 | 0.063 | CIA & MID | 0.000 | 0.019 |
| NAF & CDI | 0.077 | 0.173 | NAF & SRI | 0.000 | 0.062 | ALK & MID | 0.000 | 0.029 |
| CIA & EPU | 0.204 | 0.122 | CDI & SRI | 0.000 | 0.035 | NAF & MID | 0.000 | 0.024 |
| ALK & EPU | 0.017 | 0.063 | EPU & SRI | 0.000 | 0.034 | CDI & MID | 0.000 | 0.008 |
| NAF & EPU | 0.619 | 0.202 | SCI & SRI | 0.000 | 0.213 | EPU & MID | 0.000 | 0.008 |
| CDI & EPU | 0.157 | 0.141 | CIA & AAT | 0.027 | 0.084 | SCI & MID | 0.000 | 0.213 |
| CIA & SCI | 0.000 | 0.084 | ALK & AAT | 0.000 | 0.058 | SRI & MID | 0.000 | 0.269 |
| ALK & SCI | 0.000 | 0.040 | NAF & AAT | 0.062 | 0.104 | AAT & MID | 0.000 | 0.230 |

Table S4. *Connection coefficients of Phase 1 (before* *AsRA) and Phase 2 (during ASRA) of middle-performing group*

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Connection | Phase 1 | Phase 2 | Connection | Phase 1 | Phase 2 | Connection | Phase 1 | Phase 2 |
| CIA & ALK | 0.120 | 0.103 | NAF & SCI | 0.000 | 0.077 | CDI & AAT | 0.043 | 0.018 |
| CIA & NAF | 0.311 | 0.161 | CDI & SCI | 0.000 | 0.027 | EPU & AAT | 0.058 | 0.036 |
| ALK & NAF | 0.113 | 0.172 | EPU & SCI | 0.000 | 0.051 | SCI & AAT | 0.000 | 0.193 |
| CIA & CDI | 0.043 | 0.054 | CIA & SRI | 0.000 | 0.000 | SRI & AAT | 0.000 | 0.309 |
| ALK & CDI | 0.043 | 0.106 | ALK & SRI | 0.000 | 0.000 | CIA & MID | 0.000 | 0.000 |
| NAF & CDI | 0.034 | 0.210 | NAF & SRI | 0.000 | 0.055 | ALK & MID | 0.000 | 0.000 |
| CIA & EPU | 0.264 | 0.053 | CDI & SRI | 0.000 | 0.024 | NAF & MID | 0.000 | 0.049 |
| ALK & EPU | 0.137 | 0.039 | EPU & SRI | 0.000 | 0.005 | CDI & MID | 0.000 | 0.018 |
| NAF & EPU | 0.380 | 0.089 | SCI & SRI | 0.000 | 0.309 | EPU & MID | 0.000 | 0.000 |
| CDI & EPU | 0.039 | 0.075 | CIA & AAT | 0.037 | 0.028 | SCI & MID | 0.000 | 0.291 |
| CIA & SCI | 0.000 | 0.028 | ALK & AAT | 0.029 | 0.011 | SRI & MID | 0.000 | 0.208 |
| ALK & SCI | 0.000 | 0.011 | NAF & AAT | 0.061 | 0.062 | AAT & MID | 0.000 | 0.291 |

Table S5. *Connection coefficients of Phase 1 (before* *AsRA) and Phase 2 (during ASRA) of low-performing group*

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Connection | Phase 1 | Phase 2 | Connection | Phase 1 | Phase 2 | Connection | Phase 1 | Phase 2 |
| CIA & ALK | 0.316 | 0.203 | NAF & SCI | 0.000 | 0.101 | CDI & AAT | 0.000 | 0.000 |
| CIA & NAF | 0.508 | 0.417 | CDI & SCI | 0.000 | 0.000 | EPU & AAT | 0.000 | 0.000 |
| ALK & NAF | 0.248 | 0.120 | EPU & SCI | 0.000 | 0.000 | SCI & AAT | 0.000 | 0.269 |
| CIA & CDI | 0.068 | 0.000 | CIA & SRI | 0.000 | 0.000 | SRI & AAT | 0.000 | 0.273 |
| ALK & CDI | 0.000 | 0.000 | ALK & SRI | 0.000 | 0.000 | CIA & MID | 0.000 | 0.000 |
| NAF & CDI | 0.058 | 0.000 | NAF & SRI | 0.000 | 0.021 | ALK & MID | 0.000 | 0.000 |
| CIA & EPU | 0.147 | 0.124 | CDI & SRI | 0.000 | 0.000 | NAF & MID | 0.000 | 0.021 |
| ALK & EPU | 0.153 | 0.016 | EPU & SRI | 0.000 | 0.000 | CDI & MID | 0.000 | 0.000 |
| NAF & EPU | 0.197 | 0.181 | SCI & SRI | 0.000 | 0.273 | EPU & MID | 0.000 | 0.000 |
| CDI & EPU | 0.042 | 0.000 | CIA & AAT | 0.000 | 0.063 | SCI & MID | 0.000 | 0.273 |
| CIA & SCI | 0.000 | 0.063 | ALK & AAT | 0.000 | 0.028 | SRI & MID | 0.000 | 0.160 |
| ALK & SCI | 0.000 | 0.028 | NAF & AAT | 0.000 | 0.101 | AAT & MID | 0.000 | 0.273 |