

Tutorial 10: PCA and Factor Analysis

ENVX2001 – Applied Statistical Methods

Semester 1

PCA and Factor Analysis

Students in class gave “Characteristics of a good ecology lecturer”. They scored from 1-10 on a range of characteristics:

- accessible
- attractive
- Wide range of topics
- Do teaching research
- Dress well
- Complex issues
- Example exam questions
- Notes before
- humour
- Easy marking
- Move around lecture
- Detailed lecture notes
- Clear objective to lecture
- Solicit questions
- Use textbook closely
- Focus on primary research
- Use their own research
- Teach in team
- Understand principles of teaching
- Use pointers
- respected

The students also indicated whether they were:

- a gender (male/female)
- studied mainly a system (marine/terrestrial)
- studied mainly an organismal group (plants/animals)

We are going to use principal components analysis and factor analysis to interpret this dataset.

Setup

Load these packages to make the plots look better:

```
CODE
library(FAtools)
library(ggplot2)
library(ggfortify)
```

Load the data

First open your dataset:

```
CODE
lecturers ← read.csv("data/lecturers.csv", header = TRUE)
```

Correlation matrix

Let's first do a correlation matrix:

```
CODE
cor(lecturers[, 8:28])
```


| | accessible | attractive | wide_range |
|-------------------------|-------------------------|--------------|--------------|
| accessible | 1.00000000 | -0.61876084 | 0.190062066 |
| attractive | -0.61876084 | 1.00000000 | -0.011570169 |
| wide_range | 0.19006207 | -0.01157017 | 1.00000000 |
| teaching_based_research | 0.24021638 | -0.21382943 | 0.462870058 |
| Dress_nicely | -0.53198037 | 0.81887024 | -0.022848836 |
| focus_on_complex_issues | 0.28252341 | -0.04447540 | 0.567443460 |
| gives_example | -0.23669223 | 0.23435837 | 0.065815857 |
| gives_out_note | -0.31173854 | 0.36819405 | -0.187661524 |
| sense_of_humour | -0.29068273 | 0.33747896 | 0.081503385 |
| mark_easily | -0.34976811 | 0.44361281 | -0.158545138 |
| moves_around | -0.23371225 | 0.18475768 | -0.087292839 |
| offers_lecture_notes | -0.25762452 | 0.28256570 | -0.070931605 |
| clear_objective | -0.21819811 | 0.14978520 | -0.176518448 |
| solicit_questions | 0.10349600 | -0.076667948 | -0.022123679 |
| text_book | 0.03170769 | 0.02849978 | -0.241108100 |
| primary_research | 0.14147306 | -0.06238516 | -0.009628388 |
| own_research | -0.01089281 | 0.15175696 | 0.157013029 |
| teach_in_team | 0.09004589 | -0.13904104 | 0.005163136 |
| understand_principles | -0.08521319 | -0.01080764 | -0.097173242 |
| use_a_pointer | -0.51717009 | 0.25526667 | -0.131935123 |
| well_respected | -0.12789662 | 0.04222022 | 0.037698097 |
| | teaching_based_research | Dress_nicely | |
| accessible | 0.24021638 | -0.531980374 | |
| attractive | -0.21382943 | 0.818870242 | |
| wide_range | 0.46287006 | -0.022848836 | |
| teaching_based_research | 1.00000000 | -0.079662581 | |
| Dress_nicely | -0.07966258 | 1.00000000 | |
| focus_on_complex_issues | 0.36612054 | -0.074522662 | |

| | | |
|--|--------------|--------------|
| gives_example | -0.23626944 | 0.207509283 |
| gives_out_note | -0.13154529 | 0.349298764 |
| sense_of_humour | -0.37115541 | 0.326981372 |
| mark_easily | -0.26802282 | 0.293513890 |
| moves_around | 0.35915941 | 0.175612992 |
| offers_lecture_notes | -0.26062206 | 0.304730151 |
| clear_objective | -0.10137698 | 0.162176313 |
| solicit_questions | 0.06997014 | -0.047353486 |
| text_book | -0.02511112 | 0.065661794 |
| primary_research | 0.08627931 | -0.125765210 |
| own_research | 0.24450347 | 0.131114596 |
| teach_in_team | 0.05621459 | -0.081891992 |
| understand_principles | 0.13360929 | 0.003830791 |
| use_a_pointer | -0.40503932 | 0.246189390 |
| well_respected | -0.21574299 | 0.082434616 |
| focus_on_complex_issues gives_example gives_out_note | | |
| accessible | 0.28252341 | -0.23669223 |
| attractive | -0.04447540 | 0.23435837 |
| wide_range | 0.56744346 | 0.06581586 |
| teaching_based_research | 0.36612054 | -0.23626944 |
| Dress_nicely | -0.07452266 | 0.20750928 |
| focus_on_complex_issues | 1.00000000 | -0.15606162 |
| gives_example | -0.15606162 | 1.00000000 |
| gives_out_note | -0.31138949 | 0.41459959 |
| sense_of_humour | -0.07005663 | 0.22759892 |
| mark_easily | -0.18475242 | 0.18880641 |
| moves_around | 0.06116819 | -0.15496603 |
| offers_lecture_notes | 0.04438636 | 0.67139954 |
| clear_objective | -0.05740760 | 0.22152350 |
| solicit_questions | 0.12547982 | -0.10034117 |
| text_book | -0.14904151 | 0.23189356 |
| primary_research | 0.33824172 | -0.05502391 |
| own_research | 0.21007669 | -0.03858742 |
| teach_in_team | -0.05016868 | 0.22073735 |
| understand_principles | 0.12582565 | 0.06367067 |
| use_a_pointer | -0.19722690 | 0.29421612 |
| well_respected | -0.15321258 | 0.20022401 |
| sense_of_humour mark_easily moves_around | | |
| accessible | -0.29068273 | -0.349768108 |
| attractive | 0.33747896 | 0.443612809 |
| wide_range | 0.08150339 | -0.158545138 |
| teaching_based_research | -0.37115541 | -0.268022817 |
| Dress_nicely | 0.32698137 | 0.293513890 |
| focus_on_complex_issues | -0.07005663 | -0.184752419 |
| gives_example | 0.22759892 | 0.188806413 |
| gives_out_note | 0.25028755 | 0.392596691 |
| sense_of_humour | 1.00000000 | 0.279195853 |
| mark_easily | 0.27919585 | 1.000000000 |
| moves_around | 0.14798126 | -0.102624026 |
| offers_lecture_notes | 0.40350521 | 0.004540766 |
| clear_objective | 0.30494267 | 0.241714172 |
| solicit_questions | 0.22196924 | 0.221507736 |
| text_book | 0.11515826 | 0.493885950 |
| primary_research | -0.11402253 | 0.013988221 |
| own_research | 0.19400676 | -0.136905883 |
| teach_in_team | -0.13889755 | -0.029214646 |
| understand_principles | 0.08973153 | 0.029511600 |
| use_a_pointer | 0.60147995 | 0.200483903 |
| well_respected | 0.31777004 | 0.204840208 |
| offers_lecture_notes clear_objective solicit_questions | | |
| accessible | -0.257624516 | -0.21819811 |
| attractive | 0.282565698 | 0.14978520 |
| wide_range | -0.070931605 | -0.17651845 |
| teaching_based_research | -0.260622062 | -0.10137698 |
| Dress_nicely | 0.304730151 | 0.16217631 |

| | | | |
|-------------------------|---|--------------|--------------|
| focus_on_complex_issues | 0.044386363 | -0.05740760 | 0.125479819 |
| gives_example | 0.671399539 | 0.22152350 | -0.100341166 |
| gives_out_note | 0.326501972 | 0.49329825 | 0.373066471 |
| sense_of_humour | 0.403505211 | 0.30494267 | 0.221969236 |
| mark_easily | 0.004540766 | 0.24171417 | 0.221507736 |
| moves_around | 0.116586008 | 0.32802964 | 0.357039548 |
| offers_lecture_notes | 1.000000000 | 0.51135418 | 0.134906607 |
| clear_objective | 0.511354179 | 1.000000000 | 0.667857876 |
| solicit_questions | 0.134906607 | 0.66785788 | 1.000000000 |
| text_book | 0.241763186 | 0.50985104 | 0.514856144 |
| primary_research | 0.027238866 | -0.05933422 | 0.008953955 |
| own_research | 0.014724611 | 0.04037952 | 0.313649567 |
| teach_in_team | 0.134589361 | 0.09431599 | 0.129502715 |
| understand_principles | 0.204933977 | 0.52773521 | 0.525180942 |
| use_a_pointer | 0.475656687 | 0.48740938 | 0.245720968 |
| well_respected | 0.173541917 | 0.20806935 | 0.217669413 |
| | text_book primary_research own_research | | |
| accessible | 0.031707686 | 0.141473062 | -0.01089281 |
| attractive | 0.028499784 | -0.062385161 | 0.15175696 |
| wide_range | -0.241108100 | -0.009628388 | 0.15701303 |
| teaching_based_research | -0.025111119 | 0.086279306 | 0.24450347 |
| Dress_nicely | 0.065661794 | -0.125765210 | 0.13111460 |
| focus_on_complex_issues | -0.149041509 | 0.338241715 | 0.21007669 |
| gives_example | 0.231893556 | -0.050239007 | -0.03858742 |
| gives_out_note | 0.417052411 | -0.002582330 | 0.11486585 |
| sense_of_humour | 0.115158256 | -0.114022533 | 0.19400676 |
| mark_easily | 0.493885950 | 0.013988221 | -0.13690588 |
| moves_around | 0.018944976 | 0.201361759 | 0.52178832 |
| offers_lecture_notes | 0.241763186 | 0.027238866 | 0.01472461 |
| clear_objective | 0.509851042 | -0.059334220 | 0.04037952 |
| solicit_questions | 0.514856144 | 0.008953955 | 0.31364957 |
| text_book | 1.000000000 | -0.092231864 | -0.11384268 |
| primary_research | -0.092231864 | 1.000000000 | 0.35299282 |
| own_research | -0.113842676 | 0.352992824 | 1.00000000 |
| teach_in_team | 0.176402014 | -0.085933891 | -0.08668898 |
| understand_principles | 0.287773155 | 0.017218953 | 0.06370238 |
| use_a_pointer | 0.001337384 | -0.149851010 | 0.15399945 |
| well_respected | 0.274222528 | 0.016210854 | -0.10140227 |
| | teach_in_team understand_principles use_a_pointer | | |
| accessible | 0.090045886 | -0.085213191 | -0.517170092 |
| attractive | -0.139041035 | -0.010807636 | 0.255266673 |
| wide_range | 0.005163136 | -0.097173242 | -0.131935123 |
| teaching_based_research | 0.056214590 | 0.133609295 | -0.405039321 |
| Dress_nicely | -0.081891992 | 0.003830791 | 0.246189390 |
| focus_on_complex_issues | -0.050168682 | 0.125825652 | -0.197226905 |
| gives_example | 0.220737347 | 0.063670673 | 0.294216117 |
| gives_out_note | 0.071017950 | 0.095647419 | 0.427989355 |
| sense_of_humour | -0.138897546 | 0.089731525 | 0.601479950 |
| mark_easily | -0.029214646 | 0.029511600 | 0.200483903 |
| moves_around | -0.002012914 | 0.281044416 | 0.247735287 |
| offers_lecture_notes | 0.134589361 | 0.204933977 | 0.475656687 |
| clear_objective | 0.094315990 | 0.527735214 | 0.487409381 |
| solicit_questions | 0.129502715 | 0.525180942 | 0.245720968 |
| text_book | 0.176402014 | 0.287773155 | 0.001337384 |
| primary_research | -0.085933891 | 0.017218953 | -0.149851010 |
| own_research | -0.086688981 | 0.063702380 | 0.153999453 |
| teach_in_team | 1.000000000 | 0.101857142 | -0.016777680 |
| understand_principles | 0.101857142 | 1.000000000 | 0.104631048 |
| use_a_pointer | -0.016777680 | 0.104631048 | 1.000000000 |
| well_respected | 0.545915684 | 0.207782811 | 0.318541502 |
| | well_respected | | |
| accessible | -0.12789662 | | |
| attractive | 0.04222022 | | |
| wide_range | 0.03769810 | | |
| teaching_based_research | -0.21574299 | | |

| | |
|-------------------------|-------------|
| Dress_nicely | 0.08243462 |
| focus_on_complex_issues | -0.15321258 |
| gives_example | 0.20022401 |
| gives_out_note | 0.24197769 |
| sense_of_humour | 0.31777004 |
| mark_easily | 0.20484021 |
| moves_around | 0.10727553 |
| offers_lecture_notes | 0.17354192 |
| clear_objective | 0.20806935 |
| solicit_questions | 0.21766941 |
| text_book | 0.27422253 |
| primary_research | 0.01621085 |
| own_research | -0.10140227 |
| teach_in_team | 0.54591568 |
| understand_principles | 0.20778281 |
| use_a_pointer | 0.31854150 |
| well_respected | 1.00000000 |

CODE
`Corrmatrix ← cor(lecturers[, 8:28])`

Bartlett's Test of Sphericity

Now we can do the Bartlett's Test of Sphericity. This test compares the correlation matrix to an identity matrix. If it is significant, it is worth doing a PCA.

CODE
`BARTLETT(Corrmatrix, N = 34, cor_method = c("pearson"))`

OUTPUT

✓ The Bartlett's test of sphericity was significant at an alpha level of .05.
 These data are probably suitable for factor analysis.
 $\chi^2(210) = 355.07, p < .001$

Principal Components Analysis

Note: to make this a PCA based on a correlation matrix, we have to scale the variables, hence `scale = TRUE`. There are two main principal components functions, but they are very similar. Note `prcomp` calls the loadings “rotations”, not to be confused with rotations below.

CODE
`pca1 ← prcomp(lecturers[, 8:28], scale = TRUE)`
`pca2 ← princomp(lecturers[, 8:28], cor = TRUE)`

CODE
`summary(pca1)`

OUTPUT

```

Importance of components:
      PC1    PC2    PC3    PC4    PC5    PC6    PC7
Standard deviation   2.2206 1.6616 1.5324 1.29807 1.19561 1.12098 1.08311
Proportion of Variance 0.2348 0.1315 0.1118 0.08024 0.06807 0.05984 0.05586
Cumulative Proportion 0.2348 0.3663 0.4781 0.55833 0.62641 0.68624 0.74211
      PC8    PC9    PC10   PC11   PC12   PC13   PC14
Standard deviation   1.0737 0.95681 0.79545 0.73119 0.7055 0.65580 0.50887
Proportion of Variance 0.0549 0.04359 0.03013 0.02546 0.0237 0.02048 0.01233
Cumulative Proportion 0.7970 0.84060 0.87073 0.89619 0.9199 0.94037 0.95270
      PC15   PC16   PC17   PC18   PC19   PC20   PC21
Standard deviation   0.49817 0.47309 0.42640 0.36970 0.32493 0.24020 0.19872
Proportion of Variance 0.01182 0.01066 0.00866 0.00651 0.00503 0.00275 0.00188
Cumulative Proportion 0.96452 0.97518 0.98384 0.99034 0.99537 0.99812 1.00000

```

```

CODE
summary(pca2)

```

```

OUTPUT
Importance of components:
      Comp.1   Comp.2   Comp.3   Comp.4   Comp.5
Standard deviation   2.2205654 1.6615887 1.5324030 1.29806969 1.19560985
Proportion of Variance 0.2348053 0.1314703 0.1118219 0.08023738 0.06807062
Cumulative Proportion 0.2348053 0.3662756 0.4780975 0.55833484 0.62640546
      Comp.6   Comp.7   Comp.8   Comp.9   Comp.10
Standard deviation   1.12097809 1.08311410 1.07371597 0.95680927 0.79544930
Proportion of Variance 0.05983771 0.05586363 0.05489838 0.04359448 0.03013046
Cumulative Proportion 0.68624317 0.74210679 0.79700517 0.84059965 0.87073010
      Comp.11  Comp.12  Comp.13  Comp.14  Comp.15
Standard deviation   0.73119377 0.70551609 0.65579857 0.50886890 0.49817027
Proportion of Variance 0.02545925 0.02370252 0.02047961 0.01233084 0.01181779
Cumulative Proportion 0.89618936 0.91989188 0.94037149 0.95270232 0.96452011
      Comp.16  Comp.17  Comp.18  Comp.19
Standard deviation   0.4730918 0.426395520 0.369702631 0.324933440
Proportion of Variance 0.0106579 0.008657769 0.006508573 0.005027702
Cumulative Proportion 0.9751780 0.983835781 0.990344355 0.995372057
      Comp.20  Comp.21
Standard deviation   0.240198751 0.198724365
Proportion of Variance 0.002747402 0.001880542
Cumulative Proportion 0.998119458 1.000000000

```

Loadings

Let's look at the loadings. Called "rotations" in prcomp and "loadings" in princomp. They are the Pearson's correlation between that variable and that Principal Component.

```

CODE
pca1

```

```

OUTPUT
Standard deviations (1, .., p=21):
[1] 2.2205654 1.6615887 1.5324030 1.2980697 1.1956099 1.1209781 1.0831141
[8] 1.0737160 0.9568093 0.7954493 0.7311938 0.7055161 0.6557986 0.5088689
[15] 0.4981703 0.4730918 0.4263955 0.3697026 0.3249334 0.2401988 0.1987244

Rotation (n x k) = (21 x 21):
      PC1     PC2     PC3     PC4

```

| | | | | |
|-------------------------|--------------|-------------|--------------|--------------|
| accessible | -0.27105784 | 0.21481141 | 0.22284903 | -0.109380126 |
| attractive | 0.25953819 | -0.19001404 | -0.35322829 | 0.047967149 |
| wide_range | -0.11796047 | 0.14523503 | -0.23536689 | -0.465316942 |
| teaching_based_research | -0.17807186 | 0.33523672 | -0.16973235 | -0.005540905 |
| Dress_nicely | 0.24737662 | -0.15550598 | -0.32565089 | 0.019172145 |
| focus_on_complex_issues | -0.13467331 | 0.28837561 | -0.24412817 | -0.297540766 |
| gives_example | 0.22797978 | -0.11739164 | 0.06984178 | -0.437201342 |
| gives_out_note | 0.32056620 | 0.04438472 | 0.02749136 | 0.100499687 |
| sense_of_humour | 0.27564472 | -0.03120757 | -0.13957405 | -0.145704311 |
| mark_easily | 0.23686285 | -0.11243202 | 0.08113616 | 0.196601185 |
| moves_around | 0.13236700 | 0.32827473 | -0.27087444 | 0.213497862 |
| offers_lecture_notes | 0.28307512 | 0.02357872 | -0.01627849 | -0.372830743 |
| clear_objective | 0.31573398 | 0.26378859 | 0.12826236 | 0.066194937 |
| solicit_questions | 0.18991164 | 0.43659484 | 0.13380240 | 0.160366349 |
| text_book | 0.21299001 | 0.16712512 | 0.33485831 | 0.124899445 |
| primary_research | -0.05608411 | 0.19206706 | -0.16387602 | 0.001745603 |
| own_research | 0.04318371 | 0.28387549 | -0.37836892 | 0.056442158 |
| teach_in_team | 0.04818137 | 0.11021896 | 0.29523823 | -0.327405642 |
| understand_principles | 0.14556568 | 0.33936721 | 0.10777339 | 0.053017840 |
| use_a_pointer | 0.32019196 | -0.03811643 | -0.08101559 | -0.080227102 |
| well_respected | 0.19384039 | 0.06977679 | 0.22029921 | -0.263146206 |
| | PC5 | PC6 | PC7 | PC8 |
| accessible | -0.006862732 | 0.20175545 | 0.075192964 | 0.13471983 |
| attractive | -0.304217305 | -0.05278985 | -0.006014137 | -0.01346850 |
| wide_range | -0.251311171 | 0.08634713 | -0.331523146 | 0.07096692 |
| teaching_based_research | -0.307853355 | -0.22290900 | -0.040540304 | -0.27328747 |
| Dress_nicely | -0.299180796 | -0.12573075 | -0.046516486 | -0.12380132 |
| focus_on_complex_issues | -0.170654964 | 0.29340602 | -0.050872762 | 0.07474147 |
| gives_example | -0.075647764 | 0.06855598 | 0.364935010 | -0.17131172 |
| gives_out_note | -0.125013318 | -0.08366732 | 0.223406707 | 0.02145305 |
| sense_of_humour | 0.216056466 | 0.21464296 | -0.328598912 | 0.27397871 |
| mark_easily | -0.421810061 | 0.15983061 | -0.046406386 | 0.38018642 |
| moves_around | 0.166526391 | -0.35024271 | 0.055092321 | -0.07707096 |
| offers_lecture_notes | 0.146235397 | 0.18757528 | 0.287000528 | -0.27400475 |
| clear_objective | 0.060342195 | 0.17777324 | -0.032682046 | -0.21837583 |
| solicit_questions | -0.005900941 | 0.14588578 | -0.182965113 | 0.09074671 |
| text_book | -0.356204508 | 0.15361788 | 0.084096939 | 0.02338965 |
| primary_research | 0.039054189 | 0.06897414 | 0.592731543 | 0.45913721 |
| own_research | 0.156844077 | -0.09496398 | 0.160942737 | 0.20826388 |
| teach_in_team | -0.096207102 | -0.54758870 | 0.037625674 | 0.05473642 |
| understand_principles | 0.010243773 | 0.05372028 | -0.114475017 | -0.27603888 |
| use_a_pointer | 0.411769112 | 0.01616452 | -0.180288938 | 0.05917537 |
| well_respected | 0.013159486 | -0.40377696 | -0.183055505 | 0.39655405 |
| | PC9 | PC10 | PC11 | PC12 |
| accessible | 0.23711499 | 0.41979852 | 0.03945146 | 0.148881566 |
| attractive | -0.16438427 | 0.20365082 | 0.06904042 | -0.107432225 |
| wide_range | 0.22155409 | -0.26438749 | -0.03259079 | -0.018048262 |
| teaching_based_research | 0.19889412 | -0.24510749 | -0.11135378 | 0.247899071 |
| Dress_nicely | -0.10406494 | 0.38639604 | 0.08377430 | 0.098387712 |
| focus_on_complex_issues | -0.28979913 | 0.00432150 | 0.36226348 | -0.066562002 |
| gives_example | 0.19510676 | -0.15342441 | -0.35973985 | -0.159175284 |
| gives_out_note | 0.41895610 | -0.21289394 | 0.20038838 | 0.006019332 |
| sense_of_humour | 0.09730489 | 0.19787809 | -0.29410062 | 0.309619454 |
| mark_easily | -0.04288340 | -0.25885827 | -0.05713892 | -0.143735223 |
| moves_around | 0.02114182 | -0.04788447 | 0.02682634 | 0.353171999 |
| offers_lecture_notes | -0.07931457 | 0.16874959 | 0.11255136 | 0.207814735 |
| clear_objective | -0.04989256 | -0.08180409 | 0.29595319 | 0.009127372 |
| solicit_questions | 0.10754501 | 0.13028684 | 0.14132328 | -0.276862219 |
| text_book | 0.12628767 | 0.17521009 | -0.12180066 | 0.267854799 |
| primary_research | -0.30348754 | -0.18921946 | 0.01954047 | 0.138689169 |
| own_research | 0.28543090 | 0.27973695 | -0.29907250 | -0.427500246 |
| teach_in_team | -0.07446630 | 0.20427502 | 0.21413563 | -0.322896702 |
| understand_principles | -0.49690454 | -0.08895650 | -0.50033599 | -0.189676003 |
| use_a_pointer | 0.09757553 | -0.27912944 | 0.22992547 | -0.115886008 |
| well_respected | -0.19000184 | -0.03498965 | -0.08926599 | 0.276488059 |

| | PC13 | PC14 | PC15 | PC16 |
|-------------------------|--------------|--------------|--------------|--------------|
| accessible | 0.29231904 | 0.29580819 | -0.222218786 | 0.095682695 |
| attractive | 0.10512874 | 0.20004636 | 0.069413634 | -0.326657310 |
| wide_range | 0.14339377 | -0.15578216 | -0.042633744 | -0.346118318 |
| teaching_based_research | -0.16129758 | -0.08569727 | -0.291561886 | 0.304862272 |
| Dress_nicely | 0.22024728 | -0.29025496 | -0.196064822 | 0.331319175 |
| focus_on_complex_issues | -0.11651678 | 0.21121417 | 0.380088085 | 0.275036237 |
| gives_example | -0.02596566 | 0.13003779 | 0.073844050 | -0.048615414 |
| gives_out_note | 0.52366782 | 0.22815294 | 0.150396690 | 0.187752138 |
| sense_of_humour | -0.09102492 | 0.24787583 | -0.269328590 | 0.077361879 |
| mark_easily | -0.30618081 | 0.26528469 | -0.239118638 | 0.067806707 |
| moves_around | -0.19413727 | 0.41519824 | 0.163481854 | -0.233951595 |
| offers_lecture_notes | -0.18626080 | -0.01943147 | -0.008128194 | -0.028997162 |
| clear_objective | 0.02299500 | -0.21161788 | -0.392005665 | -0.377275931 |
| solicit_questions | 0.07959209 | -0.06601352 | 0.067535709 | -0.098815936 |
| text_book | -0.31596633 | -0.28217199 | 0.346092878 | 0.063696048 |
| primary_research | 0.11269387 | -0.18656539 | -0.263215477 | -0.012502540 |
| own_research | -0.14671997 | -0.23213427 | 0.082887276 | 0.001508984 |
| teach_in_team | -0.23420220 | 0.19002827 | -0.271548974 | 0.056217287 |
| understand_principles | 0.29771815 | 0.14826763 | -0.020146024 | 0.175848894 |
| use_a_pointer | -0.10543967 | -0.11603812 | -0.008762183 | 0.433779829 |
| well_respected | 0.22357927 | -0.22236358 | 0.251201419 | -0.060389007 |
| | PC17 | PC18 | PC19 | PC20 |
| accessible | -0.487523780 | -0.092943639 | 0.11623660 | -0.08184741 |
| attractive | -0.106937105 | -0.195239242 | 0.45086924 | -0.09762660 |
| wide_range | 0.009616636 | 0.068156323 | 0.05963088 | -0.34244915 |
| teaching_based_research | 0.006376281 | 0.018683190 | 0.22919635 | 0.23688191 |
| Dress_nicely | -0.124236446 | 0.174946567 | -0.38290347 | -0.11111538 |
| focus_on_complex_issues | 0.057689702 | -0.197551507 | -0.21480326 | 0.19658872 |
| gives_example | -0.206970055 | 0.030539850 | -0.40647428 | -0.01600380 |
| gives_out_note | 0.321857496 | -0.107588372 | 0.08121002 | 0.10250939 |
| sense_of_humour | 0.430141107 | -0.113398698 | -0.08853507 | 0.02641527 |
| mark_easily | -0.269651092 | 0.167631153 | 0.01976224 | 0.19779113 |
| moves_around | -0.207902119 | 0.101506396 | -0.24054414 | -0.20539739 |
| offers_lecture_notes | 0.024256519 | 0.371837654 | 0.41986631 | 0.20173823 |
| clear_objective | -0.097333800 | -0.419634434 | -0.21848656 | 0.23314508 |
| solicit_questions | 0.094290088 | 0.606166863 | -0.05758082 | -0.04550053 |
| text_book | 0.072364215 | -0.254638772 | 0.07071928 | -0.35855399 |
| primary_research | 0.130404141 | 0.041767487 | 0.01625913 | -0.25697656 |
| own_research | -0.068753059 | -0.196939862 | 0.08026083 | 0.24801010 |
| teach_in_team | 0.247146896 | -0.095095343 | 0.00645715 | -0.19776650 |
| understand_principles | -0.001605969 | -0.075193184 | 0.12987739 | -0.13337875 |
| use_a_pointer | -0.352414119 | -0.113600108 | 0.19774694 | -0.34608373 |
| well_respected | -0.231089402 | 0.008802903 | 0.03736378 | 0.36974689 |
| | PC21 | | | |
| accessible | -0.002932735 | | | |
| attractive | 0.405148279 | | | |
| wide_range | -0.308435374 | | | |
| teaching_based_research | 0.335322467 | | | |
| Dress_nicely | -0.150318850 | | | |
| focus_on_complex_issues | 0.045604055 | | | |
| gives_example | 0.338040434 | | | |
| gives_out_note | -0.184254445 | | | |
| sense_of_humour | 0.144536843 | | | |
| mark_easily | -0.277239849 | | | |
| moves_around | -0.151918843 | | | |
| offers_lecture_notes | -0.289119982 | | | |
| clear_objective | -0.008051690 | | | |
| solicit_questions | 0.367111373 | | | |
| text_book | -0.026709294 | | | |
| primary_research | 0.123144467 | | | |
| own_research | -0.206478451 | | | |
| teach_in_team | -0.055864220 | | | |
| understand_principles | -0.183080778 | | | |

| | |
|----------------|-------------|
| use_a_pointer | 0.121125177 |
| well_respected | 0.079347988 |

CODE
`loadings(pca2)`

OUTPUT

Loadings:

| | Comp.1 | Comp.2 | Comp.3 | Comp.4 | Comp.5 | Comp.6 | Comp.7 | Comp.8 |
|-------------------------|---------|---------|---------|---------|---------|---------|---------|--------|
| accessible | 0.271 | 0.215 | 0.223 | 0.109 | | 0.202 | | 0.135 |
| attractive | -0.260 | -0.190 | -0.353 | | | 0.304 | | |
| wide_range | 0.118 | 0.145 | -0.235 | 0.465 | 0.251 | | -0.332 | |
| teaching_based_research | 0.178 | 0.335 | -0.170 | | 0.308 | -0.223 | | -0.273 |
| Dress_nicely | -0.247 | -0.156 | -0.326 | | 0.299 | -0.126 | | -0.124 |
| focus_on_complex_issues | 0.135 | 0.288 | -0.244 | 0.298 | 0.171 | 0.293 | | |
| gives_example | -0.228 | -0.117 | | 0.437 | | | 0.365 | -0.171 |
| gives_out_note | -0.321 | | | -0.100 | 0.125 | | 0.223 | |
| sense_of_humour | -0.276 | | -0.140 | 0.146 | -0.216 | 0.215 | -0.329 | 0.274 |
| mark_easily | -0.237 | -0.112 | | -0.197 | 0.422 | 0.160 | | 0.380 |
| moves_around | -0.132 | 0.328 | -0.271 | -0.213 | -0.167 | -0.350 | | |
| offers_lecture_notes | -0.283 | | | 0.373 | -0.146 | 0.188 | 0.287 | -0.274 |
| clear_objective | -0.316 | 0.264 | 0.128 | | | 0.178 | | -0.218 |
| solicit_questions | -0.190 | 0.437 | 0.134 | -0.160 | | 0.146 | -0.183 | |
| text_book | -0.213 | 0.167 | 0.335 | -0.125 | 0.356 | 0.154 | | |
| primary_research | | 0.192 | -0.164 | | | | 0.593 | 0.459 |
| own_research | | 0.284 | -0.378 | | -0.157 | | 0.161 | 0.208 |
| teach_in_team | | 0.110 | 0.295 | 0.327 | | -0.548 | | |
| understand_principles | -0.146 | 0.339 | 0.108 | | | -0.114 | -0.276 | |
| use_a_pointer | -0.320 | | | | -0.412 | | -0.180 | |
| well_respected | -0.194 | | 0.220 | 0.263 | | -0.404 | -0.183 | 0.397 |
| | Comp.9 | Comp.10 | Comp.11 | Comp.12 | Comp.13 | Comp.14 | Comp.15 | |
| accessible | 0.237 | 0.420 | | 0.149 | 0.292 | 0.296 | 0.222 | |
| attractive | -0.164 | 0.204 | | -0.107 | 0.105 | 0.200 | | |
| wide_range | 0.222 | -0.264 | | | 0.143 | -0.156 | | |
| teaching_based_research | 0.199 | -0.245 | -0.111 | 0.248 | -0.161 | | 0.292 | |
| Dress_nicely | -0.104 | 0.386 | | | 0.220 | -0.290 | 0.196 | |
| focus_on_complex_issues | -0.290 | | 0.362 | | -0.117 | 0.211 | -0.380 | |
| gives_example | 0.195 | -0.153 | -0.360 | -0.159 | | 0.130 | | |
| gives_out_note | 0.419 | -0.213 | 0.200 | | 0.524 | 0.228 | -0.150 | |
| sense_of_humour | | 0.198 | -0.294 | 0.310 | | 0.248 | 0.269 | |
| mark_easily | | -0.259 | | -0.144 | -0.306 | 0.265 | 0.239 | |
| moves_around | | | 0.353 | -0.194 | 0.415 | -0.163 | | |
| offers_lecture_notes | | 0.169 | 0.113 | 0.208 | -0.186 | | | |
| clear_objective | | | 0.296 | | | -0.212 | 0.392 | |
| solicit_questions | 0.108 | 0.130 | 0.141 | -0.277 | | | | |
| text_book | 0.126 | 0.175 | -0.122 | 0.268 | -0.316 | -0.282 | -0.346 | |
| primary_research | -0.303 | -0.189 | | 0.139 | 0.113 | -0.187 | 0.263 | |
| own_research | 0.285 | 0.280 | -0.299 | -0.428 | -0.147 | -0.232 | | |
| teach_in_team | | 0.204 | 0.214 | -0.323 | -0.234 | 0.190 | 0.272 | |
| understand_principles | -0.497 | | -0.500 | -0.190 | 0.298 | 0.148 | | |
| use_a_pointer | | -0.279 | 0.230 | -0.116 | -0.105 | -0.116 | | |
| well_respected | -0.190 | | | 0.276 | 0.224 | -0.222 | -0.251 | |
| | Comp.16 | Comp.17 | Comp.18 | Comp.19 | Comp.20 | Comp.21 | | |
| accessible | | 0.488 | | 0.116 | | | | |
| attractive | -0.327 | 0.107 | 0.195 | 0.451 | | -0.405 | | |
| wide_range | -0.346 | | | | 0.342 | 0.308 | | |
| teaching_based_research | 0.305 | | | 0.229 | -0.237 | -0.335 | | |
| Dress_nicely | 0.331 | 0.124 | -0.175 | -0.383 | 0.111 | 0.150 | | |
| focus_on_complex_issues | 0.275 | | 0.198 | -0.215 | -0.197 | | | |
| gives_example | | 0.207 | | -0.406 | | -0.338 | | |
| gives_out_note | 0.188 | -0.322 | 0.108 | | -0.103 | 0.184 | | |

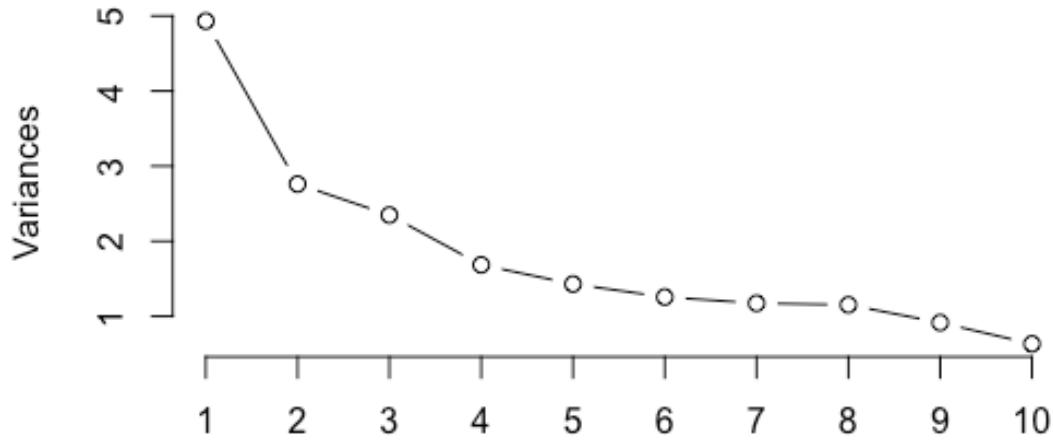
| | | | | | | | | | |
|-----------------------|---------|---------|---------|---------|---------|---------|---------|---------|--------|
| sense_of_humour | -0.430 | 0.113 | | | -0.145 | | | | |
| mark_easily | 0.270 | -0.168 | | | -0.198 | 0.277 | | | |
| moves_around | -0.234 | 0.208 | -0.102 | -0.241 | 0.205 | 0.152 | | | |
| offers_lecture_notes | | | -0.372 | 0.420 | -0.202 | 0.289 | | | |
| clear_objective | -0.377 | | | 0.420 | -0.218 | -0.233 | | | |
| solicit_questions | | | -0.606 | | | -0.367 | | | |
| text_book | | | 0.255 | | 0.359 | | | | |
| primary_research | | -0.130 | | | 0.257 | -0.123 | | | |
| own_research | | | 0.197 | | -0.248 | 0.206 | | | |
| teach_in_team | | -0.247 | | | 0.198 | | | | |
| understand_principles | 0.176 | | | 0.130 | 0.133 | 0.183 | | | |
| use_a_pointer | 0.434 | 0.352 | 0.114 | 0.198 | 0.346 | -0.121 | | | |
| well_respected | | 0.231 | | | -0.370 | | | | |
| | Comp.1 | Comp.2 | Comp.3 | Comp.4 | Comp.5 | Comp.6 | Comp.7 | Comp.8 | Comp.9 |
| SS loadings | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Proportion Var | 0.048 | 0.048 | 0.048 | 0.048 | 0.048 | 0.048 | 0.048 | 0.048 | 0.048 |
| Cumulative Var | 0.048 | 0.095 | 0.143 | 0.190 | 0.238 | 0.286 | 0.333 | 0.381 | 0.429 |
| | Comp.10 | Comp.11 | Comp.12 | Comp.13 | Comp.14 | Comp.15 | Comp.16 | Comp.17 | |
| SS loadings | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | |
| Proportion Var | 0.048 | 0.048 | 0.048 | 0.048 | 0.048 | 0.048 | 0.048 | 0.048 | |
| Cumulative Var | 0.476 | 0.524 | 0.571 | 0.619 | 0.667 | 0.714 | 0.762 | 0.810 | |
| | Comp.18 | Comp.19 | Comp.20 | Comp.21 | | | | | |
| SS loadings | 1.000 | 1.000 | 1.000 | 1.000 | | | | | |
| Proportion Var | 0.048 | 0.048 | 0.048 | 0.048 | | | | | |
| Cumulative Var | 0.857 | 0.905 | 0.952 | 1.000 | | | | | |

Screeplot

To do a screeplot, follow the commands below. Note this is the standard deviations, which are just square root of the variances or eigenvalues.

```
CODE
screeplot(pca1, type = "lines")
```

pca1



Principal Component Scores

To get your principal components scores for plotting and analysis, do the following:

```
CODE  
pca1$x
```

OUTPUT

| | PC1 | PC2 | PC3 | PC4 | PC5 | PC6 |
|-------|--------------|-------------|------------|------------|-------------|--------------|
| [1,] | 0.834364400 | -0.44633674 | -0.7389322 | 0.6505980 | 0.67162071 | -0.059426515 |
| [2,] | -0.057591233 | 2.43259604 | 0.3643921 | 0.1044273 | -1.35364156 | -1.513379283 |
| [3,] | -1.414356172 | -0.85486631 | 0.2591048 | -0.7950895 | 0.39445964 | -0.362282532 |
| [4,] | -3.007651543 | -1.54426710 | 1.8013306 | -1.4495208 | -0.06900951 | -0.378437639 |
| [5,] | -0.913357854 | 0.15572053 | 1.9852660 | 0.26474465 | 0.05455313 | -0.190589811 |
| [6,] | 2.715375811 | -0.61458292 | 1.2581973 | 0.6291478 | 1.66664928 | 0.980101358 |
| [7,] | -3.260274779 | -1.46022078 | -1.3182136 | -1.5445289 | 2.59801832 | 1.373084699 |
| [8,] | 1.690020920 | 4.10059174 | -0.8286511 | -2.7204201 | -0.89839668 | 0.477869956 |
| [9,] | -2.017591018 | -0.19055562 | 1.2282190 | -0.1591693 | -1.81724286 | -0.504760633 |
| [10,] | 2.684027310 | -0.28238921 | -2.7053968 | -0.6373616 | 1.24913045 | 0.114945320 |
| [11,] | 1.602080176 | 1.73848677 | -0.7560946 | -0.1669273 | 1.46214681 | -1.241067456 |
| [12,] | 3.864282071 | 0.91902758 | -3.0506154 | -0.3116270 | 0.14774890 | -1.707816527 |
| [13,] | -1.537400621 | 0.79553155 | 0.2734490 | 2.2991348 | -1.33509038 | 1.020459263 |
| [14,] | -3.180580364 | -1.55370059 | -1.1043790 | 0.3994455 | -0.21820422 | -0.416321249 |
| [15,] | 0.251424671 | -0.87357501 | 0.8416185 | 1.3248859 | 1.62509470 | -1.332946815 |
| [16,] | 2.892895033 | -0.54107588 | -0.4987349 | 0.5314171 | -0.40738282 | -0.008629769 |
| [17,] | 2.025139659 | 0.87994104 | 2.1794942 | 1.4021183 | -1.10315491 | -1.185333328 |
| [18,] | -4.509205462 | 2.93089784 | -2.9570995 | 3.4152682 | 0.56608967 | 1.421754123 |
| [19,] | -0.363910804 | 0.59536235 | 1.0533136 | -0.1849003 | -0.12823425 | -0.808435775 |
| [20,] | 0.513833400 | 1.34820539 | 1.7227901 | -1.3132714 | -1.04480943 | 0.987729132 |

| [21,] | 0.671318696 | -1.57314535 | 0.3233421 | -0.3775963 | 1.07805278 | 0.122220926 |
|-------|--------------|-------------|-------------|---------------|--------------|--------------|
| [22,] | -1.199789658 | -0.75223096 | 0.2125650 | -1.9753352 | -0.38988416 | 2.577574944 |
| [23,] | 2.699925571 | -4.05301101 | -2.2580650 | 0.1089181 | -2.08232998 | 0.035139868 |
| [24,] | 3.671607537 | -2.76308860 | 2.3108314 | 1.9763565 | -0.12222446 | 1.145347105 |
| [25,] | 1.708338444 | 1.14870366 | 0.1941423 | -0.8978228 | 0.53891069 | 1.218476886 |
| [26,] | 0.697044049 | -0.09475043 | -0.9235260 | 0.5556583 | 1.51777743 | -0.726583470 |
| [27,] | -3.637428809 | -1.19350763 | -0.2178772 | -1.3363292 | -0.26449368 | -3.193959083 |
| [28,] | 0.919217152 | 1.59671229 | 1.9213986 | 0.1968770 | 0.58065284 | 0.264448784 |
| [29,] | -0.012679393 | 2.32518659 | 0.2155462 | 0.3501560 | -0.47396645 | 0.658332807 |
| [30,] | -2.075112687 | -0.04538414 | 0.2156446 | -1.0632633 | 0.42197992 | 0.038464825 |
| [31,] | -2.320188992 | -0.57228262 | -0.1349819 | 2.0161446 | -0.36632609 | -0.152398000 |
| [32,] | 0.005054503 | -1.40748778 | -2.5517407 | -0.5548639 | -3.02867573 | 0.937512584 |
| [33,] | 0.061169986 | -0.15050467 | 1.6836625 | -0.7372732 | 0.53018221 | 0.408905305 |
| | PC7 | PC8 | PC9 | PC10 | PC11 | PC12 |
| [1,] | 0.94163613 | 1.01611660 | 0.65086100 | 0.7049538165 | -0.12679861 | 1.07464589 |
| [2,] | 2.49608290 | -1.03057653 | 0.99789650 | -0.6955702786 | 0.62054036 | 0.43728658 |
| [3,] | -1.14833452 | -0.13690605 | 1.56172193 | -1.0103974039 | -0.22663448 | -0.62688596 |
| [4,] | 1.55864777 | -2.37956477 | -1.88594310 | 0.1842266066 | 0.56734997 | -0.37865892 |
| [5,] | -0.90420171 | -1.46124279 | -0.41077774 | 0.7877696717 | 0.87274235 | -0.40364293 |
| [6,] | -0.48508037 | -0.39417790 | -0.13586330 | -0.5943650505 | -0.20101933 | 0.39114013 |
| [7,] | 0.92263413 | 0.27756052 | 0.64943390 | 0.6951735358 | 0.85851959 | -0.18227075 |
| [8,] | 1.01619589 | 1.42931518 | -0.35783368 | -0.0705759673 | 0.38608546 | -0.45604663 |
| [9,] | -3.06056251 | 0.01542140 | 0.97910235 | -0.3689951357 | -0.81042854 | 0.29905809 |
| [10,] | -1.15019858 | -2.22756355 | 1.92108719 | 1.1858684843 | 0.03051034 | -0.44295070 |
| [11,] | -1.38076963 | 0.10114808 | -1.28404266 | 0.4344189806 | 0.24591922 | -0.18193776 |
| [12,] | 0.63745807 | -0.33245072 | -0.46272040 | -0.4907654143 | -0.49725530 | 0.06959804 |
| [13,] | 0.50021492 | 1.64298989 | -0.02204408 | -0.0008218307 | -0.32919047 | -1.47757160 |
| [14,] | 0.96910614 | -0.33466161 | 1.43687692 | -0.8126002209 | -1.05968338 | -0.42468108 |
| [15,] | 0.80890447 | -0.52662610 | -0.88626822 | 0.4773237243 | -0.83842767 | 0.73180898 |
| [16,] | 0.99711436 | 1.01401737 | -0.40202982 | 0.1817443327 | -0.53794142 | -0.60055239 |
| [17,] | 0.20967322 | -0.58311856 | 0.70515256 | -0.0396632716 | 0.45009864 | 0.68839301 |
| [18,] | -0.81537520 | -0.85666393 | -0.94273181 | 0.0414522567 | 0.07186325 | 0.63521158 |
| [19,] | -0.39788697 | 0.90638787 | -0.41749861 | 0.8035047424 | -0.32339287 | -0.65225431 |
| [20,] | -1.71530837 | -0.05810388 | -0.44792612 | 0.6080155185 | 0.04950397 | 0.22979058 |
| [21,] | -0.17473258 | -0.49430919 | -0.74983375 | -2.3172182635 | -0.86711224 | -0.89907281 |
| [22,] | 0.963355825 | 0.59588805 | -0.69173585 | 0.7875438802 | -1.58060139 | 0.69952356 |
| [23,] | -0.79226369 | 0.31761740 | -1.80001880 | -0.5911334313 | 0.33709088 | 0.50027519 |
| [24,] | 0.66242150 | 0.79456398 | 1.28229789 | 1.1369072252 | 0.36494912 | 0.29993320 |
| [25,] | 0.11491096 | -0.67752131 | 1.55591224 | -0.9531517638 | -0.43306504 | 0.96727700 |
| [26,] | -0.97171844 | 2.00236186 | 0.03915553 | 0.0979107090 | 1.01294064 | -0.86467646 |
| [27,] | -0.10713776 | 1.13254478 | 0.06800519 | 1.3104870153 | -0.78844151 | 0.38194366 |
| [28,] | -0.11368363 | -1.13303668 | -0.44515516 | -0.0309968966 | -0.05286304 | -0.17959227 |
| [29,] | 0.03995439 | -0.06103477 | -0.17348145 | 0.3417751499 | -1.22149166 | -0.09463653 |
| [30,] | -0.61338026 | 1.72693492 | -0.07276041 | -1.2660686396 | 1.38200547 | 1.95263797 |
| [31,] | 0.79663725 | 0.35281020 | 0.08109498 | -0.5131215937 | 0.67712222 | -0.13873520 |
| [32,] | -0.05972762 | -1.30023954 | 0.11504776 | 0.5298008516 | 1.06058730 | -0.29503060 |
| [33,] | 0.25541147 | 0.66221148 | 0.44501905 | -0.5534313394 | 0.90651818 | -1.05932657 |
| | PC13 | PC14 | PC15 | PC16 | PC17 | |
| [1,] | 1.04550104 | 0.30220825 | -0.26493487 | 0.990718773 | -0.161522621 | |
| [2,] | -0.51140324 | 0.23962723 | 0.04514841 | -0.864576510 | 0.021378514 | |
| [3,] | -0.45367844 | 0.47042709 | 0.44536737 | 0.117387548 | 1.132044168 | |
| [4,] | 0.76623701 | 0.33414241 | -0.06674780 | 0.005890288 | -0.317090528 | |
| [5,] | -0.22473438 | 1.02668595 | -1.11036905 | 0.253771120 | 0.573823233 | |
| [6,] | -0.21758119 | 0.35417045 | 0.55539524 | 0.380784887 | 0.577014348 | |
| [7,] | -1.13189958 | -0.40654870 | 0.30620976 | 0.183130027 | -0.149934970 | |
| [8,] | 0.48772693 | -0.20754494 | 0.30040817 | 0.432882057 | -0.190155729 | |
| [9,] | 0.47865039 | 0.06044313 | 0.29758301 | 0.065987000 | -0.412015158 | |
| [10,] | -0.03562393 | 0.19804842 | 0.33881205 | -0.396898429 | -0.531313384 | |
| [11,] | -0.90180692 | -0.34546312 | -0.75620771 | 0.625598888 | -0.544476288 | |
| [12,] | 0.30509441 | 0.08813338 | -0.58059025 | -0.035026694 | 0.625823661 | |
| [13,] | -0.73594105 | 0.53970030 | -0.79585891 | 0.555871566 | -0.252855797 | |
| [14,] | -0.21555707 | -0.91839176 | -1.10063830 | -0.346724418 | -0.207470713 | |
| [15,] | 0.72072562 | -0.64024769 | -0.07151878 | -0.333963902 | 0.392495606 | |
| [16,] | 0.13959352 | 0.68049473 | 0.84486635 | -0.265106061 | -0.372669045 | |
| [17,] | -1.02024905 | -0.87052303 | 0.58413566 | 0.839988817 | 0.250265142 | |

| | PC18 | PC19 | PC20 | PC21 |
|--------|--------------|--------------|---------------|--------------|
| [1,] | 0.512534055 | 0.403637255 | -0.2288274019 | -0.180597545 |
| [2,] | 0.929440714 | 0.048122004 | 0.2051146098 | -0.271152883 |
| [3,] | 0.403516656 | -0.074179505 | -0.2401958070 | -0.046316428 |
| [4,] | -0.380413260 | -0.016801083 | 0.0236080284 | 0.075154120 |
| [5,] | -0.121436088 | 0.216713273 | -0.2532722027 | 0.163180806 |
| [6,] | 0.016193332 | -0.176022291 | 0.8096079044 | -0.052570563 |
| [7,] | -0.041349452 | 0.491356049 | 0.1502223084 | -0.205615503 |
| [8,] | -0.169826040 | -0.182268894 | -0.0271317045 | 0.331935144 |
| [9,] | -0.170416032 | 0.311027931 | 0.4390800414 | -0.032482679 |
| [10,] | -0.228929235 | -0.629795038 | -0.1373141246 | 0.072909759 |
| [11,] | 0.223418908 | -0.399313078 | 0.1457129024 | -0.346000339 |
| [12,] | -0.361282411 | 0.136577651 | 0.1213875759 | 0.000801914 |
| [13,] | 0.048394699 | -0.297878346 | 0.0857017322 | -0.076965204 |
| [14,] | -0.556266739 | 0.183329956 | 0.1575056075 | 0.005626377 |
| [15,] | 0.003248088 | -0.275646771 | -0.0488034493 | -0.010278083 |
| [16,] | -0.569143575 | 0.610124017 | 0.0001699299 | -0.165370989 |
| [17,] | -0.876273716 | 0.145493206 | -0.3407035497 | -0.133229363 |
| [18,] | 0.139800530 | 0.266416571 | -0.0612808299 | 0.138282533 |
| [19,] | -0.288699113 | -0.005113258 | 0.1267147465 | -0.263464768 |
| [20,] | 0.261595957 | 0.070258777 | -0.3355360658 | -0.432480871 |
| [21,] | 0.478432361 | -0.146679334 | -0.3985086902 | -0.071646635 |
| [22,] | -0.090751620 | -0.213675088 | -0.1815364089 | -0.142428632 |
| [23,] | 0.266768773 | 0.195774478 | -0.1770461524 | 0.191720088 |
| [24,] | 0.354865033 | -0.239914062 | 0.0937794098 | 0.244839284 |
| [25,] | -0.161337294 | 0.208473109 | -0.0508044281 | 0.105092550 |
| [26,] | -0.040945263 | 0.377943641 | -0.1672829144 | 0.091569499 |
| [27,] | 0.419873948 | -0.083337959 | 0.0482601803 | 0.312179849 |
| [28,] | 0.322418197 | 0.609269862 | -0.0166547989 | 0.337744117 |
| [29,] | 0.091695107 | -0.301130070 | -0.0161094691 | 0.322694249 |
| [30,] | -0.412731002 | -0.414631089 | 0.0294813311 | 0.084790553 |
| [31,] | -0.298987891 | -0.721677547 | -0.2130771535 | -0.111634161 |
| [32,] | 0.187128445 | -0.059177362 | 0.2716590271 | -0.102730154 |
| [33,] | 0.109463929 | -0.037277006 | 0.1860798156 | 0.166443959 |

So to combine them with the original variables, do this:

```
CODE
lecturerpcscores ← cbind(lecturers, pca1$x)
```

Biplot

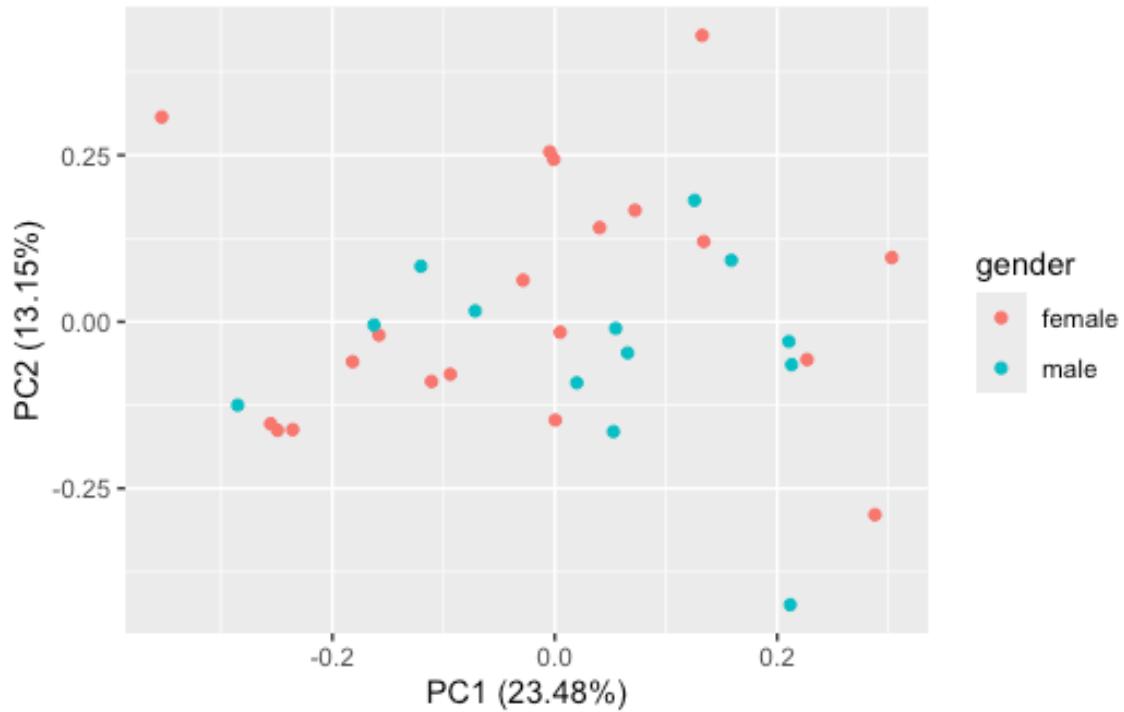
We can produce a biplot in ggplot2, using the factor gender as the colour:

```

CODE
autoplot(pca1, data = lecturerpcscores, colour = 'gender')

OUTPUT
Warning: `aes_string()` was deprecated in ggplot2 3.0.0.
i Please use tidy evaluation idioms with `aes()``.
i See also `vignette("ggplot2-in-packages")` for more information.
i The deprecated feature was likely used in the ggrepel package.
  Please report the issue at <https://github.com/sinhrks/ggrepel/issues>.

```



We could add the loadings, but they are a bit messy, best to look at loadings or rotations tables.

You can make the plot using different symbols, change background etc through reading the ggplot2 documentation.

ANOVA on PC scores

You can use this file to do the ANOVAs, you will have to do yourself. For example for differences in PC scores for gender:

```

CODE
AOV1 ← aov(lecturerpcscores$PC1 ~ gender, data = lecturerpcscores)
summary(AOV1)

```

OUTPUT

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) |
|-----------|----|--------|---------|---------|--------|
| gender | 1 | 4.6 | 4.596 | 0.93 | 0.342 |
| Residuals | 31 | 153.2 | 4.942 | | |

You can do something similar for your projects and regression, using your PC scores as the predictors.

Boxplot

To do a boxplot of variables use ggplot2:

```
CODE
ggplot(lecturerpcscores, aes(x = gender, y = PC1)) +
  geom_boxplot()
```



Factor Analysis with Varimax Rotation

To do a Varimax rotation on your principal components, follow these commands. Do a factor analysis with the rotation being Varimax:

```
CODE
fa1 ← factanal(lecturers[, 8:28], 10, rotation = "varimax")
fa1
```

OUTPUT

```

Call:
factanal(x = lecturers[, 8:28], factors = 10, rotation = "varimax")

Uniquenesses:
      accessible        attractive       wide_range
accessible           0.381          0.005          0.005
teaching_based_research
      0.005          0.283          0.332
      gives_example    gives_out_note   sense_of_humour
      0.005          0.448          0.473
      mark_easily      moves_around    offers_lecture_notes
      0.005          0.294          0.141
      clear_objective  solicit_questions text_book
      0.244          0.005          0.310
      primary_research own_research    teach_in_team
      0.310          0.237          0.548
      understand_principles use_a_pointer well_respected
      0.584          0.067          0.005

Loadings:
      Factor1 Factor2 Factor3 Factor4 Factor5 Factor6 Factor7
accessible           -0.583  -0.426   0.222  -0.110      -0.130
attractive            0.961   0.106
wide_range            -0.177
teaching_based_research
      0.356   0.374  -0.114
Dress_nicely          0.829   0.100
focus_on_complex_issues  0.116
      0.674      -0.163  -0.141
gives_example          0.122   0.112
gives_out_note          0.362   0.290   0.216  -0.196   0.305   0.125   0.261
sense_of_humour          0.127   0.229   0.599   0.125
mark_easily             0.150   0.298   0.143
moves_around             0.326   0.244   0.186  -0.102  -0.155
offers_lecture_notes     0.362   0.240   0.333
clear_objective          0.768   0.109   0.343
solicit_questions         0.880  -0.139   0.130   0.109  -0.156
text_book                0.611
      -0.141  -0.152   0.166   0.202   0.427
primary_research
      0.100
own_research              0.154
teach_in_team              0.155   0.614
understand_principles      0.608
      0.155
use_a_pointer              0.164   0.146   0.902  -0.142   0.165
well_respected             0.133   0.287
      0.931   0.101

      Factor8 Factor9 Factor10
accessible
attractive           -0.121
wide_range             0.102   0.137  -0.126
teaching_based_research  0.158   0.819
Dress_nicely
focus_on_complex_issues
      0.369
gives_example
gives_out_note          0.244
      -0.120
sense_of_humour
mark_easily             -0.113  -0.106
moves_around             0.429   0.444   0.217
offers_lecture_notes     -0.159
      0.167
clear_objective
solicit_questions        0.326
text_book                -0.146
primary_research          0.213
      0.790
own_research              0.784   0.119   0.255
teach_in_team
understand_principles
      0.110
use_a_pointer             0.109

```

| | |
|----------------|---|
| well_respected | -0.100 |
| | Factor1 Factor2 Factor3 Factor4 Factor5 Factor6 Factor7 Factor8 |
| SS loadings | 2.654 2.398 1.996 1.705 1.667 1.423 1.325 1.137 |
| Proportion Var | 0.126 0.114 0.095 0.081 0.079 0.068 0.063 0.054 |
| Cumulative Var | 0.126 0.241 0.336 0.417 0.496 0.564 0.627 0.681 |
| | Factor9 Factor10 |
| SS loadings | 1.039 0.970 |
| Proportion Var | 0.049 0.046 |
| Cumulative Var | 0.731 0.777 |

Test of the hypothesis that 10 factors are sufficient.
The chi square statistic is 28.56 on 45 degrees of freedom.
The p-value is 0.973